Parthasarathi Shome · Pooja Sharma
Editors

Emerging Economies

Food and Energy Security, and Technology and Innovation

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Chapter 1
Introduction and Overview

Parthasarathi Shome and Pooja Sharma

1.1 Introduction

There is growing global concern over the increase in the levels and volatility of world food and energy commodity prices and, in turn, their ramifications for food security and energy security, particularly amongst the poor. This inevitable link has deepened with the financialisation of commodity markets whereby investments in the latter reflect primarily a financial motive without adequate reflection of the fundamental conditions of demand and supply in commodity markets (Shome 2013a). As a result there is also a concern over the extent to which the prices in food and energy markets reflect their actual availability in world markets. In turn, the absence of appropriate linkages might turn out to be inadvertent constraints on inflation and growth in particular in emerging and developing economies (EDEs).[1] Questions arise regarding how the patterns and spreads in economic activity, incomes and wealth would affect emerging patterns between EDEs and advanced economies. Further, domestically, how would the EDEs address their internal challenges of securing the food and energy needs of their populations with rising per capita incomes and changing consumption patterns, in an environment where supply is being

[1] Different international organisations define EDEs differently. In this chapter, unless otherwise indicated, EDEs are taken to refer to all countries other than those classified in the industrial country category of the International Monetary Fund's (IMF's) pre-1997 country classification system. See the IMF's World Economic Outlook website (http://www.imf.org/external/pubs/ft/weo/data/changes.htm) for further details.

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constantly challenged? How could technological, institutional and policy innovations be effectively deployed in addressing food security and energy security in the EDEs?[2] What catalytic role could global governance institutions play in providing the necessary information and coordination in the provision of global public goods?

This volume brings together policy research in three crucial areas of contemporary global relevance: agriculture and food security, energy security, and technology and innovation institutions. It covers six of the largest emerging economies in the world, of which three are from Asia (China, India, Malaysia), two from Latin America (Brazil, Mexico) and one from Africa (South Africa). The aim is to enhance the common understanding of how selected, major EDEs have addressed the complex and increasingly inter-related issues of food security and energy security, as part of their growth and development experience, over the last three decades while underscoring the role of technology and innovation in addressing these challenges. The volume also helps to underscore the current challenges in improving food security and access to energy and the approaches and policy options for meeting these challenges.

This volume is organised in three parts. Part I deals with agriculture and food security. Part II is dedicated to the energy sector, including the roles of energy efficiency and renewable resources in enhancing energy security. Parts I and II also cover the role of the major sector-specific technological and institutional innovations for enhancing food and energy security respectively. Part III turns to the economy-wide institutions of science, technology and innovation for supporting growth and development.

The remainder of this introductory chapter is organised as follows. Section 2 frames the current concern over the increasingly inter-linked issues of agriculture, food security and energy security, and the institutions of technology and innovation, synthesising them in the context of the rising economic and political weight of the EDEs in the world economy. Sections 3–5 consider the same issues independently, as areas in their own right. Section 6 concludes.

1.2 Food and Energy Security and the Role of Technology and Innovation

The last decade was characterised by large fluctuations in world agricultural, food and energy commodity prices, which continue to remain elevated in the second half of 2013. World food and energy commodity prices, as measured by the World Bank's monthly price indices (2005 = 100) in nominal US dollar terms, reached a peak in mid-2008 but declined steeply during the fourth quarter of 2008 in the wake of the global financial crisis (Fig. 1.1). However, energy and food commodity prices recovered from 2009 and, by early 2011 reached close to, or above, the 2008 peak.

[2] Food security is defined as 'availability and access to sufficient, safe, and nutritious food to meet the dietary needs and food preferences for an active and healthy life' (FAO 2011). Energy security has been defined as 'access to clean, reliable, and affordable energy services for cooking and heating, lighting, communications and productive uses', and as 'uninterrupted physical availability (of energy) at a price which is affordable, while respecting environment concerns' (IEA 2011).

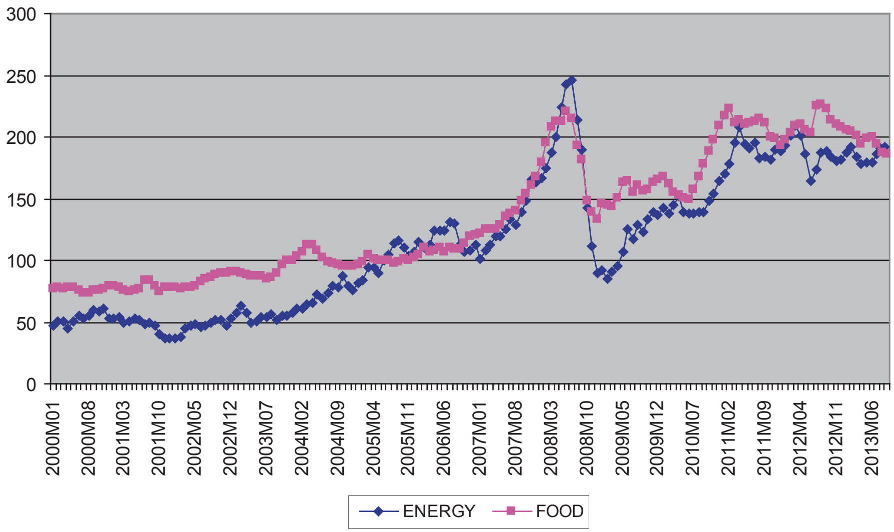

Fig. 1.1 World Bank monthly nominal price indices (2005 = 100), 2000–2013. (Source: World Bank commodity price data (*Pink Sheet*). Available at http://siteresources.worldbank.org/INTPROSPECTS/Resources/334934-1304428586133/PINK_DATA.xls)

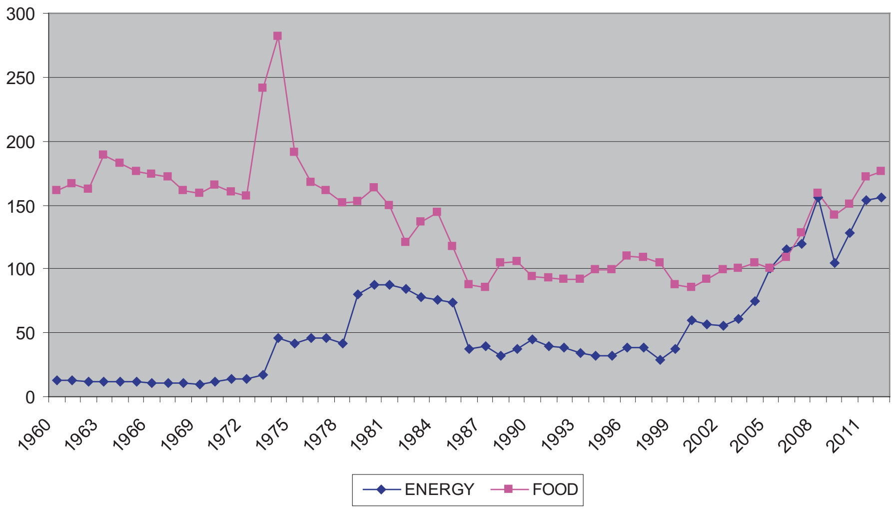

Fig. 1.2 World Bank annual real (2005) price indices (2005 = 100), 2000–2013

The World Bank's annual food price index averaged 212 points in 2012, up 25 % from its average in 2010 and 13.5 % from the average in 2008. The energy price index averaged 187 in 2012, compared to an average of 182 in 2008. During the crisis, as per the World Bank's annual price indices in real (2005) US dollar terms, while energy commodity prices crossed the previous peak reached in 1980, agricultural and food commodity prices remained below their 1974 peak (Fig. 1.2).

Although the recent price fluctuations are not unprecedented for individual commodities, what appears distinctive from previous commodity price cycles is the large amplitude of price swings for a broad range of commodities (See Baffes and Haniotis 2010; Calvo-Gonzalez et al. 2010; Jacks et al. 2009). As discussed later, with the increase in the utilisation of food crops for the production of biofuels and financialisation of the commodities markets over the last decade, both the fundamental and financial factors appear to have contributed to the strengthening of the links between food and energy markets. Moreover, due to the unprecedented trade and investment liberalization since the 1980s, the EDEs have become more integrated and closely connected with world markets so that higher volatility in world prices has become more of a concern for the EDEs.

The resource-intensive agriculture, food and energy sectors are critical to human well-being and sustainable development. Only increased efficiency in resource use and appropriate technology and institutional frameworks are likely to determine the likelihood of success in achieving these objectives. The increase in the levels and volatility of world agricultural, food and energy commodity prices has not helped global efficiency or institutional stability, and has become a source of deep concern for policymakers across the world. Since the 2008 global financial crisis reared its head in food and fuel markets, food security and energy security emerged as issues on both domestic and global governance agendas.[3] Access to adequate food, nutrition and energy is essential for meeting basic human needs. Yet, it is far from being achieved. Approximately 1.4 billion people worldwide were estimated to be living in extreme poverty in 2005. Over a billion people were food-insecure in 2009 (Table 1.1), though its extent has declined somewhat thereafter.[4] Over 1.3 billion people, or 19 % of the global population, did not have access to electricity in 2009 or were considered energy-poor. Around 2.7 billion people were without access to clean cooking facilities (IEA 2011). There is considerable overlap between those who are undernourished and those who do not have access to electricity (SEI 2011). The overall picture, therefore, remains stark.

[3] Although there are many definitions of the terms food and energy security, some of the most commonly used definitions are as follows: 'Food security [is] a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life' (FAO 2004). Energy access has been defined as 'access to clean, reliable, and affordable energy services for cooking and heating, lighting, communications and productive uses' (AGECC 2010) and 'energy security is defined in terms of the physical availability of supplies to satisfy demand at a given price' (IEA 2001), recently redefined as 'uninterrupted physical availability (of energy) at a price which is affordable, while respecting environmental concerns' (IEA 2011).

[4] The FAO has since revised downwards its previous estimate of food insecurity in the world during 2009–2011 to 870 million, representing 12.7 % of the world's population (FAO 2013).

Table 1.1 Selected food security, energy security and science and technology indicators. (Source: WDI 2011)

Indicator	Year	Brazil	China	India	Malaysia	Mexico	South Africa	World
Population (millions)	2009	194	1331	1155	27	107	49	6775
Surface area (thousand sq. km)	2009	8515	9600	3287	331	1964	1219	134,123
GNI ($ billion)	2009	1564	4856	1405	201.8	962	284	59,163
GNI per capita ($)	2009	8070	3650	1220	7350.0	8960	5760	8732
GNI PPP ($ billion)	2009	1968	9170	3786	376.6	1506	496	71,774
GNI per capita PPP ($)	2009	10,160	6890	3280	13,710.0	14,020	10,050	10,594
GDP growth (% p.a.)	1990–2000	2.7	10.6	5.9	7	3.1	2.1	2.9
	2000–2009	3.6	10.9	7.9	5.1	2.2	4.1	2.9
Population below international poverty line $ 1.25 (2005 PPP) a day (%)	Survey year	2009	2005	2005	2009	2008	2000	2005
		3.8	15.9	41.6	<2	<2	26.2	25
Gini index		53.9	41.5	36.8	46.2	51.7	57.8	–
Food security								
Prevalence of undernourishment (% of population)	1990–1992	11	18	20	<5	<5	<5	17
	2006–2008	6	10	21	<5	<5	<5	14
Prevalence of child malnutrition								
Underweight	2004–2009	2.2	4.5	43.5	–	3.4		21.3
Stunting	2004–2009	7.1	11.7	47.9	–	15.5		31.7
Overweight	2004–2009	7.3	5.9	1.9	–	7.6		6.1
Energy and emissions								
Energy production (Total million metric tons of oil equivalent)	1990	104.2	886.3	291.8	48.8	193.4	114.5	8840.1
	2008	228.1	1993.3	468.3	93.1	233.6	163	12357.7

Table 1.1 (continued)

Indicator	Year	Brazil	China	India	Malaysia	Mexico	South Africa	World
Energy use (total million metric tons of oil equivalent)	1990	140.2	863	318.9	22	121.3	90.9	8569.9
	2008	248.5	2116.4	621	72.7	180.6	134.5	11899.4
Energy use (per capita kilogram of oil equivalent)	1990	937	760	362	1208	1453	2667	1661
	2009	1243	1695	560	2391	1559	2921	1788
Energy use (% of total)	1990	51.2	75.5	55.4	88.8	87.2	86.6	80.9
	2009	51.3	87.4	73.0	94.7	88.9	87.8	80.7
Fossil fuel	1990	34.1	23.2	42.1	9.7	7.0	11.1	10.2
Combustible renewable and waste	2009	31.6	9.0	24.5	4.5	4.8	9.8	10.0
Alternative and nuclear energy (% of total energy use)	1990	13.1	1.3	2.5	1.6	5.9	2.4	8.7
	2009	15.6	3.7	2.3	0.9	6.3	2.4	9.2
Energy dependency (net energy imports, % of energy use)	1990	26	−3	8	−122	−60	−26	−3
	2008	8	6	25	−28	−29	−21	−4
Energy efficiency GDP per unit of energy use (2005 PPP $ per kg of oil equivalent)	1990	7.7	1.4	3.3	5.5	6.9	3.1	4.2
	2008	7.4	3.6	5.1	4.9	7.9	3.5	5.5
CO_2 emissions (Total million metric tons)	1990	208.7	2458.7	690	56.5	357.2	333.2	22,529
	2007	368	6533	1611	194.3	471.1	433.2	30,649
CO_2 emissions per capita metric tons	1990	1.4	2.2	0.8	3.1	4.3	9.5	4.3
	2007	1.9	5	1.4	7.3	4.5	9	4.6
Access to electricity (% of population)	2009	98.3	99.4	66.3	99.4	–		74.1

Table 1.1 (continued)

Indicator	Year	Brazil	China	India	Malaysia	Mexico	South Africa	World
Science and technology								
R&D expenditure as % of GDP	2000–2008	1.1	1.44	0.8	0.64	0.37	0.93	2.07
Researchers in R&D per million people	2000–2008	694	1071	137	372	353	393	1281
Scientific and technical journal articles	2007	11,885	56,806	18,194	808	4223	2805	758,132
High-technology exports	2009							
$ millions		8316	348,295	10,143	51,560	37,354	1418	1,858,138
% of manufactured exports		14	31	9	47	22	6	20
Royalty and license fee ($ millions)	2009							
Receipts		434	429	193	266	656	48	181,636
Payments		2512	11,065	1860	1133	0	1658	188,861
Patent applications filed	2009							
Residents		4023	229,096	5314	818	822	3596	994,324
Non-residents		17,802	85,477	23,626	4485	13,459	207	634,131

GDP gross domestic product

1.2.1 Increasing Inter-Linkages Between Food and Energy Markets

Food and energy markets have become increasingly inter-linked overtime. At the household and individual levels, the poor, particularly women, children and other vulnerable groups, continue to suffer from food and energy insecurity, spending considerable amounts of their time in collecting firewood to prepare meals and for other uses. Energy is an important input directly and indirectly in agriculture and food supply chains. The energy intensity of agriculture has increased since the development of green revolution technologies, the rise of industrial food systems, and the spread of comparable practices with integration and multinationalisation of global food markets.[5] Agriculture uses energy directly as fuel or electricity to operate machinery and equipment, including irrigation and pumping, and indirectly through the use of fertilisers, pesticides and other agro-chemicals which have embedded energy components. Energy is also used in the processing, transportation and refrigeration of food products. Of late, the rapid increase in the utilisation of agricultural and food commodities and re-allocation of arable land for biofuel production, with the objective of enhancing energy security, have added to the growing linkages between food and energy markets. Agricultural and food commodity prices are found to be increasingly correlated with oil prices. Also, looking to the future, volatile oil prices could contribute to volatility in agricultural and food commodity prices (Food and Agricultural Organization, FAO et al. 2011). Recent research that has examined price volatility linkages between agricultural and energy markets, points to volatility spillovers between energy, food and feed markets (Busse et al. 2011).

The increasing inter-connectedness, across space and time, between food, energy and other resource sectors, such as water, has led to a recognition of the need for adopting a ‘nexus approach’ for improved food and energy security (SEI 2011). The nexus approach aims, among other things, at increasing resource use efficiency and policy coherence to reduce trade-offs and build synergies across sectors. The central guiding principles of this nexus approach comprise investing to sustain ecosystem services by preventing the diminution of ecosystem diversity on biodiversity, creating more with less through increasing overall sectoral as well as resource use efficiency, reducing wastage along the production and supply chains, and integrating the poor by accelerating the process of enhanced access through innovative means.

Technology and innovation have played a critical role in enhancing food and energy security in the past and are expected to play an even more important role in the future, albeit with increasing supply constraints. Mechanisation and improved technologies have helped to increase crop yields in the past, although energy inputs into agriculture have also risen. Energy-efficient technologies and improved farming techniques can increase agricultural productivity by reducing the use and cost of energy inputs. The conversion of agricultural waste biomass or biofuel can help

[5] Although energy inputs into agriculture have increased, globally, the share of agriculture in total energy consumption has declined from 3.9 % in 1990 to 2.5 % in 2001 (http://earthtrends.wri.org/pdf_library/data_tables/ene3_2005.pdf).

to promote alternative cost-effective sustainable development. Technological and institutional innovations together can help improve overall resource efficiency, sustainable resource management and equitable distribution of benefits. These matters are addressed below.

1.2.2 The Rise of EDEs in an Enhanced Role

The EDEs of Asia, Latin America and Africa have become formidable drivers of global growth and are projected to become dominant contributors to global income in the forthcoming years, with the 2008 financial crisis further accelerating the shift in economic weight towards them (Table 1.2). The EDEs' share of world exports and imports has increased dramatically since the 1990s, growing by more than 20% points between 1990 and 2010. For the first time in 2010, developing and transition economies together attracted more than half of global foreign direct investment (FDI) flows (UNCTAD 2011). Outward FDI from these economies also reached record highs, with most of the investment directed towards other countries in the south.

The increasing importance of the EDEs in the global economy has been accompanied by a rapid rise in cross-border trade and investment flows among themselves.

Table 1.2 EDEs in the global economy. (Source: IMF, WEO database, September 2011)

	(% of world total)			
	1990	2000	2010	2016 projection
GDP, PPP				
Emerging and developing economies	31	37	48	54
BICS (Brazil, India, China, South Africa)	11	14	23	28
BICSMM (BICS + Malaysia, Mexico)	14	17	25	31
Advanced economies	69	63	52	46
NIAEs	3	4	4	4
US	25	24	20	18
Euro area	–	18	15	12
GDP, current prices				
Emerging and developing economies	20	20	34	41
BICS	6	8	16	20
BICSMM	8	10	18	22
Advanced economies	80	80	66	59
NIAEs	2	3	3	3
US	26	31	23	20
Euro area	–	19	19	16

In this table, the EDEs are defined as per the latest country classification system of the IMF and not the pre-1997 country classification

For instance, China, which became the second largest economy in the world in 2010 and the biggest trading nation in the world in 2012, has emerged as the largest trading partner of Brazil, India and South Africa over the past few years. China was the largest single foreign investor in Brazil in 2010. China has also been building her trade, investment and assistance relations with African countries, including South Africa. In South Africa, the focus continues to be on trade in resources. In Brazil, although Chinese investments were until recently concentrated in acquiring oil stakes and in electricity distribution, the Chinese firms are starting to build manufacturing plants in the automotive, telecommunications, electrical and electronic sectors.[6]

Over the past decade, Brazil, China and India have also become important development partners of low-income economies. Commodity and resource-oriented linkages are an important, although not the only, dimension of the complex and evolving patterns of inter-relationships among these economies. China and India have the widest geographical reach with low-income economies as regards trade, remittances, investments and financial flows, while Brazil is an important partner for countries within its own region.[7]

The increase in demand for agriculture and food commodities, and energy services in the EDEs, particularly in China and India, reflecting their high rates of growth, have been widely cited as one major factor behind the rising global food and energy prices. However, the research on the relative roles of various factors behind rising and volatile global commodity prices is still preliminary. Demand–supply factors that have short-term influences and affect long-term trends, have been offered as explanations for rising prices. Burrowing deeper, the causes are wider including weather disruptions and poor harvests, particularly in Australia; low food stocks, particularly in China; increase in the prices of agricultural inputs, particularly oil; global quantitative easing and fiscal stimuli (Shome 2012, 2013b); speculation in food commodity markets, particularly by financial institutional investors (FIIs) such as hedge funds, pension funds and investment banks; diversion of food crops into the production of biofuels; decades of underinvestment in agriculture; climate change and water table depletion; avoidable food losses in developing economies and food wastage in industrialised economies. Some of the same reasons have been offered as explanations for rising oil prices, for example, rising demand from EDEs, under-investment in production and infrastructure, changing consumption and urbanisation patterns, an accommodative global monetary stance and speculation in commodity markets.

Although the three large EDEs (Brazil, China and India) have been recognised for their recent growth and development experiences, the respective patterns are significantly different. The growth performance in Brazil has been led by agriculture. In China and India, growth has been led by the industry and services sector respectively. Brazil is a major global exporter of commodities, including food and agricultural commodities. China is the leading exporter of manufactured products, while India has acquired a reputation for being an important exporter of services, particularly information and communication technology (ICT)-enabled services.

[6] See *The Economist*, January 14–20, 2011.

[7] See UNCTAD (2011).

As regards technological developments, these countries display strengths in line with their production structures and resource endowments. For instance, according to Cassiolato in Chap. 11 of this volume, despite the difficulties in measuring the success of innovations in services and agricultural sectors, an analysis of Brazil's innovation trajectory suggests that the country has built scientific excellence and developed strong productive and innovative capabilities in natural resources, the agro-industrial complex and energy related manufacturing and services. According to Bound (2008),[8] Brazil's innovation system is in large part built upon its natural and environmental resources, endowments and assets, and Brazil may in fact be characterised as a 'natural knowledge economy'. Similarly, India is most recognised for its success in ICT services. As regards energy, all these large EDEs are making significant investments in environmental technologies in line with their resource endowments. In 2007, they were already focusing on renewable energy technologies more than the global average, as seen in their higher-than-average patent applications (OECD 2010), and have set even more ambitious targets over the next decade.

There are also notable institutional differences in the nature of social policies and programmes that have been adopted in these EDEs to address poverty and inequality. The Latin American countries, comprising Brazil and Mexico, have successfully adopted conditional cash transfers as a significant instrument for social protection. India has of late pursued a rights-based approach by legislating the right to employment, the right to food security for the poor and the right to education. China has until recently focused largely on a growth-led strategy, including rural industrialisation for lifting millions out of poverty. The differences also point to the complementarity among the EDEs in their focus on policies for equitable social outcomes.

1.2.2.1 The Governance of Global Food and Energy Markets in a Multi-Polar World

The issues of food and energy security have risen to the top of the global agenda in the aftermath of the 2008 financial crisis that had deleterious ramifications for food and energy security. The crisis focused the attention of national governments and multi-lateral organisations on investment in the fields of food and energy security after decades of neglect. For instance, after experiencing a decline over the previous decades, the volume and share of official development assistance (ODA) for agriculture registered an increase during 2007–2011 (OECD 2011). The recent increase in global funding for development in general and agriculture in particular have been accompanied by an increase in the number of actors, including bilateral and multi-lateral donors, private foundations and multi-national corporations as well as new funding modalities. Among the new donors are large EDE donors including Brazil, China, India and South Africa.[9] They have acquired enhanced roles in global

[8] As quoted in Cassiolato in Chap. 11.

[9] Although still modest in comparison to DAC aid, development assistance from non-DAC donors is rising rapidly. It more than doubled between 2005 and 2008. China pledged to provide

governance institutions. Their inclusion in the G20, the revived leading industrial and emerging economies grouping, is testimony to their observable enhanced role.

Agriculture and food security became the focus of discussions at the G8, for example, the 2008 Tokyo, Japan Summit and the 2009 L'Aquila, Italy Summit where the initiative on food security was launched with a pledge of US$ 22 billion over 3 years for agriculture and food security. The G20 placed improvements in information on food stocks and production projections as an essential component of Action 2 (mitigate risk in price volatility and enhance protection for the most vulnerable) on the Food Security Pillar of the G20's Multiyear Action Plan on Development. The French presidency of the G20 in 2011 placed the Food Security Pillar at the top of its global governance agenda for 2011. A UN High Level Task Force (UNHLTF) on the Global Food Security Crisis was set up in 2008 when food prices were near their peak. The UNHLTF immediately developed a Comprehensive Framework for Action (CFA) on Food Security and updated it in 2010. The Madrid meeting on Food Security for All in January 2009 and the November 2009 summit on World Food Security called for the re-vitalisation of the earlier Committee on World Food Security (CFS).

The G8 emerged in the aftermath of the 1973 oil crisis.[10] But with the decline in oil prices, during the 1980s and 1990s energy was relegated to less attention at G8 summits. The increase in the level and volatility of oil prices in the 2000s has once again elevated energy in the G8 and G20 agendas. The G8 Gleneagles summit in 2005 and the St. Petersburg summit in 2006 resulted in initiatives for energy efficiency, cleaner energy, technological collaboration as well as a set of "Global Energy Security Principles." This G8 dialogue was opened to other major energy consuming countries including Brazil, China, India, Mexico and South Africa. The G20 summit in Pittsburgh in 2009 took note of the G8's St Petersberg Principles. The G20 has attempted to address the issue of curbing excessive volatility in oil prices and enhancing transparency in oil gas trade. The Joint Organisation Data Initiative (JODI Oil) and phasing out of fossil fuel subsidy currently comprise key elements of the G20 energy agenda. The G20 (2011) formed a new Clean Energy and Energy Efficiency (C3E) Working Group that was expected to address these issues on an ongoing basis.

1.3 Agriculture and Food Security[11]

Part I of this volume provides the national experiences of selected EDEs in enhancing food security of their populations in terms of augmenting availability of food, providing economic access to food, ensuring improved absorption of nutrition and reducing vulnerability in achieving long-term food security. They are among the world's leading producers and account for a large proportion of global production

US$ 10 billion over 2010–13 and the Indian prime minister pledged US$ 5 billion over 5 years to Africa at the 2011 India–Africa Summit in Ethiopia.

[10] See G8 utoronto website (http://www.g8.utoronto.ca/).

[11] This section is based on Sharma and Gulati (2012).

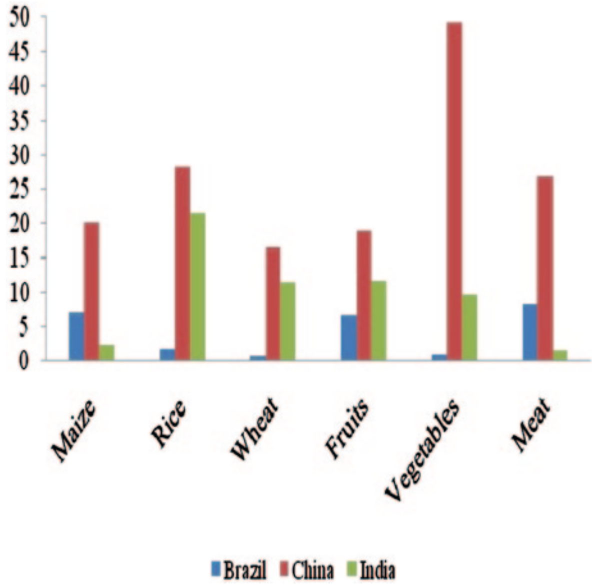

Fig. 1.3 Share in global production (%), 2008. (Source: Computed from FAOSTAT database)

of agricultural and food commodities, including staple crops such as wheat, rice and maize as well as horticultural, dairy and meat products (Fig. 1.3). Brazil is a leading competitive exporter of several agricultural and food products. The papers underscore the diversity in country experiences in their public policies and programmes adopted for improving social and economic access to food and nutrition, as well as the timing, pace and forms of structural reforms.

The countries differ in both these aspects. China began its agriculture sector reforms with the dismantling of the commune system in favour of household-based farming during 1978–1981. The reforms in China were characterised by their sequencing and gradual pace of implementation (Huang and Rozelle in Chap. 3). Market-oriented reforms were initiated in Mexico in the 1980s and included rapid implementation of constitutional amendments to enhance private property rights in communal lands, elimination of agricultural price support programmes, and multilateral and preferential trade liberalisation. Such agricultural reforms in Mexico were marked by the rapidity of the pace of implementation of a wide-ranging set of institutional and policy reforms (Yunez-Naude in Chap. 6). In India, wide-ranging economic liberalisation was introduced in 1991 and, although it was not specifically focused on agriculture, it led to an improvement in agriculture's terms of trade. Brazil launched the Real Plan in 1994 which combined fiscal, monetary, and institutional reforms with controlled trade and financial liberalisation. Malaysia, where agriculture had been relegated to the back burner from the 1980s as the country embarked on an industrialisation drive, re-prioritised agriculture after sharp food price increases in the aftermath of the 1997–1998 Asian financial crisis.

Brazil and China stand out as the leaders with respect to increasing the access, availability and utilisation of food by their citizens. Malaysia also did well, particularly over the past decade in enhancing food security at the national and household levels. In Mexico, the outcome of market-oriented trade reforms were not entirely in line with expectations. India emerged as a country with some of the greatest challenges for achieving food security based on a range of relevant indicators, including lack of food availability, the prevalence of undernourishment and anthropometric indicators of child malnutrition.

1.3.1 Ensuring Availability

Globally, per capita availability of calories increased by approximately 550 kilocalories (kcal) per day between (Triennium) TE1963 and TE2007 (Table 1.3). One of the sharpest increases in availability was recorded in China, where per capita calories increased by over 1400 kcal over the same period. The rapid increase in agricultural output after 1978 and a slowdown in the growth of population together contributed to the improvement in per capita food availability in China. Brazil and Mexico also recorded impressive increases in food availability although the availability stagnated in the case of Mexico during the 1990s. The increase in availability was the lowest for India, where per capita availability of calories increased by less than 290 kcal between TE1963 and TE2007.

The differences across countries in food availability are reflected in the production performance of the agricultural sector. Brazil and China experienced the most robust and sustained growth in agricultural output since the late 1970s. During 1978–2009, agricultural output grew most rapidly in China (4.4 % per annum), followed by Brazil (3.2 %) with India, Malaysia and Mexico registering growth rates of approximately 3, 2 and 1.5 % per annum respectively.

Growth in agricultural output in the EDEs was largely driven by growth in crop yield and overall productivity as a result of institutional and policy reforms, technological change and enabling investment in agricultural research and development (R&D).[12] China witnessed perhaps the most impressive improvement in crop yield and productivity. The improvements in productivity, particularly after 1984, when the effects of institutional reforms levelled off, were attributable to technological progress, enabled by investments in agricultural R&D (Huang and Rozelle in Chap. 3). Followed by relatively stagnant growth during the 1990s, total public sector expenditure on agricultural R&D has surged once again in recent years (Fig. 1.4). Institutions, policies and markets have all played important roles in transforming Brazil's agriculture in the 1990s. However, a strong national system of innovation in agriculture since the 1970s was the anchor from which subsequent policies could take off successfully. India made considerable progress in increasing the production

[12] Crop yield represents a partial productivity measure whereas multi-factor productivity measures express output relative to a more comprehensive measure of all measurable inputs (including land, labour and capital, as well as energy, chemicals and other purchased inputs). Total factor productivity growth itself is a combination of pure technological progress and the increase in efficiency in utilisation of factors of production, the latter often being made possible by economic and institutional reforms that enhance productivity.

Table 1.3 Food security indicators. (Source: FAOSTAT database, WDI database)

Country	1961–1969	1970–1979	1980–1989	1990–1999	2000–2007
Food supply (kcal/capita/day)					
Brazil	2334.5	2500.7	2668.3	2812.7	3020.2
China	1726.9	1969.9	2433.3	2744.8	2941.3
India	1998.2	2048.0	2180.9	2303.8	2289.4
Malaysia	2463.7	2628.0	2710.0	2857.5	2869.1
Mexico	2436.3	2725.1	3132.8	3103.1	3236.5
South Africa	2737	2850	2864	2824	2943
World	2292.0	2411.8	2584.7	2669.9	2752.5
Proteins supply quantity (g/capita/day)					
Brazil	59.8	60.8	64.3	73.1	82.7
China	45.6	49.0	61.8	76.4	87.6
India	50.6	50.6	53.7	55.7	55.4
Malaysia	49.5	55.0	59.7	72.7	77.0
Mexico	65.7	71.3	83.7	83.6	91.7
South Africa	72	75	74	73	78
World	63.1	65.1	69.3	72.4	75.7
Fat supply (g/capita/day)					
Brazil	42.3	54.1	68.4	83.4	103.1
China	22.0	26.9	43.8	68.0	85.5
India	30.4	31.5	36.4	42.7	45.9
Malaysia	52.8	63.2	87.8	86.8	84.7
Mexico	53.8	64.1	84.3	84.3	92.1
South Africa	63	65	66	69	78
World	50.9	55.2	63.4	69.8	76.4
Average annual % growth in agriculture value added	*1978–2009*	*1970–1979*	*1980–1989*	*1990–1999*	*2000–2009*
Brazil	3.2	4.0		3.6	3.7
China	4.4	2.2	3.1	4.2	4.4
India	3.0	1.7	6.1	3.3	2.9
Malaysia	2.0	5.3	3.0	0.3	3.5
Mexico	1.5	3.1	3.5	1.5	2.0
South Africa	1.5	3.0	0.7	0.7	1.5
World	2.2	1.7	2.9	1.8	2.5
Average annual population growth (%)	*1978–2009*	*1970–1979*	*1980–1989*	*1990–1999*	*2000–2009*
Brazil	1.6	2.4	2.1	1.5	1.1
China	1.1	1.9	1.5	1.1	0.6
India	1.9	2.3	2.2	1.9	1.5

Table 1.3 (continued)

Country	1961–1969	1970–1979	1980–1989	1990–1999	2000–2007
Malaysia	2.4	2.4	2.7	2.5	2.0
Mexico	1.7	2.9	2.0	1.7	1.3
South Africa	1.9	2.6	2.4	2.0	1.2
World	1.5	1.9	1.8	1.4	1.2

Food supply is measured as average for the period indicated; agricultural growth rate is computed using the least squares method and constant (US$ 2000) price data for agriculture value added; the population growth is the exponential change in the population for the period indicated

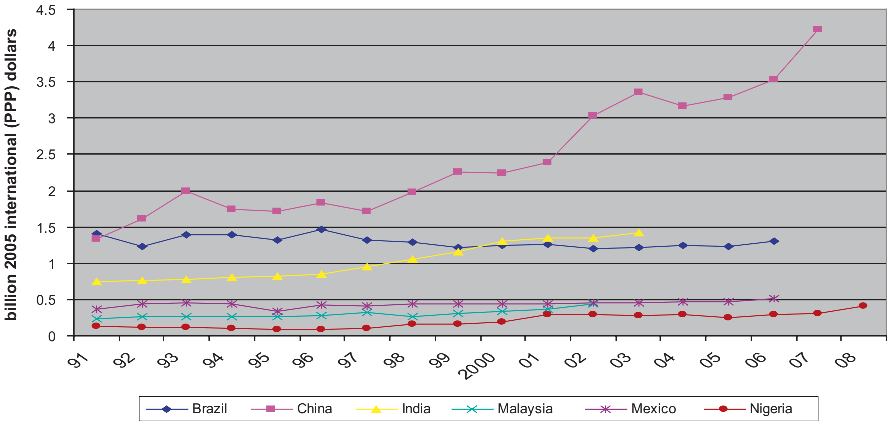

Fig. 1.4 Public sector R&D investments, 1991–2008. (Source: Agriculture science and technology indicators. Available at http://www.asti.cgiar.org)

of food grains during the 1970s and 1980s, after its Green Revolution based on seed fertiliser technology was introduced in the mid-1960s. India also experienced a 'white' revolution in the 1970s, comprising an innovative cooperative sector model, in the milk sector. The more recent private sector-led biotechnology revolution has re-vitalised production and productivity of cotton in the country (Fig. 1.5).

The three large emerging economies (Brazil, China and India) together accounted for 19 and 47 % of global and developing world public sector agricultural R&D expenditures respectively in 2000 (Beintema and Stads 2010). In a global ranking, China, India and Brazil rank third, fourth and fifth respectively in terms of total public investment in agricultural R&D after the USA and Japan. China has the world's largest public agricultural R&D system in terms of research staff numbers. However, private sector investment spending on agricultural research was found to be limited in EDEs as compared to industrialised economies. In emerging and developing countries as a group, only 6.4 % of agricultural R&D was private, with observed disparities in the private share among regions (James et al. 2008). For

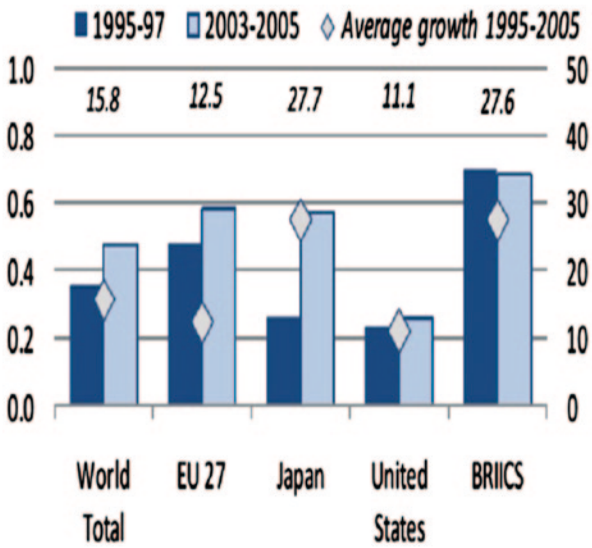

Fig. 1.5 Share of patents relating to renewable energy in total patents (%). Note: Patent counts are based on the priority date, the inventor's country of residence and use fractional counts on PCT filings at international phase (EPO designations). BRIICS refers to Brazil, China, India, Indonesia, the Russian Federation and South Africa. (Sources: OECD, Patent Database, June 2008; EPO Worldwide Statistical Patent Database, October 2007)

example, in the Asia and Pacific region, around 9% of agricultural R&D was private compared to 1.4% in sub-Saharan Africa.

1.3.2 Ensuring Access

Economic access to food or the ability to acquire available food from earnings and transfers is the second important pillar of food security. Access to food depends on a variety of factors including national income, the share of agriculture to GDP and employment, distribution of income, consumption and land holdings, and income and food transfers. China, which began with favourable initial conditions in terms of equitable distribution of land holdings, has made considerable progress in reducing the prevalence of undernourishment from 18% in 1990–1992 to 10% in 2005–2007 (Table 1.4). India comes out as the weakest performer on this account, where around 20% of its population suffers from undernourishment (Shome and Singh 2011).

The Latin American EDEs (Brazil and Mexico) have higher levels of per capita income as well as higher land and income inequalities in contrast to the Asian EDEs. In the mid-to-late 1990s, farm size averaged 1.6 ha in Asia as well as in Africa compared to 67 ha in Latin America, reflecting a much higher concentration in land distribution in the latter region (Nagayets 2005). Yet, agriculture contributes a larger proportion of GDP and employment in the Asian countries. One explanation appears in Chap. 3 where the authors indicate that, in China, rural industrialisation and off-farm employment played a catalytic role, and have contributed to improving access to food. In Brazil and Mexico, social policies and safety nets have played an important role. They have emphasised conditional cash transfers (CCTs) to improve food and nutritional security although the CCTs are part of much broader social

Table 1.4 Household food consumption and prevalence of under-nourishment. (Source: FAO-STAT database and FAO (2010))

Country	Share of household expenditure on food (%) (year)	No. of people under-nourished (million) 2005–2007	Under-nourished in total population (%)			
			1990–1992	1995–1997	2000–2002	2005–2007
Brazil	20.8 (2002)	12.1	11	10	9	6
China	39.8 (2006)	130.4	18	12	10	10
India	50 (2004)	237.7	20	17	19	21
Malaysia	49.5 (2004)	ns	–	–	–	–
Mexico	30.7 (2002)	ns	–	–	–	–
South Africa	–	ns	–	–	–	–
World	–	847.5	16	14	14	13

ns not significant

protection and food security programmes. India also uses a wide array of instruments, including in-kind transfers, public works programmes and school mid-day meal programmes to tackle food security, albeit with perceived disappointing outcomes on the whole, despite their impinging impact on the national budget.

1.3.3 Ensuring Utilisation

Anthropometric measures of child nutritional status show that India has among the highest prevalence of child malnutrition in the world with over 43.5 and 47.9% of children under the age of 5 years estimated to be underweight (low weight-for-age) and stunted (low height-for-age) respectively in 2005–2006 (Table 1.5). Trends in child malnutrition show that, while India has made progress in reducing the prevalence of underweight children under 5 from over 67.3% in 1974–1975 to 41% in 1996–1997, it rose to 44.4% in 1998–1999 and remained almost unchanged at 43.5% in 2005–2006, in contrast to the other EDEs which made rapid progress. China also made progress in reducing malnutrition, as did the Latin American countries.[13]

1.3.4 Ensuring Stability

Global food commodity prices rose steeply between 2006 and 2008, reaching a peak in mid-2008. Food prices rose by 83% between 2005 and 2008, with maize prices nearly tripling, wheat prices increasing by 127% and rice prices increasing

[13] However, obesity is emerging as an important challenge in these countries while low child nutrition continues to be a blemish on India's overall socio-development indicators.

Table 1.5 Prevalence of child malnutrition. (Source: WDI Database; WHO (http://www.who.int/nutgrowthdb/estimates/en/index.html))

Country	Year	Under-5 mortality rate (per 1000 live births)	Year	% of children under age 5		
				Under-weight	Stunted	Over-weight
Brazil	1990	59	1975	16.1	38.2	11.5
	1995	48	1989	6.1	20.4	8.5
	2000	36	1996	4.5	13.5	6.6
	2010	19	2002–2003	3.7	–	–
			2006–2007	2.2	7.1	7.3
China	1990	48	1987	18.7	38.3	–
	1995	43	1992	15.3	37.6	6.9
	2000	33	1998	7.9	20.7	6.8
	2010	18	2000	8.7	19	4.4
			2002	6.8	21.8	9.2
India	1990	115	1974–1979	67.3	75.1	–
	1995	10	1988–1990	59.5	66.2	–
	2000	86	1991–1992	56.6	65.4	–
	2010	63	1992–1993	48.7	57.0	2.9
			1996–1997	41.1	48.5	5.0
			1998–1999	44.4	51.0	3.6
			2005–2006	43.5	47.9	1.9
Malaysia	1990	18	1990	22.1	–	–
	1995	14	1991	23.1	–	–
	2000	11	1992	22.6	–	–
	2010	6	1993	20.5	–	–
			1994	19.7	–	–
			1995	17.7	–	–
			1999	16.7	20.7	5.5
Mexico	1990	49	1988	12.4	28.7	6.1
	1995	38	1989	13.9	40.4	9.8
	2000	29	2006	3.4	15.5	7.6
	2010	17	1998–1999	6.0	21.7	7.6
South Africa	1990	60				
	1995	61	1994–1995	8	28.7	10.3
	2000	78	1999	10.1	30.9	9.6
	2010	57				
World	2010	58	2004–2009		31.7	6.1

by 170 % between January 2005 and June 2008 (UNCTAD 2008). Food commodity prices fell sharply in the second half of 2008. They rose again between October 2010 and January 2011 when they fell below the 2008 peak. The sharp increases were observed in the global prices of wheat, maize, sugar and edible oils, with a relatively smaller increase in rice prices (World Bank 2012). Such price volatility reflects various back-end elements. Agricultural production is variable reflecting yield variations largely on account of weather, natural disasters and pest infestations. Low demand and supply elasticities as well as lagged supply responses add to the degree of variability observed in agricultural commodity markets, where prices have suffered high volatility in the recent past (Shome 2013). The financialisation of commodity markets has also contributed to volatility.

Although international price volatility was large, a wide variation was observed in domestic price volatility among countries. In general, price volatility was substantially lower in the case of China and India in contrast to Brazil. The lower volatility in the former could be attributed to domestic price stabilisation policies including price support policies, and managed trade environments (OECD—FAO 2010). Responses to the 2008 food crisis also varied depending on the policy framework for agriculture and food security. This is reflected in the country studies in this volume.

A general consensus prevails that there were deficiencies in international coordination and responses to the food crisis pertaining to supply and volatility. The debate over the main factors responsible has underscored the cross-border effects of domestic policy action and the global public good aspects of agricultural and nutritional knowledge. No doubt there is an urgent need for greater co-ordination and more effective governance of agriculture and food security at the global level.

1.4 Energy[14]

The large, rapidly industrialising and urbanising EDEs are facing new challenges on the energy and environment fronts. The demand for energy in these countries, particularly in China, is growing at an unprecedented pace pari passu with high rates of economic growth and improvements in living standards. At the same time, it must be admitted that emerging social and environmental factors are limiting the formulation of suboptimal future policies that would ignore the limits to the use natural resources. In 2008, Brazil, China, India and South Africa together accounted for 41 % of the world's population and 26 % of global energy supply (Table 1.6). Although the energy profiles of these EDEs vary, the country studies in this volume point to the importance accorded by them to improve energy efficiency, demand side management and the development of renewable sources of energy. Their objectives are to achieve energy security by reducing dependence on energy imports and foreign technology and enhancing, if not ensuring, security of supply. All the

[14] See Parikh (2012) for a synthesis of the individual country studies. Several of the tables in this chapter are sourced from that comparative study.

Table 1.6 Total primary energy supply (TPES) and CO_2 intensities. (Source: Parikh 2012 (based on http://www.iea.org/co2highlights/co2highlights.pdf))

Countries	Population in billion (2008)	GDP/cap (2008) in billion PPP US$ 2000	CAGR of per capita GDP in PPP US$ 2000 (1990–2008) in %	TPES 2008 (million tonnes of oil equivalent)	Percent change of TPES (1990–2008)	CO_2/energy (tonnes CO_2/terajoule) of 2008	Percent change CO_2/energy from 1990 to 2008
Brazil	0.19	8582	1.6	249	77	35	5.9
China	1.33	8295	9.1	2131	144	73	19.4
India	1.14	3781	4.7	621	95	55	24.1
South Africa	0.05	10,920	1.0	135	48	60	−10.5
Total 4 countries	*3*			*3136*			
World	6.69	9549	2.3	12,267	40	57	0.3
5 Countries/ world	*0.41*			*0.26*			

countries have a high potential for the development of renewable resources, including solar and wind power. However, since various renewable energy sources are at different levels of R&D and commercialisation, the exploitation of this potential is likely to take time.

In the meanwhile, the EDEs are, by and large, seeking environmental space to contribute to global growth and development. The studies point to the need for a correct policy mix including programmes and technologies for promoting energy efficiency and renewable energy on the one hand, and evolving appropriate links between such policies and their commercialisation on the other. Successful development of renewable resources also requires global co-ordination. A successful framework for global governance could be designed through co-ordinated burden sharing for the development of renewable resources. Burden sharing assumes importance for EDEs since it would have long-term cost implications for them.

1.4.1 Energy Mix

The primary energy mix and the composition of renewable technologies in the EDEs are naturally related to their respective natural resource endowments and technological capabilities. China, India, and South Africa are coal-dependent economies (Tables 1.7 and 1.8). Brazil's primary energy profile, on the other hand, is more diversified and is among the cleanest in the world. Renewables, including hydro, ethanol, biodiesel, charcoal and firewood are in use in Brazil. A significant

Table 1.7 Total primary energy supply and percentage share of sources for 2008. (Source: Parikh 2012 (based on http://www.iea.org/stats/index.asp (International Energy Agency)))

TPES (%)	Brazil	China	India	South Africa
Coal and peat	5.5	66.4	42.1	71.3
Crude oil and oil production	38.5	17.2	23.3	12.8
Gas	8.5	3.2	5.7	3.1
Nuclear	1.5	0.8	0.6	2.5
Hydro	12.8	2.4	1.6	0.1
Geothermal, solar etc.	0.1	0.3	0.2	0.0
Combustible renewable	31.6	9.6	26.3	10.4
Electricity imports	1.5	−0.1	0.1	−0.2
Heat	0.0	0.0	0.0	0.0
Total supply[a] (ktoe)	248,528	2,116,427	620,973	134,489
Total net imports (ktoe)	20,920	174,462	153,001	−21,046
Stock changes (ktoe)	−518	−51,341	−336	−7415
Total domestic production (ktoe)	*228,126*	*1,993,306*	*468,308*	*162,950*

[a] Totals may not add up due to rounding

Table 1.8 Electricity production, sources and access, 2009. (Source: WDI 2012)

	Brazil	China	India	South Africa
Electricity production (billion kW h)	466.5	3695.9	899.4	246.8
Coal	2.1	78.8	68.6	94.1
Natural gas	2.9	1.4	12.4	0
Oil	3.1	0.4	2.9	0
Hydropower	83.8	16.7	11.9	0.6
Renewable sources	5.2	0.8	2.2	0.1
Nuclear power	2.8	1.9	2.1	5.2
Access to electricity	98.3	99.4	66.3	75.0

Table 1.9 Net imports in 2008 as percentage of supply. (Source: Parikh 2012 (based on http://www.iea.org/stats/balances.asp))

Net import[a]/TPES (%)	Brazil	China	India	South Africa
Coal and peat	86.0	−1.1	14.0	−40.9
Crude oil and oil products	−1.3	52.2	73.5	94.5
Gas	44.6	1.7	26.1	58.2
Nuclear	0.0	0.0	0.0	0.0
Hydro	0.0	0.0	0.0	0.0
Geothermal, solar etc.	0.0	0.0	0.0	0.0
Combustible renewable	−3.4	0.0	0.0	−1.9
Electricity	1.5	−0.1	0.1	−0.2
Total net imports/TPES[b]	8.4	8.2	24.6	−15.6

[a] Net imports includes marine and air bunkers
[b] Totals may not add up due to rounding

share of electricity in China and India is also generated from renewables in contrast to South Africa where it has a negligible share. Although hydro dominates the renewable energy mix in all of them, Brazil has achieved a strong increase in biomass-fired electricity production, while India, followed later by China, has deployed wind power (IEA 2011). Reliance on nuclear technologies is low in all four EDEs when compared to advanced economies. In 2009, nuclear power accounted for around 2 % of the electricity produced in China and India, around 3 % in Brazil, and 5 % in South Africa. The dependence on energy imports, particularly of oil and gas, is significant for some of them. China and India's oil import dependence stood at 52 and 74 % respectively in 2008 (Table 1.9). Although all these countries have set their own national targets, or put in motion national plans and strategies for increasing the share of renewables in the primary energy mix, it is not fully clear from available analysis as to what extent these goals are achievable in the medium term.

In 2007, 46 % of Brazil's primary energy was from renewable resources. These consisted of hydropower (15 %), sugarcane (16 %), wood and charcoal (12 %) and other renewables (3 %) (Chap. 7). Ethanol, used as liquid fuel for transportation, and sugarcane bagasse, used for power generation, have substantially increased their contribution in recent years and are together the second most important source of primary energy, surpassing hydroelectricity, after oil and oil derivatives. Hydropower is however, the main source of electricity in Brazil, accounting for over 83 % of electricity production in 2009 (Table 1.8). Less than 6 % of electricity production in Brazil uses coal or oil. On the demand side, the share of energy used by the agriculture sector has risen significantly from 1.6 % in 1971 to 4.5 % in 2008 due to a substantial increase in agricultural output. There has been a decline in the share of energy used by the industrial sector from 50.4 % to 46.2 % and an increase in the share of the residential sector from 20.6 % to 22.3 % over the same period.

In 2010, China overtook the USA as the world's biggest consumer of energy, accounting for around 20 % of global demand as compared to 19 % in the USA (Swartz and Oster 2010). According to Gao (Chap. 8), in 2008, more than 90 % of the energy consumed in China came from hydrocarbons, of which coal—much of it high-sulphur coal—accounted for 67 %. Coal accounted for close to 80 % of the electricity produced in China, while 17 % came from hydropower. The secondary sector, which is the largest energy consuming sector and accounts for 47 % of GDP, increased its share in total energy consumption from 66 % in 1980 to 73 % in 2010. The share of the primary sector declined from 8 % to 2 % over the same period. China's domestic energy resources which are distributed unevenly across its regions, are insufficient to meet its demand. Consequently, it has adopted a 'going abroad' strategy, actively encouraging its oil companies to acquire overseas oil and gas resources.

Coal continues to be the largest source of energy in India followed by combustible renewables. In 2009, 69 % of the electricity produced was based on coal, 12 % on natural gas and 3 % on oil. The share of electricity produced from hydro was 12 %, having declined over time. The industrial sector accounted for the largest share (45 %) in energy consumption in 2006–2007 followed by the transport sector (18 %). The shares of agriculture and the residential and commercial sectors rose from 4 to 10 % respectively in 1990–1997 and 15 % in 2007. India faces onerous challenges in securing its energy needs. It has limited hydropower resources, a small wind power potential, meagre oil and gas resources and a scarcity of land. Although it has a high solar energy potential, the current capacity is limited reflecting high—albeit declining—cost of the technology (Sawhney and Mehra in Chap. 9).

South Africa has no oil, little gas and a low hydro potential. It is largely dependent on coal with 200 years worth of reserves. In 2008, 71 % of energy supply was from coal, 13 % from oil, 10 % from combustible renewables, 3 % from gas, and 2.5 % from nuclear power. Coal provides 90 % of South Africa's electricity. It produced 255 million t of coal in 2010 of which 25 % was exported and 53 % used for power generation. South Africa is the second largest coal exporter in the world after Australia. On the whole, South Africa has concentrated on fossil and nuclear fuel development despite high solar and wind potential. However, as discussed by Fig in

Table 1.10 CO_2 emissions, total, per capita and cumulative from 1900 to 2005. (Source: Parikh 2012 (based on http://cait.wri.org/cait.php?page=yearly (World Resource Institute)))

Countries	CO_2 Eq. for 2007		CAGR (2000–2007) in %		Cumulative emissions (1900–2005)	
	Total	Per capita (metric tons)	Total	Per capita	Total (Mt CO_2e)	% world
Brazil	374	2.0	1.7	0.6	4572	1.2
China	6703	5.1	9.1	8.8	55,150	14.8
India	1410	1.3	4.0	3.3	14,633	3.9
South Africa	353	7.4	1.9	0.9	4666	1.3
Four countries	*8840*	*16*			*79,021*	*21*
World	*29,630*				*373,312*	

Chap. 10, given the growing threat of climate change and the increasing scarcity of fossil fuels, these resources have to be 'embraced', howsoever 'reluctantly'.

1.4.2 Development of Renewable Energy

CO_2 emissions per unit of energy are among the lowest for Brazil, much below the global average, reflecting the significant role of hydropower and ethanol in its energy use (Table 1.6). According to Moreira (Chap. 7), deforestation accounts for 57.5% of total emissions in Brazil, followed by agriculture (22.1%), and energy (16.4%). China's energy mix is more CO_2-emitting than the global average. India and South Africa are around the global average. China was responsible for a significant fraction of greenhouse gas (GHG) accumulation in the atmosphere, at 14.8% during 1900–2005. The others are small, with Brazil at 1.2% of global emissions, India at 3.9% and South Africa at 1.3% (Table 1.10). However, if not curbed, their emissions could be substantial in the future. Thus, there is international pressure on them to contain emissions. The Emerging Economies Research Dialogue (EERD) that was held on the basis of which this volume emerged, revealed that energy security concerns comprise the main driver behind the energy strategies and policies of the large EDEs under discussion, though local environmental challenges are also assuming importance. Climate change concerns remain secondary, however. Therefore, to reduce dependence on energy imports and to adequately address their environmental and related social concerns, the use of renewable energy sources has become attractive in the EDEs.

Many renewable energy sources tend to cost more than conventional sources. Different EDEs have adopted different policies and programmes to foster investment in renewables and promote a switch towards the production and consumption of renewables. These measures include blending mandates for biofuels, feed-in tariffs, tax concessions and investment subsidies for renewables as well as reduction in fossil fuel subsidies. Brazil has mandated blending petrol with ethanol and charging consumers the full cost of the blended product. India has used feed-in tariff, renewable portfolio standards and capital subsidies. China has deployed a variety of tools including fuel incentives, tax concessions, differential pricing and investment subsidies for energy efficient products.

Moreira indicates that Brazil has a long-standing programme, beginning in the early 1960s, for the development of renewables when support was extended by multi-lateral institutions to harness the country's huge hydro potential. Brazil's ethanol programme received a big push through the establishment of the National Alcohol Programme (PROALCOOL) in 1975 in the aftermath of the global oil price shocks of 1973–1975. The attractive financial incentives, blending mandate, price and tax differentiation between gasoline and ethanol, together led to increased demand and supply of ethanol between 1976 and 1986. After a phase of stagnation and redefinition of the sector, ethanol production received a boost from 2001 due to the introduction of the flexi-fuel cars.

In Brazil, interest and research in fostering the construction of small hydro, solar collectors, and biomass-based thermoelectric plants arose in the early 1980s. However, significant investments in most of these options began only in 1995 following major changes in energy related legislation that led to the creation of independent power producers. In 2002, Brazil established a national programme, PROINFA, which has provided financial support to new investors. A 2005 biodiesel programme has also helped to develop biodiesel from edible oils (mainly soya beans). The programme provides financial support and captive markets to producers. It began with a blending mandate of 2 %, which was raised to 5 % in 2010. One of the distinguishing features of the biodiesel programme, as compared to PROALCOOL, was the former's social content in terms of privileging the participation of family farms. Biofuels provide a comparatively significant share of the energy consumed in road transport, Brazil is the largest consumer and exporter of sugarcane based ethanol. However, Brazil's official energy plan for 2008–2017 provides for large investments in oil exploration and production after the recent discovery of major off-shore oil resources.

Although Brazil's programme of ethanol based on sugarcane and biodiesel based on soybeans has been a great success, it cannot be replicated in other EDEs that do not have the same abundance of land and water resources as Brazil. However, Moreira's review of Brazil's experience in deploying its natural resources suggests that it was not merely the abundance of resources but also the policies, institutions and technologies that were formulated and implemented that drove Brazil's success.

China had set the following energy policy targets: (i) reduce energy intensity of GDP by 20 % over 2006–2010; (ii) increase the share of non-hydrocarbon sources to 15 % by 2020; and (iii) reduce carbon emission intensity of GDP by 40–45 % over 2005–2020. China had not reached its extremely ambitious first goal for 2006–2010. As regards the second objective, in 2008, China's clean energy consumption, including that from hydropower plants, was 282.59 Mtce, which accounted for 9.9 % of the total. For 2011–2015, Chinese policy was to reduce the energy intensity of GDP by 16 %. However, having invested heavily in renewable technologies, China has become a global leader in recent years. It has made a concerted effort to diversify its sources of energy imports in order to reduce heavy dependence on the Middle East. The northeast channel is one of the major pre-existing transportation channels through which it imports crude oil, natural gas and coal from the Russian Federation. China has also set up strategic oil reserves to reduce the risk of supply suspension.

India is rapidly developing various renewables such as wind, mini hydro and solar. It established the National Action Plan on Climate Change in 2008 to address climate change concerns and to move towards a low-carbon sustainable growth path. The programme comprises eight national plans, including two that deal with clean energy (National Solar Mission) and energy efficiency (National Mission for Enhanced Energy Efficiency). The former aims to achieve parity for solar power with coal-based thermal power by the year 2030 and interim grid parity by 2020.

According to Parikh (2012), wind power can be set up quickly and requires marginal support as feed-in-tariff. India has made some progress in installing wind power capacity. The main challenges are limited availability of wind resources and its low plant load factor. Thus, full development of the wind power potential of 100,000 MW could supply no more energy than 30,000 MW of coal-based power. Nonetheless, the available potential should be exploited. The EDEs have a large potential for solar energy which is a major long-term option. The difficulty is its high cost. However, costs are declining and India's solar mission target is to be coal competitive by 2020. Reaching this goal requires setting up systems to reap economies of scale, and providing subsidies in the interim in ways that encourage competition, cost reduction and innovation. The reverse bidding process used in India, where suppliers bid for the subsidy required in the form of feed-in-tariff for solar power projects, is one way to have a market-determined level of subsidy. Another way is to stipulate renewable portfolio standards to create a competitive market for different forms of renewables. Second-generation ethanol based on cellulosic material, agricultural wastes and specially grown grasses can be an important option in the future. At present, the technology is not economically viable. Wind and solar electricity are not available on demand. While solar power availability is predictable, wind power is less predictable. Hence, wind and solar power would continue to require balancing with hydro plants, pumped storage schemes, gas turbines, and a 'smart' grid.

1.4.3 Energy Efficiency

Cross-country data on energy intensity suggest that there is considerable scope in the EDEs, particularly in China and India, for reducing the energy intensity of economic output (Table 1.11). All the countries have set targets or programmes to promote energy efficiency in specific sectors and industries. Unlike the other EDEs, Brazil initiated its programme to promote energy efficiency as early as 1985 through the establishment of PROCEL for the electricity sector, which was followed by CONPET for oil and gas in 1991. These energy efficiency programmes are administered separately for electricity and fuels through state-owned companies, namely,

Table 1.11 Energy intensity in 2007 (kgoe/US$ 1990 value added). (Source: Parikh 2012 (based on IEA 2009 and United Nations Statistical Division (UNSD)))

Country or area	Total	Agriculture	Industry	Transport	Commercial and others	Total (kgoe/capita)
Australia	0.15	0.14	0.20	0.44	0.02	3641
Brazil	0.25	0.10	0.30	1.40	0.03	998
China, People's Republic of	0.58	0.21	0.48	1.26	0.07	956
Germany	0.11	0.11	0.08	0.33	0.02	2831
India	0.45	0.11	0.47	0.37	0.03	337
Indonesia	0.53	0.07	0.42	0.93	0.04	646
Japan	0.09	0.05	0.07	0.30	0.03	2682
Saudi Arabia	0.47	0.03	0.15	2.46	0.05	3756
UK	0.10	0.05	0.09	0.29	0.02	2345
USA	0.17	0.08	0.13	0.83	0.03	5144

Electrobras and Petrobras. The electricity programme was further expanded in the late 1990s. Overall, the programmes have led to significant efficiency gains in selected areas. Energy service companies (ESCOs) providing specialised energy rationalisation and efficiency services emerged as a new sector in the mid-1990s. The electricity shortage in Brazil during 2001 was an important driver of efficiency gains in the residential sector but not in the commercial or industrial sectors.

An important way to promote energy efficiency is to have a competitive energy sector where prices of different fuels and forms of energy reflect their opportunity costs. This, however, is not easy since these countries have a large percentage of people who are too poor to be able to afford the full cost of energy. Thus, in South Africa, full marginal cost pricing for electricity connections will imply that the poor will be pushed out of such a market.

1.5 Technology and Innovation

The large EDEs covered in this volume are being increasingly recognised as innovation powerhouses (The Economist 2010). In contrast to the technologies and innovations that have emerged from industrialised economies in the past, innovations from the EDEs, particularly from China and India, are being hailed as frugal not just in terms of cost but also from the perspectives of resource use and impact on the environment. India's innovation strategy places particular emphasis on frugal, distributed, affordable innovation in promoting inclusive growth and development (NIC 2011). The importance of grassroots innovation systems linked to local knowledge and capacities as well as 'invisible' innovations targeted at local markets that typically do not appear in national statistics were particularly underscored in the course of the EERD.

Although EDEs still account for a relatively small proportion of total global expenditure on R&D, nevertheless, Brazil, China, India and South Africa among others are making significant investments in environmental technologies, an area critical to addressing the global challenges of food and energy security (OECD 2010). According to the OECD's Science and Technology data, the BRIICS (Brazil, Russia, India, Indonesia, China and South Africa) were found to be focusing more on renewable energy applications than the global norm, as seen in their higher than average patent applications in this area (Fig. 1.4). Brazil, China and India are increasingly involved in patent development in waste management, pollution abatement and renewable technologies. Brazilian technological capabilities in biomass, and Chinese and Indian investments in wind and solar technologies have been recognised globally (IEA 2011).

Based on conventional indicators, although EDEs lag behind industrialised economies, they have shown consistent progress in enhancing their science, technology and innovation capabilities. India's gross expenditure on R&D (GERD) was 0.76 % of GDP during 2005–2009, that of South Africa, 0.93 %, Brazil, 1.08 %, and China, 1.47 % (WDI 2012). GERD has increased consistently in China from 0.73 % in 1991 to 1.5 % of GDP in 2008 (OECD 2010).

In China, business expenditure on R&D (BERD) increased to 1 % of GDP in 2008 (Table 1.12). China accounted for 12 % of the world's scientific articles and a share of 1.1 % in the triadic patent families in 2008. The publication of scientific articles in China grew at one of the fastest rates in the world in the decade to 2008. China has also invested heavily in human resources in science and technology in recent years. Its innovation policy, the Medium and Long-Term Plan for Science and Technology Strategic Development: 2006–2020, aims to achieve an innovation-oriented society by 2020.

In Brazil, BERD was 0.5 % of GDP in 2008. Brazil provides a tax subsidy of 25.5 % for every USD of R&D to incentivise BERD. Its Ministry of Science and Technology has launched an Action Plan for Science, Technology and Innovation (PACTI 2007–2010). Although both public and business R&D is relatively low in India, growth in R&D has been stronger in recent years. BERD was only 0.14 % of GDP in 2004. India's 0.14 triadic patents per million population in 2008 and 35 scientific articles per million population are ranked lowest among our sample EDEs. However, the Indian President declared in 2010 the following decade as the 'decade of innovation'. Today, India is working on developing a national strategy on innovation with a focus on an Indian model of inclusive growth.[15] South Africa has also commenced its Ten-Year National Innovation Plan (TYIP) for 2008–2018 with several challenges: strengthen its bioeconomy, develop space science and technology, focus on energy security and engage in efforts to address climate change. South Africa has also established a Technology Innovation Agency (TIA) made operational in 2013.

[15] See http://www.innovationcouncil.gov.in/.

Table 1.12 Science and technology indicators for selected countries. (Source: Jager 2012; OECD 2010)

Country (reference year)	GERD as % of GDP	BERD as % of GDP	Triadic patents per million of the population	Scientific articles per million of the population	Researchers per 1000 total employment	Science and engineering degrees as % of all new degrees	HRST occupations as % of total employment	R&D spending target as % of GDP
Brazil	1.09	0.50	0.34	141.37	1.48	10.95	10.8	0.65 (business sector)
	2008	2008	2008	2008	2006	2007	2008	2010
China	1.54	1.12	0.39	156.23	2.06	39.18	9.48	2.5
	2008	2008	2008	2008	2008	2005	2005	2020
India	0.71	0.14	0.14	35.0	0.31	–	11.43	2.0
	2004	2004	2008	2008	2000		2005	–
South Africa	0.92	0.53	0.56	109.86	1.46	16.41	–	–
	2007	2007	2008	2008	2007	2003		
USA	2.77	2.01	48.69	911.07	9.53	14.98	32.32	3.0
	2008	2008	2008	2008	2007	2007	2008	Indefinite

1.5.1 The Importance of Adopting the Broad Approach to Innovation

While the sections on agriculture, food and energy describe the contribution of technology and innovation in promoting food production and energy efficiency and renewable energy, the set of papers in the technology and innovation section of this volume focus on the broader national innovation systems and strategies or their components thereof.

Thus the papers in Part III of this volume argue that it may be more useful to analyse innovation in a broader, rather than in a narrow, sense. According to Cassiolato in Chap. 11, adoption of a narrow approach to the innovation system results in policies that typically interpret a country's science and technology policy narrowly and channel its R&D efforts towards interface between the scientific, technological infrastructure sector and the productive sector. Such an approach does not address how broader institutions affect the innovation system, for example, macroeconomic policies, the financial system, industrial relations, labour market dynamics, education systems or underlying historical and cultural processes. The broader approach represents a systematic understanding of socio-economic capabilities, institutional evolution and development paths with specific local features and their dynamics.

1.5.1.1 National System of Innovation

Cassiolato analyses the Brazilian innovations system using the broad production-centred approach to NSI that includes the production and innovation subsystem; the capacity-building sub-system including the education and R&D infrastructure; the financing subsystem; and the role of demand, including income distribution, structure of consumption, social organisation and the demand for infrastructure, health and education. The Brazilian NIS evolved during 1950s–1970s as the economy transformed from a traditional supplier of raw materials and crops to an economy based on manufacturing under a strategy based on import substitution. Since then manufacturing has lost some ground to services and agro-industry that have increased their contribution to GDP.

There are strong indications that the agribusiness sector has expanded through both the development of strong innovative and productive capabilities, and specialisation in the production of export-oriented goods. An example of technological development relates to the agricultural development of the semi-arid land in Brazil's northeast regions, which was previously considered unsuitable for cultivation. Brazil's system of national and regional agrarian research is led by Embrapa, a public company responsible for the development of genetic research, and connected strongly with other state agencies, universities, private enterprises and research laboratories. Embrapa, in consortium with universities, has developed a number of crop varieties suitable to the climatic and soil specificities of the different regions of the country.

Nevertheless, Brazil exhibits fairly low overall levels of innovation reflecting that most innovation is captured by the manufacturing sector, as opposed to the services sector, particularly those related to natural resources, energy and agriculture. This points to the need for a holistic governance framework. A 'linear' vision hinders any synergy between innovation and other policies that influence the innovation process. Policy co-ordination is found to be crucial for the overall socio-economic development of the economy. In its absence, severe income inequality and unequal regional distribution of wealth have resulted in the creation of regional pockets of scientific and economic excellence without too much success in extending the benefits to backward regions.

1.5.1.2 Macro-economic Policies

The Latin American country studies on Brazil and Mexico emphasise the importance of macro-economic policies and the institutional context in understanding the dynamics of industrial and technological development. Macro-economic policies, depending on their objectives and forms, may weaken, or even nullify, policies aimed at innovative industrial development. Key variables of the economy, including the interest rate, exchange rate, inflation rate, fiscal deficit and balance of payments, have important effects on determining micro-economic business and production decisions. For instance, macro-economic regimes combining high interest rates with overvalued exchange rates may adversely influence domestic production and international competitiveness of the country's exports.

Calza and Cimoli in Chap. 15 emphasise the merits of adopting a structuralist perspective for providing effective support to innovation, grounded in the long-term consistency between economic and innovation strategies. They argue that the main lesson from the Mexican experience is that innovation systems need to be complemented by appropriate macro-economic policies and consistent industrial policies that strengthen endogenous capabilities for boosting innovation. They describe the evolution of the Mexican economy since the consolidation of economic reforms and the implementation of a structural adjustment programme from 1990. The macroeconomic and trade reforms pushed the manufacturing sector towards a peculiar configuration, defined as *industria maquiladore* (or *maquila*), characterised by reduced local content to the value added of the final product, concentration of domestic production in traditional goods (automotive, textiles and basic electronics), concentration of export markets (USA), polarisation of firm size with the large majority of plants (95 %) constituting micro-plants with a maximum of ten employees on the one hand, and large firms and multi-national enterprises on the other, and increased dependence on the import of capital goods and technology. Real exchange over-valuation made it more convenient to acquire even simple technology from abroad, thereby favouring consumption of foreign technology at the expense of the development of domestic technology and production, so that local investment was substituted by FDI. Consequently, despite 20 years of implementation of economic reforms and increased integration with the global economy, productivity growth in most sectors did not close the gap with the advanced and other major EDEs. Capability remained confined to a few sectors with low technological opportunity in others.

1.5.1.3 Science and Technology Policy

An abundance of budgetary resources, resulting from Brazil's strong growth in the late 1960s and early 1970s was channelled to the setting up of post-graduate courses focused on research in practically all scientific areas. From the point of view of technological development at the firm level, the roots of success were in agro-industry (Embrapa), airspace (Embraer, CTA, INPE), oil (in which Brazil is the world leader in technology for deep-water extraction) and energy (including biomass). Also noteworthy was the creation of sectoral R&D institutions by the federal government, in strategic areas. Institutions established even in an earlier era were not restricted to biomedical or agricultural areas. They included the Aeronautics Technical Center (CTA) founded in 1954, and the National Institute for Spatial Research (INPE) created in 1961. Institutional models were also adopted in other sectors. Petrobras was created as a public enterprise in 1953 in the oil sector, as were state-owned mining, and iron and steel enterprises with internal R&D labs. The external debt crisis that emerged in the early 1980s impacted Brazil's technological development trajectory adversely. During 1990–1998, Brazil's innovation policy reflected industrial policy based on re-structuring of the productive sector, and the opening up of the economy to international markets. From 1999, Brazil's R&D policy advocated innovation and enhanced capacity of the federal government to foster and finance innovation (Cassiolato in Chap. 11).

A Chinese national strategy to promote indigenous innovation was crafted in 2006 that resulted in the National Programming for the Development of Science and Technology in the Medium and Long Term—2006–2020. Its goal is to make China an innovative economy through an indigenous innovation strategy. Accordingly, China steadily increased R&D expenditure even during the financial crisis period. In 2009, R&D as a percentage of GDP reached 1.7%.[16] This is in stark contrast even to some developed economies where expenditure on R&D and education investment were either cut or remained stagnant following the financial crisis. Nevertheless, within China, there is growing evidence that local Chinese companies are weak in innovation. China's economic growth has been strongly dependent on foreign technology and FDI and foreign-invested enterprises have accounted for more than 85% of all high-tech exports since 2000 (NBS 2006) (Liu and Cheng in Chap. 12). China has been heavily reliant on foreign technology supply in key industries, such as chips, software, machine tools and engines, and bears low profit margins due to high royalty payments for licensing technology. There is, therefore, some scepticism regarding market-driven solutions for innovation. There are those who argue that it is necessary to use a nation-planning system (*juguotizhi*) to

[16] Since 2004, R&D expenditure as a percent of GDP has been the highest for China among Brazil, Russia, India and China (BRIC countries).

develop next generation technology (Mei 2009) that would provide the state appropriate power to implement innovation. In addition, there are suggestions that China needs more bottom-up or decentralised decision making, a greater role for the private sector, and improved coordination among agencies to promote innovation (OECD 2008).

The specific goals of Chinese innovation strategy according to the authors are to achieve R&D expenditure of 2 % of GDP in 2010, and 2.5 % by 2020, make science and technology and innovation the most important enabling factor for GDP growth, contribute 60 % of GDP growth through innovation, decrease the dependence on foreign technology[17] to less than 30 from 56 % in 2004 and, finally, be among the top five countries globally in terms of the number of domestic invention patents granted and in the number of international citations of scientific papers. Four policy instruments have been adopted to promote indigenous innovation. They are public procurement, regulation, industry linkage to research institutions and universities and public R&D subsidies, the core revolving around research consortia and public procurement.

India's recent economic progress has been driven by knowledge-intensive sectors, such as ICT, biotech or pharmaceuticals, leveraging India's labour cost advantage in these sectors. However, India's technological advantages in these skill-intensive areas have largely remained confined to the domain of minor as opposed to major innovative capabilities. India has demonstrated significant competitive strength in routine (through skill-intensive) tasks such as coding (in software) or process development (in pharmaceuticals), and perhaps less so in creativity and innovativeness per se. India's National Science Board is placing emphasis on creating knowledge intensive economies where research and intellectual pursuits along with their commercial application, would play a critical role. A new bill (Protection and Utilization of Public Funded Intellectual Property Bill 2008), inspired by the US Bayh-Dole Act of 1980, has been introduced to stimulate public-funded academic research for wider industrial application. It is often contended that even though Indian universities and research institutes have been quite active in their research pursuits, their interface with industry has remained less than optimal.

1.5.1.4 Role of the Diaspora

The return of the non-resident Indians (NRI) has been instrumental in stimulating entrepreneurial synergies, although the diaspora has been a complement rather than an initiator in India. Foreign sources of knowledge were critical in the early phase of heavy industrialisation and infrastructure development as Indian scientists and engineers were sent abroad to seek the knowledge required to build, operate and maintain them. In contrast, despite massive exposure to education abroad, most Malaysians residing abroad have not returned to participate in the government's Brain Gain programme. A combination of ethno-discriminatory policies and tardy

[17] The ratio of expenditure on technology import to total R&D expenditure.

bureaucracies not subjected to proper vetting, monitoring or appraisal, have undermined the capacity of such programmes to support the government's efforts to stimulate technological catch-up in strategic industries. The Indian experience provides important lessons where the government invested heavily through public expenditure on higher education in Indian Institutes of Technology (IITs), Indian Institutes of Science (IIS) and Indian Institutes of Management (IIMs) and the private sector started to reap the rewards once the economy started to liberalise. The Malaysian experience should be a lesson for avoiding man-made restrictions that can impede the creative synergies from being unleashed to drive any technological catch-up.

South Africa has had little success in computer hardware manufacturing or export, while Malaysia has made major strides as a global export player. In other words, while infrastructure is a necessary condition, it is not sufficient. What counts is the combination of those factors as well as the coherence and harmony of institutions and policies that can bring about change in particular environments. Furthermore, the focus should not simply be on enacting a long list of institutions that have worked elsewhere but, rather, on building harmony in institutions and policies that bring about change while incorporating relevant international experience in the local context.

1.6 Concluding Remarks

The increasing economic and political weight of EDEs has raised hopes and expectations of a more just and equitable global governance order. Although the process is incremental and is still evolving, the EDEs have begun to re-engage with global governance structures including through renewed dialogue with one another and the global community as a whole. However, there is a need for strengthening the dialogue further, for developing a common understanding, and defining the narratives emanating from EDEs.

In conclusion, the EERD should be mentioned as the fountainhead of this volume. It brought to the surface a common concern among the EDEs regarding securing their food and energy needs and technological independence. It was argued that market-oriented reforms were not sufficient for achieving agricultural growth and food and energy security, and appropriate public intervention in the areas of technology, risk management and support for small holders and small and medium enterprises was needed to enhance security. The declining supply of public goods, the shortage of funding for science and the increasing privatisation of public knowledge were raised as points of concern that should be made the subject of further analysis and debate within an emerging economy context. Other issues that were raised were global supply versus local demand for knowledge in terms of the setting of a research agenda, a global publications system versus local dissemination systems, and the inadequacy of the prevailing intellectual property rights regime in which multi-national companies dominate licensing and standards (Xue 2011).

The dialogue on energy, environment and climate change indicated that the primary driving force behind energy sector policies and strategies in the EDEs continued to be energy security concerns. Climate change was either viewed as a constraint or a secondary concern, while there was a growing concern over environmental problems. Energy policies were nonetheless contributing to improving energy efficiency and increasing investment in renewables, thereby addressing climate change concerns. The dialogue underscored the fact that policy and technology needed to move together in enabling a shift to renewables, given the continuing higher cost of renewables compared to conventional sources of energy. Other issues including the role of bridging fuels such as natural gas, energy poverty, engagement of the energy citizen, and the adoption of an eco-systemic approach to energy, were also discussed.

The resultant country studies that comprise this volume review current challenges and policy priorities, and key features of sector performance. The authors trace the evolution and recent innovations in relevant institutions, public policies and programmes. They document the significant progress that has been made over the past three decades by some of the sample large EDEs in enhancing food and energy security. They provide critical insights into the common as well as differentiated experiences and some of the innovative approaches adopted by them for improving the development outcomes. They also provide lessons for other EDEs. The analyses point to the deepening trade and investment relations among EDEs as an important element of enhanced food and energy security and economic growth.

The studies underscore the differences across countries in terms of their resource mix, the pace and sequencing of economy-wide reforms and approaches and strategies adopted for enhancing food and energy security, and for fostering technological development and innovation. They highlight the critical role played by technological, economic and social policy innovations in meeting basic human needs, keeping in mind their wider, for example environmental, impacts. The studies also provide insights into major domestic challenges and policy priorities relating to natural resources, energy efficiency and renewable sources of energy. Scaling up of investments in R&D and increasing domestic innovative capacities emerge as one of the most common strategies for addressing new challenges. More interestingly perhaps, in contrast to the conventional international concerns over the implications of rising emerging economy demand for commodities, the analysis presented in this volume alludes to the supply side dynamics and increasing production, trade, and investment inter-linkages among EDEs as potential sources of food and energy security.

References

AGECC (Advisory Group on Energy and Climate Change) (2010, April) Energy for a sustainable future. Report by the advisory group on energy and climate change, New York

Baffes J, Haniotis T (2010) Placing the 2006/08 commodity price boom into perspective. Policy research working paper 5371, The World Bank, July 2010

Beintema NM, Stads G (2010, March) Public agricultural R&D investments and capacities in developing countries: recent evidence for 2000 and beyond. Agricultural science and technology indicators, Background note

Bound K (2008) Brazil the natural knowledge economy. Demos, London

Busse S, Brummer B, Thle R (2011) Emerging linkages between price volatilities in energy and agricultural markets. In: Prakash A (ed) Safeguarding food security in volatile global markets. FAO, Rome, pp 107–126

Calvo-Gonzalez O, Shankar R, Trezzi R (2010) Are commodity prices more volatile now? A long-run perspective. Policy research working paper 5460, The World Bank

FAO (Food and Agriculture Organisation) (2004) The state of food insecurity in the world. FAO, Rome

FAO (2011) The state of food insecurity in the world. FAO, Rome

FAO (2013) The state of food insecurity in the world. FAO, Rome

FAO, IFAD, IMF, OECD, UNCTAD, WFP, The World Bank, The WTO, IFPRI, UN HLTF (2011, June) Price volatility in food and agricultural markets: policy responses

G20 (2011, November) Report of the G20 study group on commodities under the chairmanship of Hiroshi Nakaso

IEA (International Energy Agency) (2001) Towards a sustainable energy future. OECD, Paris

IEA (2011, October) World energy outlook, OECD, Paris

Jacks D, O'Rourke K, Williamson J (2009) Commodity price volatility and world market integration since 1700. NBER working paper 14748

James J, Pardey PG, Alston JM (2008) Agricultural R&D policy: a tragedy of the international commons. Staff paper series, Department of Applied Economics, University of Minnesota

Mei Y (2009, 7 September) Interview on nation-planned S&T system. The First Financing Journal (in Chinese)

Nagayets O (2005) Small farms: current status and key trends. Paper prepared for the future of small farms research workshop, Wye College, 26–29 June 2005

NIC (National Innovation Council) (2011, November) Report to the people 2011, Government of India

OECD (2008) OECD reviews innovation policy: China. OECD, Paris

OECD (2010) OECD science, technology and industry outlook. OECD, Paris

OECD (2011) International development statistics, credit reporting system. OECD, Paris

OECD–FAO (2010) Agricultural outlook 2010–2019. OECD–FAO, Paris

Parikh K (2012) Approaches to the development of renewable and clean energy in Brazil, China, Egypt, India, and South Africa: lessons for emerging economies. Policy paper No. 13, ICRIER

SEI (Stockholm Environment Institute) (2011) Understanding the Nexus. Background paper for the Bonn 2011 Nexus conference, The water, energy and food security Nexus, solutions for the green economy, 16–18 November 2011

Sharma P, Gulati A (2012) Approaches to food security in Brazil, China, India, Malaysia, and Mexico: lessons for emerging and developing economies. Policy paper No. 14, ICRIER

Shome P, Singh K (2011) Issues in utilizing India's demographic transition, thought leadership paper economic and fiscal policy environment in India. Ernst & Young, New Delhi

Shome P (2012) Fiscal stimuli and consolidation. In: Blanchard OJ, Romer D, Spence M, Stiglitz JE (eds) In the wake of the crisis: leading economist reassess economic policy (International Monetary Fund). MIT Press, Cambridge

Shome P (2013a) Political economy of debt accumulation and fiscal adjustment in a financial crisis. In: Mohanty D (ed) Monetary policy, sovereign debt and financial stability: the new Trilemma. Cambridge University Press, New Delhi

Shome P (2013b) Rebalancing and structural policies—an Indian perspective. Oxford Rev Econ Policy 28(3):587–602

Swartz S, Oster S (2010) China tops the U.S. in energy use. Wall Street Journal, New York

The Economist (2010, 17 April) The world turned upside down. A special report on innovation in emerging markets

UNCTAD (2008) Addressing the global food crisis: key trade, investment and commodity policies in ensuring sustainable food security and alleviating poverty, The high-level conference on world food security: the challenges of climate change and bioenergy, Rome, Italy

UNCTAD (2011) World investment report

World Bank (2012, January) Food price watch, Poverty Reduction Equity Group, World Bank.

Xue L (2011) Domestic reform and global integration: the evolution of China's innovation system and innovation policies, presented at the second emerging economies research dialogue, Beijing, 14–15 November 2011

Part I
Agriculture and Food Security

Chapter 2
Recent Development Patterns and Challenges of Brazilian Agriculture

Antônio Márcio Buainain and Ruiz Garcia

2.1 Introduction

In the past decade the determinants of Brazilian agribusiness[1] development have changed considerably. On the domestic scene, the government has undergone broad institutional restructuring and in terms of reorientation strategies and policies for economic development, and this has had significant impacts on agribusiness and consequently on the agriculture sector. Between 1999 and 2009, the share of Brazilian agriculture exports on the international market had increased: chicken meat, from 12 to 30 %; maize, from 0.01 to 7.8 %; and soybeans, from 22 to 35 % (FAOSTAT 2011).

The performance of Brazilian agribusiness has denied well-established beliefs amongst policy makers that for decades have sustained the need to protect domestic markets and cut down foreign trade incentives on the grounds of ensuring food security. In fact, during the same time span, in the wake of monetary stabilisation, income redistribution and economic growth, domestic food markets have expanded at a sustained high pace without any supply disruptions and price surges well known in the past.

In this context, we will argue that the presence and competitiveness of Brazilian agribusiness on the international market and overall positive economic performance is mostly the result of broad long-term domestic structural transformations, both at the macroeconomic level and within the sector, in which innovation has played a central role. In addition, we will show that recent developments have not been

[1] Agribusiness is composed of four sectors: raw materials, agriculture, industry and distribution.

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free of contradictions. Although productivity gains have operated as a powerful growth driver, new land at frontier zones was brought into cultivation, deforestation has continued, etc. Environmental and social relations have become sensitive issues whose consequences upon both the agricultural pattern of growth and sector governance cannot be ignored. Finally, the Brazilian policy experience is quite rich, particularly on land policy (agrarian reform) and in supporting the family farm segment. It will not be easy to deal with these issues in the frame of the paper, but it might be of interest to foreign colleagues to have some hints on these issues.

2.2 Agrarian Structure, Role and Performance of Brazilian Agribusiness

One of the marks of the Brazilian agrarian structure is its exacerbated concentration of land property. According to Hoffmann and Ney (2010), in 2006, the Gini Index of land property was 0.856.

The 2006 Agricultural Census registered 5.17 million holdings occupying an area of 330 million ha. Of the total, 2.5 million holdings had an area of 10 ha and below and a share of only 2.4% of the total area; and only 47,000 holdings held 147 million ha (Table 2.1). It is important to notice that in the past 15 years, the official programmes for agrarian reform redistributed 58.5–80.6 million ha and settled 1 million families (NEAD/MDA 2008), however, without impacting the overall pattern of land distribution.

It is not easy to produce hard evidence associating property rights to land use (Buainain 2008), but it is legitimate to raise the issue of weak property rights with poverty and deforestation. Around 1.23 million producers are tenants, sharecroppers, occupants and producers with no area declaration (IBGE 2006) (Table 2.1), most of them are *minifundistas* or very small poor producers, whose economic viability is increasingly contested (see Alves and Rocha 2010). Deforestation in the frontier zones is still used as proof of previous occupation of the land, which is still a strong argument for acquiring property rights over unclaimed land or in cases of conflicts over land ownership.

The heterogeneity has been evidenced in different Brazilian regions. In the Northeast, the poorest region, vastly dominated by semi-arid territory, 60% of the holdings had less than 10 ha in 2006. The majority was of poor producers without prospects for a viable market-oriented activity. In the Centre-West holdings with 10 ha and below represented only 16% of the total, while 43% were larger than 1000 ha and covered 72.3 million ha (IBGE 2006). Even though 10 ha might allow sustainable exploitation in the Centre-West *Cerrados*, viability is hindered by poor infrastructure, which requires larger-scale operations.

The levels of development and use of technology are highly differentiated amongst farmers and regions. Around 70% of holdings are served by electricity supply, but only 830,000 used electric power in agricultural activity. 2.8 million holdings use some kind of traction force, where 44% used animal traction, 34% mechanical traction and the remaining used both (Table 2.2). 47% of the holdings

Table 2.1 Number of holdings and area for condition of the producer by groups of total area: 2006. (Source: Prepared by the authors based on *Censo Agropecuário 2006*/IBGE 2006)

Condition of the producer	Total		0 < 10 ha		10 < 1000 ha		> 1000 ha	
	Holding	Area (ha)	Holding	Area (ha)	Holding	Area (ha)	Holding	Area (ha)
Total	*5,175,489*	*329,941,393*	*2,477,071*	*7,798,608*	*2,396,483*	*175,589,570*	*46,911*	*146,553,218*
Owner	3,946,276	306,847,605	1,787,949	6,284,733	2,113,167	159,683,709	45,160	140,879,163
Settlers without ownership title	189,191	5,750,283	67,367	242,377	121,547	4,713,318	277	794,589
Tenant	230,110	9,005,203	156,836	360,539	72,208	5,701,504	1066	2,943,162
Partner	142,531	1,985,085	124,512	252,041	17,866	1,154,868	153	578,180
Occupier	412,357	6,353,218	340,407	658,918	71,695	4,336,173	255	1,358,125
Producer with no declaration of area	255,024	0	0	0	0	0	0	0

Table 2.2 Share of family farming that use components for the modernisation of agriculture in Brazil: 2006. (Source: Authors modified data from Di Sabatto et al. 2011, p 16)

Technologies	%
Technical assistance	20.88
Associated with cooperative	4.18
Use electricity	74.10
Use animal force	38.75
Use mechanical force	30.21
Use manual force	31.04
Use irrigation	6.23
Use fertilisers and correctives	37.79

with an area below 100 ha used only animal force and 34 % used mechanical force. Notwithstanding, the primary use of human force and hand-held working instruments is still dominant amongst the vast majority of poor small peasant producers. In fact, 55 % of smallholdings use no other source of traction than human force. However, it is important to highlight that technological heterogeneity is also a feature amongst large holdings: about 132,000 holdings with more than 100 ha also do not use any kind of traction force (IBGE 2006).

Only 61 % of large holdings use some kind of agronomic practices, thus confirming deep differences in the production process even amongst larger holdings. To reinforce the rudimentary characteristic of the productive process, around 57 % of the Brazilian holdings did not carry out any type of soil preparation and only 10 % use direct tilling techniques. Amongst smallholdings below 100 ha, holdings that did not carry out any kind of soil preparation were 55 % and amongst larger holdings it was 58 %. Overall, 65 % of the holdings did not use any kind of green manure. The most surprising result is that around 90 % of the holdings do not use any kind of methods to control pests (IBGE 2006).

Brazilian agribusiness has been always a strategic sector and as such has played relevant roles in the structural configuration of Brazilian society as well as in the evolution and performance of the economy. In recent decades, it has been playing an anti-cyclical role, as a factor stimulating the economy as a whole. While up to the mid-90s the surge in agricultural prices have fed inflation and were subject to various types of price control policies (which proved always ineffective), since the launch of the Real Plan in 1994 the behaviour of real agricultural prices has been one of the anchors of the successful stabilisation plan. In addition, agribusiness exports have been the main source of foreign currency, whose availability has played a fundamental role in the transition from unsustainable foreign indebtedness status to the current creditor position and high credibility achieved by the Brazilian economy (Fig. 2.1).

Between 1980 and 1990 the real Agricultural GDP (Gross Domestic Product) grew 3.3 % per year; between 1990 and 2000 it grew 3.1 % and between 2000 and 2010 it grew 3.9 %, whereas Brazilian GDP grew 3 % in the first period, in the second one 1.65 % and the last one 3.7 % (Ipeadata 2011). In 2010, Agricultural GDP was

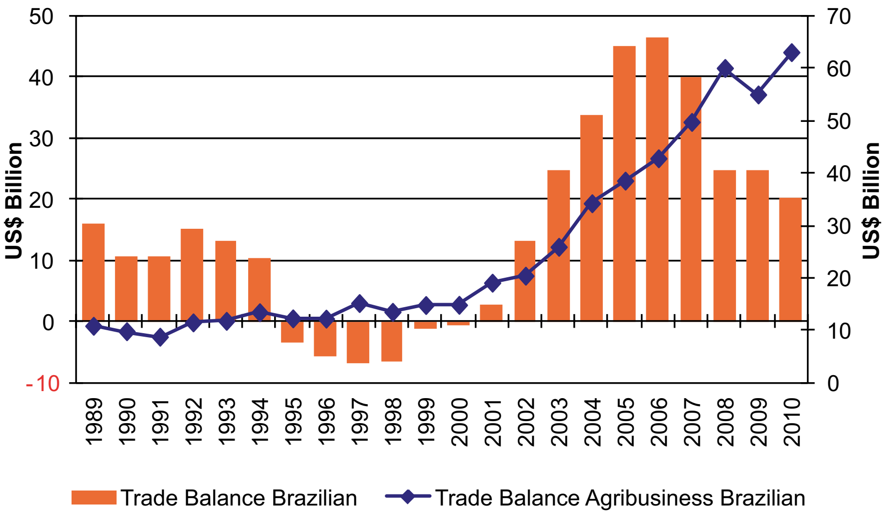

Fig. 2.1 Trade balance—total and Brazilian agribusiness: 1989–2010. (Source: Prepared by authors based on AgroStat 2011)

R$ 171 billion (US$ 97 billion), or 5.3 % of Brazilian GDP, and Agribusiness GDP reached R$ 821 billion (US$ 467 billion). The agriculture sector represented 26.5 % of Agribusiness GDP (Cepea-USP/CNA 2011) (Fig. 2.2). According to the National Agriculture Confederation—CNA (2008), agribusiness was responsible for the employment and occupation of 37 % of the employed Brazilian labour force.

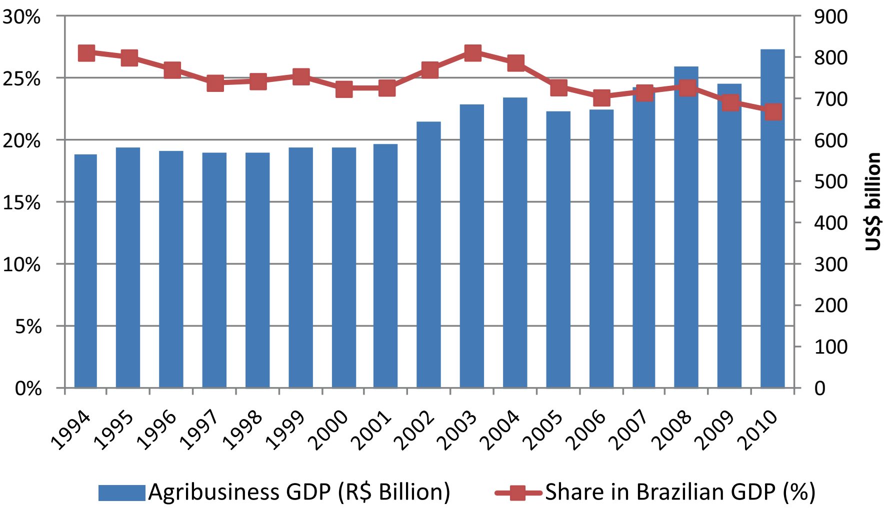

Fig. 2.2 Share in Brazilian GDP (%) and value (R$) of Brazilian agribusiness GDP: 1994–2010. (Source: Prepared by authors based on CEPEA/USP/CNA 2011)

Agribusiness has contributed most to the favourable performance of Brazilian foreign trade in recent years. Though international price increases have actually assisted in such performance, the expansion of physical exports accounts for 124 % of the gains in 2000–2009 (Cepea-USP/CNA 2011)[2]. Agribusiness exports expanded at an average annual rate of 9 % between 1989 and 2010—jumping from US$ 14 billion to US$ 76.4 billion—and its share of Brazilian exports has remained stable around 40 %, whereas agriculture's share of imports fell to approximately 7 % in 2010 (Fig. 2.3).

The recognition of the importance of agribusiness to the national economy as well as the expansion of agribusiness exports has contributed to the creation of a favourable context for investments and production; it has certainly exerted positive roles regarding policy support and fostering public and private investments as well as attracting new investors. However, at different periods, agriculture's positive performance has slid to excessive euphoria, which has probably led to overconfidence and disguised structural debilities in Brazilian agriculture.

Moreover, the expansion was not merely horizontal, sustained by the incorporation of new land and the growth of traditional tropical commodities, such as sugar and coffee, which characterise the traditional extensive pattern of growth. Both domestic institutional changes and innovation in production had a positive impact on the competitiveness and productivity of Brazilian agriculture, and allowed diversification to a broader variety of products, including fruit that, until then, had rarely been exported; it also opened up market opportunities and access to new markets

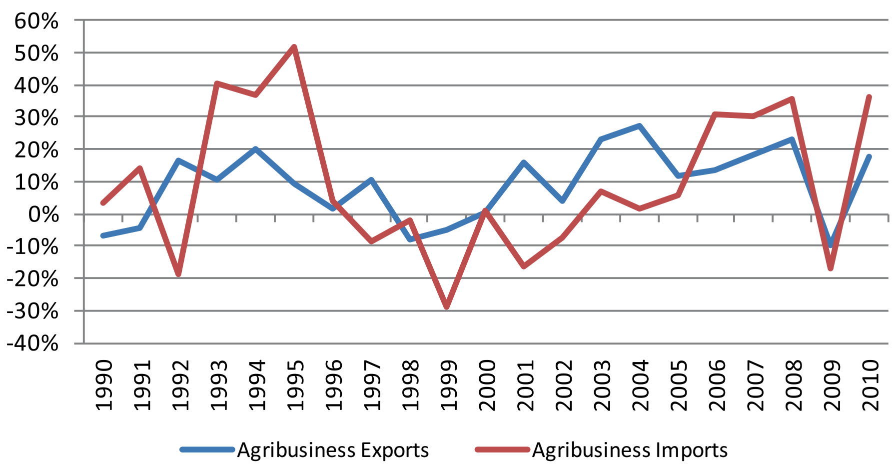

Fig. 2.3 Brazilian annual growth rate of agricultural exports and imports: 1990–2010. (Source: Prepared by authors based on AgroStat 2011)

[2] This performance is the result of the re-negotiation of farmers' debts, elimination of taxes on exports of non-manufactured products (Kandir Act), the 1999 devaluation of the Brazilian currency, high international prices of the commodities, and the emergence of animal health problems, such as mad cow disease.

(Russia, China, Middle Eastern countries, Chile, and Indonesia). The considerable increase of Brazilian share in world trade of several products, from soybeans to beef, pork and poultry, timber, sugar, bio-ethanol, paper and cellulose pulp, to quote the most important, can be taken as direct evidence of the revealed competitiveness of Brazilian producers (Silveira et al. 2005) (Fig. 2.4).

In recent decades, in the wake of institutional reforms, Brazilian agriculture and agribusiness have undergone broad economic restructuring, which is at the base of productivity gains and their competitiveness. As far as agriculture is concerned, at least four main interrelated dimensions should be mentioned: (i) innovation and technological changes; (ii) land use shifts; (iii) diversification of production; and (iv) the role of public policy.

The annual Brazilian production of grains[3] increased from 54 million t in 1990 to more than 140 million t in 2010. The new cycle of growth of agricultural production began in 1999 and gained strength recently, responding specifically to stimuli resulting from increased demand for grain in the world market, led by China. It is worth mentioning the performance of some agricultural products, which showed significant growth between 1980 and 2007: soybeans (284 %), sugar cane (254 %), maize (153 %) and oranges (67 %) (PAM/IBGE 2010) (Table 2.3).

This dynamism is related to trade liberalisation as well as to the shift in domestic agricultural policies, particularly the removal of ad hoc interventions on food price levels and on food supply flows. These included the elimination of export taxes for *in natura* products, and quotas and other imposed ad hoc restrictions due to domestic market conditions. In addition, the adoption of restrictive rules binding State

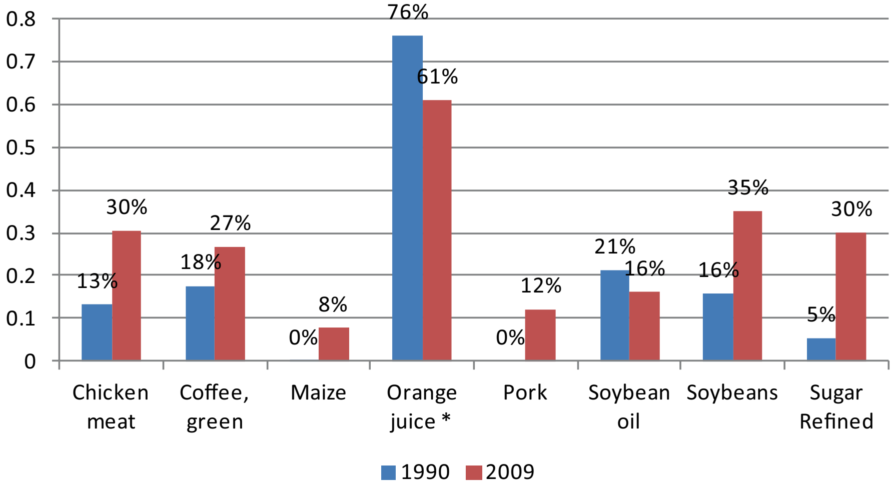

Fig. 2.4 Brazilian share in world trade by select products: 1990–2009 (Note: * concentrated). (Source: Prepared by the authors based on FAOSTAT 2011)

[3] Includes production of rice, oats, rye, barley, peas, broad beans, beans, sunflower, maize, soybeans, sorghum, wheat, and triticale.

Table 2.3 Evolution of production index of the quantity produced, productivity and harvested area by selected crops in Brazil: 1990–2010. (Source: Prepared by authors based on PAM/IBGE 2010)

Crops	Quantity produced			Harvest area (hectare)			Productivity		
	1990	2000	2010	1990	2000	2010	1990	2000	2010
Pineapple	100	182	200	100	182	176	100	100	113
Cotton (in seed)	100	113	165	100	58	60	100	195	277
Rice (paddy)	100	150	151	100	93	69	100	162	219
Sugar cane	100	124	273	100	112	212	100	110	129
Bean (grain)	100	137	141	100	93	73	100	148	193
Manioc	100	95	101	100	88	92	100	107	109
Watermelon	100	156	1409	100	118	140	100	131	1009
Melon	100	294	806	100	145	241	100	202	335
Maize (grain)	100	151	259	100	104	111	100	145	233
Soybean (grain)	100	165	346	100	119	203	100	139	170
Tomato	100	133	182	100	93	112	100	143	163
Wheat (grain)	100	56	199	100	42	81	100	131	245

interventions in agricultural markets has reduced negative market interventions and the so-called institutional risk.

Though the positive performance of Brazilian agriculture has indeed played the relevant role of securing sustainable food supply at stable and even decreasing real prices, the improvement in the food security situation is the result of a combination of several factors, among which we highlight the following: (i) price stabilisation and low rates of inflation; (ii) minimum wage real valorisation policy; and (iii) implementation and scale-up of universal pension benefits established by the 1988 Constitution. Nevertheless, these 'favourable' roles and performance cannot mask the structural changes in Brazilian agribusiness that made it possible to profit dynamically from the opportunities that arose.

2.2.1 Agriculture, Price Stabilisation, Income Redistribution and Food Security

Agriculture's positive performance is not confined to production expansion, growth of exports and trade balance surplus, but has contributed to monetary stabilisation, to improved food security, and the redistribution of income.

Brazilian food prices have shown remarkable stability since the Real Plan, and many have decreased in real terms (Fig. 2.5). In fact, the behaviour of agricultural prices—the green anchor—has been one of the successes of the Real Plan in bringing down inflation. The positive effects of food prices stability (Real Plan) and of the decrease in basic foodstuff real prices on food consumption, particularly for low-income groups, cannot be neglected. In fact, there is enough evidence to sustain the view that low-income groups have increased their consumption of poultry meat, dairy products, pasta and other industrialised food items, such as soups, canned

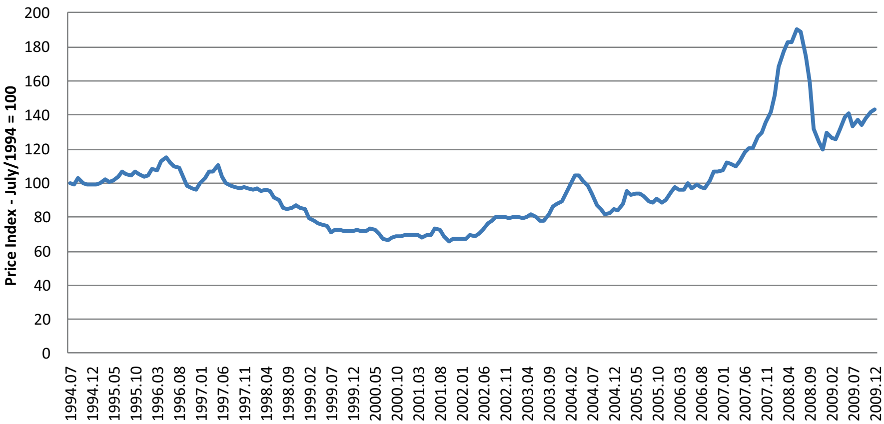

Fig. 2.5 Evolution of the price index of commodities (grains, oleaginous and fruits): 1994–2009 (July 1994 = 100). (Source: Prepared by authors based on IPEADATA 2011)

tomatoes and soft drinks. Data showing the rise in poultry meat consumption have been used for official propaganda to symbolise the positive social effects of the Real Plan.

While the behaviour of agricultural prices frustrated producers and added to the negative heritage of the inflationary period, it has certainly mitigated food security and the nutritional problems of the poor population. In fact, price stabilisation has played a significant positive role in improving the condition of the poor population.

In previous stabilisation experiences, as inflation rates fell abruptly, food demand and food prices increased. The food price increases contributed to jeopardising the heterodoxy stabilisation attempts. Short-term rigidity of agricultural supply in the context of a closed economy explains the behaviour of food prices before 1994.

After the Real Plan, this context changed and agricultural prices have indeed played a positive role in the stabilisation process. Food price trends were the result of various factors. On the one hand, trade liberalisation and import tariff cuts set an upper limit on agricultural prices and flattened seasonal fluctuations caused either by seasonal shortages or by market speculation. On the other hand, as agricultural products are mostly tradable, prices fell because of foreign exchange valorisation following the Real.

Beyond its positive macro effects, decrease in real food prices has certainly played a significant role in improving the food security status of the poor population. Food consumption increased and poverty decreased after the Real Plan. As the food needs of higher income groups are mostly satisfied, it can be assumed that lower-income groups were the main beneficiaries of cheaper food prices.

As Barros (2008) puts it, "in the 1990s, minimum wage increases took place at a time of decreasing real food prices, thus leading to higher real wages; poor families were able to spend more, not only on food but on other consumer goods as well. The redistribution of income through several sequential government programs, which culminated with the so-called *Bolsa Família*, which transferred cash to more than 11 million poor families" (p. 9).

In 2004, the *Instituto Brasileiro de Geografia e Estatística*—Brazilian Institute of Geography and Statistics (IBGE)—held the first national survey on food security; the same survey was replicated in 2009 (Table 2.4). The comparison between 2004 and 2009 allows an accurate view of the recent evolution as well as the current food security status in Brazil.

In 2004, 35 % of Brazilian households were living in some degree of food insecurity and in 2009, this percentage fell to 30.2 %, representing 65.6 million people. In 2009 there were nearly 40.1 million people in a low food insecurity situation; 14.3 million people in a moderate food insecurity situation and over 11 million people suffering from severe food insecurity. Interestingly, the percentage of households in situations of low food insecurity remained stable between 2004 and 2009 (18 % of the total), while moderate and severe food insecurity status declined from 10 and 7 % to 6.5 and 5 %, respectively (Table 2.5).

This reduction in the percentage of households with moderate and severe food insecurity cannot be attributed solely, or primarily, to the expansion of food production and the stability and/or reduction in real prices of food; nor can it be attributed

Table 2.4 Description and scale of food security situation at household level. (Source: IBGE 2010)

Food security situation	Description
Food security	Regular and permanent access to quality food in sufficient quantity without compromising access to other essential needs
Low food insecurity	Concern or uncertainty about access to food in the future; inadequate quality of food resulting from strategies that aim not to compromise the amount of food
Moderate food insecurity	Quantitative reduction of food among adults and/or disruption in eating patterns resulting from lack of food among adults
Severe food insecurity	Quantitative reduction of food among children and/or disruption in eating patterns resulting from lack of food among children; hunger, when someone goes the whole day without eating due to lack of income to buy food

Table 2.5 Brazilian householders by food security situation: 2004/2009. (Source: Prepared by the authors based on IBGE 2010)

Food security situation	Total		Urban		Rural	
	Number	%	Number	%	Number	%
2004						
Total	51.666	100.0	43.671	100.0	7.996	100.0
Food security	33.607	65.0	29.099	66.7	4.508	56.4
Food insecurity	18.035	34.9	14.55	33.3	3.485	43.6
Low	9.321	18.0	7.711	17.7	1.61	20.1
Moderate	5.123	9.9	4.012	9.2	1.111	13.9
Severe	3.592	7.0	2.827	6.5	765	9.6
2009						
Total	58.646	100.0	49.882	100.0	8.764	100.0
Food security	40.909	69.8	35.223	70.6	5.685	64.9
Food insecurity	17.738	30.2	14.659	29.4	3.079	35.1
Low	10.973	18.7	9.258	18.6	1.715	19.6
Moderate	3.834	6.5	3.082	6.2	753	8.6
Severe	2.93	5.0	2.319	4.6	611	7.0

only to the direct impact of conditional cash transfer programmes focused on the poorest and to the distribution of food baskets to vulnerable groups. We shall rew-turn to this theme.

The improvement in the food security situation is the result of a combination of several factors, among which we highlight the following: (i) price stabilisation and low rates of inflation; (ii) minimum wage real valorisation policy, which has been pursued since 1995 and has led to a real increase of 105 % in the real minimum wage from R$ 255 (US$ 277.1) to R$ 522 (US$ 296.6); and (iii) implementation and scale-up of universal pension benefits established by the 1988 Constitution, which extended pension benefits to all, irrespective of formal enrolment or previous contribution to the existing public or private pension institutions and funds. This has benefited the rural poor more, the majority of whom had no legal rights under the previous regime and were left unattended and entirely dependent on family and charity support. The basic pension benefit was set at one minimum wage per entitled person and not by household. It is currently common to find households with more than one retired person.

The conditional income transfer programme, *Bolsa Família* (BFP), was launched by the Brazilian Federal Government in October 2003, as a result of the unification of four income transfer federal programmes: *Bolsa Escola, Bolsa Alimentação, Auxílio Gás, and Cartão Alimentação* (Table 2.7). BFP has three main lines of action: (i) immediate relief of poverty (income transfers); (ii) strengthening basic social rights—health and education (conditionalities); and (iii) supporting the generation of opportunities for the development of families (complementary programmes or actions). The participation in BFP is restricted to poor families that have monthly per capita income up to R$ 140 (US$ 79.5) and are registered in the Unified Register for Social Programs (*Cadastro Único para Programas Sociais*) (MDS 2011) (Table 2.6).

In 2010, the *Bolsa Família* programme was attended by approximately 12.8 million families, who received a total contribution (transfer value) of R$ 14.4 billion (US$ 8.18 billion) (Table 2.7).

In summary, the BFP undoubtedly had positive effects, particularly for the poorest families and the vulnerable. The value of transfers is not sufficient to ensure food security for poor households; although small, it allows families to purchase some basic items and contributes mainly to improve general welfare and to promote

Table 2.6 Main modalities of BFP benefits. (Source: Prepared by authors based on MDS 2011)

Modalities	Target-public	Transfer value
Basic benefit—BB	Families with per capita income up R$ 70 (US$ 39.8)	R$ 68 (US$ 38.6)
Variable benefit—BV	Families with children and teenagers between 0 and 15 years old	R$ 22 (US$ 12.5) per child/teenager. Maximum benefit value is R$ 66 (US$ 37.5)
Variable benefit linked to teenager—BVJ	Families with teenagers between 16 and 17 years old	R$ 33 per teenager. Maximum benefit value is R$ 66 (US$ 37.5)

Maximum benefit value is R$ 200 (US$ 113.6) (sum of BB, BV and BVJ)

Table 2.7 Summary of Transfer realised by *Bolsa Família* Program: 2010. (Source: Prepared by the authors based on MDS 2011)

Region	Total poor families	Programa bolsa família		
		Municipalities assisted	Poor families assisted	Transfer (R$ million)
Middle West	789,026	466	725,216	721.9
Northeast	6,098,232	1794	6,454,764	7,582.5
North	1,283,119	449	1,348,329	1694.8
Southeast	3,562,195	1668	3,185,843	3276.7
South	1,262,623	1188	1,064,068	1096.8
Brazil	12,995,195	5564	12,785,154	14,372.7

Average monthly transfer is R$ 93.68 (US$ 53.2)

some social inclusion. The indication that families use the money to pay for electricity bills, transportation and educational material, rather than negative, confirms the importance of social transfers to ensure a minimum capacity for poor families to deal with their 'urgencies'.

2.2.2 Institutions and Policies: from State-Driven to State-Controlled Liberalisation

Public policies have played the most relevant role in shaping Brazilian agriculture as shown by recent performance as well as some of the main structural features of the sector. Until the 1980's, agricultural policy was highly interventionist and required substantial financial transfers, both to compensate producers for anti-agrarian biased macroeconomic policies as well as to induce farmers to adopt certain productive behaviour. Although compulsory measures have been used in some cases to regulate production and demand flows, government intervention in production and markets was mostly carried out through market instruments. The effectiveness of these interventions required financial transfers, such as subsidies to rural credit, government procurement at prices above market prices, public stockholding to sustain prices and so on.

During the 80s, successive ad hoc agricultural policy changes were introduced in response to short-term macroeconomic or sectorial concerns—price increases food, supply shortages, or strong political pressures from organised sectors. By the end of the 80s and at the beginning of the 90s, State intervention—and lack of intervention—had become rather chaotic. Instead of responding to pre-defined sectoral objectives and strategy, it was mainly characterised by *ex post* interventions in response to either political pressure from large agricultural producers or to monetary stabilisation concerns. Agricultural policy, which in the past had been functional and capable of regulating production flows and securing a reasonable performance from the agricultural sector,[4] became incapable of dealing with the mounting agricultural problems as well as the challenges created by the new economic and institutional context.

In 1990s, the aim of macroeconomic policy shifted to ensure both macroeconomic stability and an adequate economic environment for private investments. This change in the nature of macroeconomic policy had a direct impact upon the economy as a whole and agricultural policy in particular. As a consequence, financial transfers to both agriculture and industry were reduced. As 'cheap and abundant' rural credit was at the very core of agricultural policy, previous policy arrangements and rationale were virtually dismantled by the increasing financial constraint.

In past years, agricultural policy has indeed been successful in promoting investment and the growth of Brazilian agriculture. On the one hand, financing from the National Economic and Social Development Bank (BNDES) has been crucial to sustain farmers and agro industries' investments in machinery and new plants in the frontier zones. On the other hand, the creation of the Family Farmers Support Program (Pronaf) in 1995 has channelled increasing amounts of resources to previously excluded small and family farmers. Yet Pronaf and Agrarian Reform Programs have not been successful as far as the productive strengthening of small producers is concerned—whose majority is still excluded from the benefits of agricultural policy; both policies helped to ease social tensions in rural areas. Yet agricultural policy failed to remove structural obstacles that hinder sustainable agricultural development. It is still largely made up of short-term interventions, announced every year, and lack long-term planning and institutional reforms and the definitions needed to create a sound environment for inclusive and sustainable agricultural growth.

The government seems to be aware that it is not just possible to discontinue traditional policy instruments and replace them automatically by alternative instruments. It is therefore introducing new instruments, testing alternative arrangements, and educating and stimulating farmers to make use of the new instruments. The strategy is to introduce market instruments slowly and eventually to replace traditional government-managed instruments. While capitalist agriculture would rely mostly on market mechanisms, the government would focus and channel its resources to support rural development, agrarian reform and family farmers. The cornerstone of this strategy is the Agrarian Reform and PRONAF (*Programa Nacional de Fortalecimento da Agricultura Familiar*) (Box 1).

[4] Agricultural policy was functional, in spite of its inefficiency and overall negative side effects—at least for some producers and crops.

Box 1—PRONAF

PRONAF was first presented in 1995 with the creation of Program of Small Rural Production to provide small producers with special financing conditions. In June 28, 1996, Brazilian Government through Decree No 1.946 created officially the PRONAF. In 1997/1998, over R$ 1 billion (US$ 927 million) was allocated to PRONAF. In 2010/2011, Brazilian Government will allocate around R$ 16 billion (US$ 9.1 billion) to two million family farming (MDA 2011a).

PRONAF's development objective is to enhance family farms production capacity, to generate employment and income in the rural areas, to reduce rural poverty and improve overall life quality in rural areas. Its specific objectives are: adjust public policies to the needs of family farm; provide and improve rural infrastructure required for sustainable development of family farms; strengthen support services to family farms; strengthen family farmers' managerial and technological capacity and facilitate family farmers' access to financing and support services.

2.3 Sources of Growth and Competitiveness of Brazilian Agribusiness: Empirical Evidence

Brazil has a continental territory and the occupation of the frontier has always been part of the process. In the past 30 years, agricultural activity has led, for good and bad, the settlement and incorporation of the new areas into the national economy, the creation of new poles of development, and the creation and expansion of new urban centres that are responsible for the absorption of sizeable populous groups. Although the incorporation of new areas has played an important part in the recent evolution of agricultural production in Brazil, the reallocation of land use and increased productivity were factors that are even more significant.

Gasques et al. (2004, 2007, 2011) analyse the determinants of the growth of Brazilian agriculture between 1975 and 2010, based on Total Factor Productivity (TFP) methodology.[5] The results confirm that more efficient use of the land—associated with innovations and production management—has played a major positive role in the sector's performance (Table 2.8).

Over the long run, viz., 1975–2010, agricultural production expanded at an annual rate of 3.74%; more recently (period 2001–2010) the annual rate of growth

[5] The PTF is the relationship of all products and inputs measured by rates. If the total relationship of products and inputs is growing, the relationship can be interpreted as indicating that more products can be obtained from a given amount of inputs. The growth rate of the PTF is calculated as the difference between the product's growth rate versus the overall growth rate of inputs. As is common knowledge, a higher PTF represents increases in a product in terms of more efficient use of production factors, given the use of a different technological level. Variations in the PTF over time can be the result of differences in efficiency at different moments, of variations in production scales or levels, or of technological changes (Gasques et al. 2007).

Table 2.8 Sources of Brazilian agriculture growth, 1975–2010. (Source: Gasques et al. 2011)

Year	Product	Input	PTF	Labour force	Land	Capital
Annual rate of growth (%)						
1975–2010	*3.74*	*0.12*	*3.62*	*−0.48*	*0.02*	*0.70*
1980–1989	3.38	1.09	2.27	1.23	0.47	0.49
1990–1999	3.01	0.35	2.65	3.11	2.06	3.14
2001–2010	4.75	−0.53	5.31	−1.00	−0.58	0.53

was 4.75%. There was a significant growth of the TFP, around 3.62% per year between 1975 and 2010. The capital rate increased 0.7% per year between 1975 and 2010. In any case, an analysis of the annual growth rates shows that the increase in production is set off by more efficient use of inputs and higher labour productivity, which identified a TFP of 2.65% for the 1990's (Gasques et al. 2011).

It is worth drawing attention to the increase in labour productivity, traditionally a low-qualified resource. However, this situation is still largely true; there is a clear association between the increase in labour productivity and the professional qualifications of the labour force. Balsadi (2007) identified higher educational level amongst rural workers; new technology is certainly leading to the selection of higher qualified and better-paid workers.

Another source is the acquisition of fertilisers, pesticides, machinery and agricultural appliances between 1996 and 2009, that evolved favourably in the domestic market, in spite of the difficulties of the Brazilian economy and financing restrictions faced by producers until 1999, when broad debt restructuring was enforced. The acquisition of machinery and equipment increased steadily in the period 1997–2005, and again in 2008 and 2009, as a response to a federal government's support programme for the modernisation of the country's tractor fleet. Domestic sales of fertilisers and inputs in general have also increased in the late 1990s. Pesticide use has fallen considerably since 1999, certainly in response to changes in relative prices due to the 1999 devaluation but also to improvements in production management and the introduction of reduced pesticide requirement techniques (ANDA 2010; MAPA 2010).

The introduction of new varieties and mechanisation were, undoubtedly, the leading vectors of innovation. Sales of farm vehicles registered an enormous growth in the period 1996–2009, jumping from a modest 11,926 units in 1996 to more than 50,000 units in 2009. Sales of harvesters rose from less than 1000 units in 1996 to over 5000 at the end of the period, a 500% growth (ANFAVEA 2010)[6] (Table 2.9).

The apparent consumption of agro chemicals—herbicides, fungicides and insecticides—has also shown steady growth over the period 1996–2005. Fertiliser consumption has also increased over the period, with sales rising from 13,800,000 t to over 22,800,000 t between 1997 and 2005, and in 2007 reached 24,600,000 t (ANDA 2010; MAPA 2010) (Fig. 2.6).

[6] Associação Nacional dos Fabricantes de Veículos Automotores—Brasil (Anfavea).

Table 2.9 Domestic wholesale sales (Brazilian-made and imported) distributed by groups of products. (Source: Prepared by the authors based on ANFAVEA 2010)

Year	Tillers (motorised cultivators)	Wheeled tractors	Combines (harvesters)	Total
1994	1.308	38.518	4.049	43.875
1995	1.210	17.594	1.423	20.227
1996	714	10.312	900	11.926
1997	707	16.049	1.709	18.465
2002	1.050	33.217	5.648	39.915
2003	1.585	29.476	5.440	36.501
2005	2.141	17.729	1.534	21.404
2009	2.960	44.206	3.817	50.983

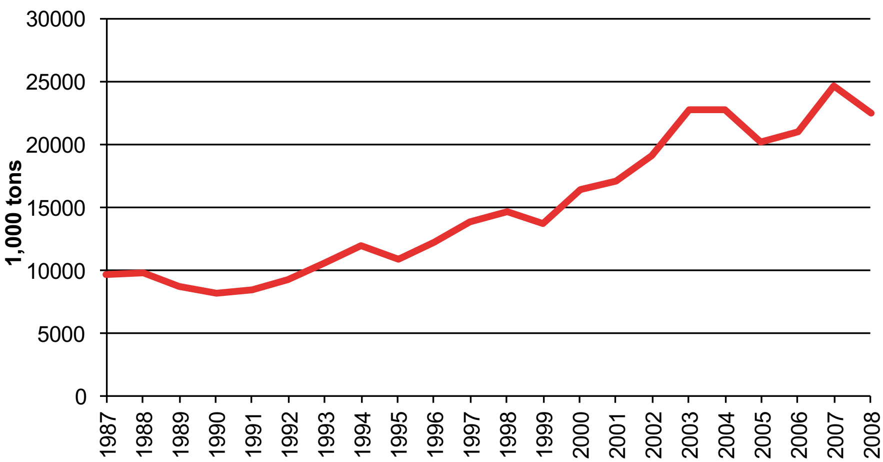

Fig. 2.6 Fertilisers delivered to final consumer between 1987 and 2008 (1000 t). (Source: Prepared by the authors based on ANDA (2010) and MAPA (2010))

The increase in fertiliser consumption is closely related to the incorporation of new arable land into production rather than to intensification of fertiliser use. Early occupation of the Central West frontier in the 1960–1980s had left behind large tracts of degraded land, improper for cultivation and even for semi-intensive cattle raising. These areas were reclaimed during the 1990s for productive exploitation through the application of soil correction techniques and the introduction of modern and sustainable farming methods.

In this regard, it should be noted that it is no longer possible to associate, without proper qualification, the use of chemical inputs with innovation and technological modernisation. On the contrary, many technological innovations, including genetically modified seeds and more efficient management methods, are specifically focused on reducing the use of such inputs. In the case of Brazilian agriculture, the analysis of the TFP showed lower use of these inputs, and this fact, associated with higher productivity, leads to the conclusion that management of agricultural production systems has improved.

No less important, the seed-producing sector is also partially responsible for the success of Brazilian agribusiness. This sector showed increases in production and productivity in a context of intense scientific and biotechnological research. In this case, the public sector is strongly representative in both its institutional and operational modes, and in making financial resources available for research and development (R&D). Publicity regarding improved seeds and their use has contributed to the introduction of new, hybrid varieties, and this has favoured the growth of farm production in general. Seed market is highly concentrated in three crops: soybeans (56.7 %), wheat (14.6 %) and corn (12.2 %).

Buainain et al. (2005) found a high positive correlation between the rate of use of seeds and average productivity. Analysing the evolution of productivity amongst regions, they found that productivity increased faster in those states that presented broader use of improved seeds. The obvious conclusion is that more intensive use of improved seeds is a strategic and fundamental factor for the progress of grain production in Brazil. They point out that the incorporation of improved seeds by farmers is usually accompanied by the introduction of better production practices, including plant health, pest and disease control and the intensification of technological transfer among farmers.

Finally, another source is the reduction in tariff and non-tariff barriers that led to the reduction of prices of inputs and imported equipment, thus partially offsetting the fall in prices suffered by producers between 1995 and 2003. Favourable terms of trade have played a key role in the recent boom of Brazilian agribusiness. The combination of higher international prices and the devaluation of the national currency can offset, at least partially, the systemic inefficiencies that hinder the economic growth of Brazilian agriculture.

2.3.1 Brazilian System of Innovation in Agriculture: key features and roles

The pattern and rhythm of growth are also the result of structural and particular institutional features of Brazilian society as well as of planned and fortuitous policy interventions rather than of the workings of any invisible hand. Innovation was a key factor, but financing, trade, and industrial and price policies were quite important. Land distribution, land ownership and the accompanying land policy are key institutional features of Brazilian agriculture. In fact, land policy was highly permissive and allowed, for decades, unlawful land grabbing of vast areas in the frontiers zones; legal ownership of land was granted without any financial compensation or clear social and environmental contracts regarding the appropriation and use of fiscal land. It is such permissiveness, and not the colonial heritage that explains the skewed land distribution pattern in contemporary Brazilian society, which has shaped the recent modernisation of Brazilian agriculture.

The public sector has played a central role both in the innovation of processes and in the diffusion of technology in the agricultural sector. Since the early 1970s, Brazil has been developing a solid system of innovation in agriculture, whose construction, consolidation and effectiveness are all the results of consistent long-term efforts of multiple public and private stakeholders.

In 1992 the National Agricultural Research System (SNPA) was formally created and was integrated with Embrapa (Brazilian Agricultural Research Company) (Box 2), State Agricultural Research Organisations (OEPAs), universities and research institutes at the federal and state as well as other public and private organisations engaged to varying extents in agricultural research. It also includes privatised companies, subsidiaries of international corporations and private R&D Brazilian companies that usually occupy 'market niches' (Fonseca et al. 2004). Approximately 22 state research organisations (OEPAs), operating in all five regions in Brazil, participate in the SNPA (Embrapa 2011b). According to Vieira Filho (2010), in 2006 OEPAs had more than 1800 researchers, carrying out around 2100 R&D projects in 230 laboratories and 215 experimental stations.

Box 2—EMBRAPA: A Case of Successful Institutional Innovation

Embrapa was created in 1972 and is bound to the Ministry of Agriculture. In 2010, Embrapa had 9249 employees (Embrapa 2011a). In 2009, 2010 and 2011 the Embrapa budget was almost US$ 800 million. Embrapa can be considered a case of successful institutional innovation that has many distinctive characteristics: a public corporation model of organisation; scale of operation at the national level; spatial decentralisation; specialised research units; enhanced training and remuneration of human resources; and a vision of an agriculture based on science, technology and innovation. The main aspects of the organisation's development and consolidation can be summarised in: (1) Continuous support from the Federal Government; (2) Diversified R&D portfolio; (3) Timing and social support; (4) Option for a public corporation model; (5) Scale, interactivity and decentralisation; (6) A concentrated organisation model for the research units; (7) Human resources; (8) Professional relations and coexistence with power; (9) Independent reviews and evaluations of impact; (10) Communication with society; (11) Foresight and institutional flexibility. Source: Lopes and Arcuri (2010)

Embrapa emerged as the most prominent organisation, undervaluing the contribution of several other relevant institutions, such as the Agronomic Institute of Campinas (AIC), the *Escola Superior de Agricultura "Luiz de Queiroz"* (Esalq), a faculty of the University of São Paulo (USP), the Federal University of Viçosa in Minas Gerais, and the Federal University of Santa Maria in the southern state of Rio Grande do Sul, which are all good examples of highly productive agro research centres. Figure 2.7 depicts the evolution of Brazilian agricultural research institutions.

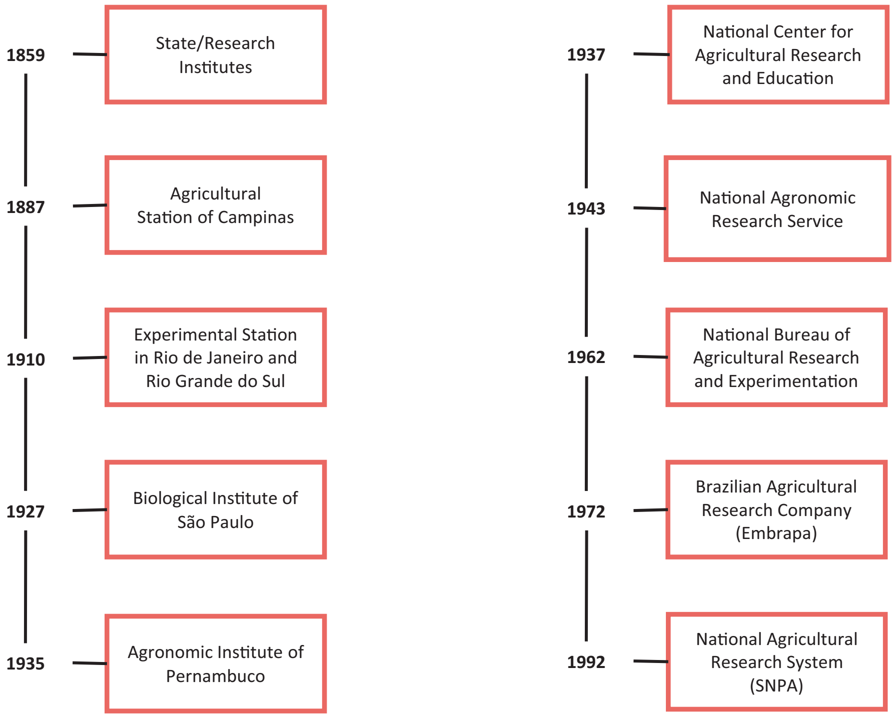

Fig. 2.7 History of Brazilian agricultural research. (Source: Prepared by the authors based on Faccion 2010)

The work carried out by Embrapa played a fundamental role in the increase in the production of grains in Brazil, especially the introduction and spread of soybeans. Soybean—a crop grown in temperate climates—was adapted to the conditions of the Brazilian climate and today Brazil is the world's second largest producer. Approximately 50 % of the area cultivated with soybeans in the country uses plants developed with the participation of Embrapa and approximately 90 % of the area where rice and beans are grown uses plants that it developed. The company contributed to the promotion of the technological advances in modern Brazilian farming that addressed the development of techniques for biological and integrated control of harmful biological agents. It should also be noted that, thanks to these efforts, Brazil now has one of the largest areas of direct planting in the world.

Embrapa is focusing on the development of solutions for the sustainable development of Brazilian agribusiness through the generation, adaptation, and transfer of knowledge and technologies. While committed to efficient use of public funds, the allocation of resources is based on a strategic view regarding the needs of Brazilian agribusiness but also on short-term political pressures exerted by the government, parliament, producers' organisations, NGOs and even international stakeholders. Since 2007, Embrapa has received a renewed burst from the Federal government, which invested in modernisation and construction of new installations, creation of new centres, and hiring of 600 new young scientists. Yet Embrapa can hardly provide support to all segments and regions related to agribusiness and, unless priorities are clearly defined to guide the company's actions, the increasing number of priorities and level of dispersion may jeopardise its future.

However, there are centres of excellence in research and even cases where there is a process of competition and cooperation with Embrapa in important areas, such as the improvement of plant varieties (especially for the Rural Agency of Goiás, IAC, IAPAR), food technology, and support to programmes aimed at conservationist and environmental questions, such as that of the micro basins in São Paulo (APTA) and Paraná (IAPAR) (CONSEPA 2011).

2.4 Obstacles and Challenges for Brazilian Agriculture

The current challenges for the agricultural sector are not different from the ones the Brazilian economy as a whole is facing: how to achieve real sustainable competitiveness and simultaneously overcome mounting social inequalities, in particular rural and urban poverty and misery.

Brazil has 90–150 million ha of unused arable land (most conservative estimate) to sustain the increase in agricultural production without further deforestation. They are mostly degraded pastures and savannah land with high potential to be used for agriculture, whose exploitation under appropriate production systems would have minor environmental impact. Besides, as Brazilian agriculture is deeply heterogeneous, there are opportunities to improve the use of land and to increase the productivity of many productive systems, from sugar cane to cattle breeding and even traditionally extractive crops.

This improvement, based on a greener technology than the current ones, depends fundamentally on investments in R&D and financing for innovation at the farm level. It also depends on new institutional arrangements to remunerate producers for valuing nature, an evident problem for countries facing serious social problems that in the end are a priority over environmental concerns.

In addition to favourable weather and abundant lands, Brazil has well-informed elite of rural producers that may lead sector growth, grasp current opportunities and create others. They are aware of technological innovations, market demands and conditions and of increasing social and environmental requirements regarding the production process.

Without neglecting external restrictions, the main obstacles faced by Brazilian agribusiness are domestic: (i) poor infrastructure; (ii) producers' high indebtedness; (iii) capacity to sustain innovation; (iv) institutional frame and property rights; (v) financing and fixed capital relative cost; and (vi) lack of risk management tools.

To sustain Brazilian agribusiness' growth it is necessary to combine and to converge several highly complex processes. The scientific and technological innovations should be fundamental.

As mentioned above, in recent years innovation made possible the occupation of the agricultural frontier in areas previously considered inappropriate for agriculture, with bearable environmental effects. However, to sustain further growth a substantial increase in the productivity of lands already cultivated will be required. Based only on the occupation of degraded land and productivity increase, it will be possible to expand without further damage to the environment. This is not an easy task, particularly when considering the lack and/or inadequacy of mechanisms to avoid negative externalities and to economically value the environment and nature. In Brazil, a standing tree is still undervalued (if it is valued at all) by landowners, while a cut tree may complement revenue and may secure the tenure of new areas for agricultural use. While this reality remains, political objectives and decisions on zero deforestation will remain nice paper plans, full of good and sincere intentions.

It should be noted that after 1990 the rate of productivity increase of several crops has suffered a slowdown. This might be associated with high heterogeneity and lack of incentives and conditions for many producers to invest in innovation, and also to technological and institutional barriers to the introduction of innovation. It is not at all absurd to raise doubts about the limits of the current technological paradigm to sustain further and significant productivity growths as registered in the past.

In fact, Vieira Junior (2006) maintains that the productivity of the main vegetable species commercially explored is quite close to their respective potential productivities. According to him, at least in the near future, technological innovations based on transgenic species resistant to pests and diseases will not contribute to increased yield productivity. The major impacts of this technology will be on cost and environment concerns. Genetic engineering's best contribution to increasing agricultural production shall be the development of species more tolerant to environmental stress that are still not available.

The challenge to meet demand's growth is not a small one. In the past, Brazilian agriculture met relatively permissive conditions to answer economic incentives and to expand agricultural production. On one side, a wide availability of relatively fertile land and of relatively easy incorporation into production allowed the fast expansion of the agricultural frontier, with relatively low economical costs—although with high environmental costs. On another side, the institutional environment was not so strict regarding the incorporation of technical progress. The growth of demand, associated with the outstanding experiences of food insecurity, created favourable conditions to mobilise public resources for R&D applied to agriculture and to apply, almost without restrictions, any technologies that could contribute to increase yield per area and total productivity factors. Conditional requirements such as environmental concerns, global warming, food safety and food security, which are now part of the equation to be solved, at that time were not even raised as matters of concern.

In the first 80 years of the past century, Brazilian agriculture expanded into new lands. The incorporation of additional new land into production is currently subject to increasing regulatory restrictions, and growth will have to be sustained by innovation, more efficient use of land and higher productivity. Although Brazil still has between 90 and 150 million of ha that could be used for agriculture, barriers for an immediate increase of production are higher and will require more efforts than in the past. Let us get a closer look at the context and obstacles ahead.

In the past two decades, the institutional context, composed of trade rules and norms, consumers' demands, technology, macro and sectoral policies as well as the cultural aspects, have suffered deep transformations that substantially affect the productive and technological dynamics of all productive chains.

As mentioned, the Brazilian economy, relatively closed until the 1990s, was subjected to quite deep institutional changes, particularly trade liberalisation, which is more comprehensive and deep than the simple analysis of tariffs and trade flows might indicate.

In the international scene, the globalisation process enlarged in geographical terms and deepened in a remarkable way. The integration of China in the world market as well as its affiliation to WTO is the most outstanding symbols of globalisation and had a major impact in the restructuring of world markets. Also remarkable is the presence of India, Russia, South Africa and Brazil as new players in the global economy.

A set of structural factors is provoking deep transformations in food consumption trends, with direct impacts on the organisation of agribusiness chains. World population continues to grow and is getting older. The demographic changes, by themselves, have important implications on the food market, not only because of its enlargement but also mainly because of consumers' new demands.

The broadcast and the diffusion of information on a global scale contribute to instill real life into the so-called 'global village', changing consumption habits and consumers' preferences. The elevation of educational level and income of the population are also important factors.

Brazilian agriculture does not have relevant subsidies and it is competitive to expand into the world market. However, important sectors such as beef, ethanol, orange juice, and fruit face market access restrictions that hinder their growth potential.

On the other side, the Brazilian experience of using the WTO to reverse illegal trade practices—as in the case of cotton—did not produce concrete results in terms of market access. Even the effectiveness of the retaliation authorised by the WTO is questionable, as its application may be followed by unilateral counter-retaliation by the USA that may affect Brazilian exports more than the authorised retaliation will damage US exports to Brazil.

Climate change is already distorting well-known weather patterns and increasing climate risk in many traditional farming zones. In Brazil, the expected negative impact varies from 15 to 25 % in the south, central and northeast areas and above 25 % in Western Amazonia. Embrapa forecasts regarding the immediate effects of climate change are not optimistic. According to the study 'Global Warming and Future Brazilian Agriculture Scenarios' that evaluates the impact of temperature increase on agriculture in 2020, 2050 and 2070, 'global warming may provoke a significant change in Brazilian agriculture's map, reducing producing areas and economic damages of R$ 7.4 billion in 2020 and R$ 14 billion in 2070'

(Assad and Silveira Pinto 2008, p 13). The study evaluated the following crops: cotton, rice, bean, coffee, sugar cane, sunflower, manioc, corn and soy.

An increasing number of people understand the seriousness of the environmental problem, locally or globally. The concern with natural resources has deep impacts over the whole logic of the sector, particularly regarding the use of technologies. In the past, the technological drive was to increase production and revenue and secondarily to reduce cost, without major concern for environmental impacts. This 'philosophy' guided the Green Revolution and was responsible for the enormous progress of agriculture as well as for the removal, in these past 50 years, of the Malthusian ghost. The total productivity factor increased considerably and allowed the multiplication of food in proportions perhaps equivalent to the biblical miracle of the multiplication of fishes.

This progress was reached, at least partly, with the sacrifice of natural resources and with negative impacts on the environment in general. The current context is different. Productivity elevation and/or production cost reduction no longer may be reached at the expense of the environment. The analysis of environmental impact became, in the new context, a pre-condition for the feasibility of any technology, from the simplest to the most sophisticated one.

The new environmental rules impose, in a brand new way, the convergence between micro and macro interests, between the producers and society interests, expressed by the international trade rules and by a set of demands, many of them still not transformed into written norms and approved for the bodies that regulate the economy and consumers in general.

In the current context, although technology may be profitable from the microeconomic point of view, it shall hardly become hegemonic and disseminated if it does not conform to established patterns, especially the ones related to food quality and safety as well as to environmental requirements.

At the same time that the market and consumers value, more and more, the product with all its attributes and qualities, a growing concern is observed—non-existent until some time ago—with the production process. It is not enough to know that the product is good; it is necessary to know how it was done. What inputs were used in the production? Is the technology friendly to the environment? Is it socially sustainable? Was child labour employed? Where was it produced, in what country? How did it get here? In this new context, more and more, it is fundamental to identify the technology used and the production processes, and to track and certify the whole production of the agribusiness.

This institutional context that is partially new and still being consolidated points out, in an unequivocal way, to future tendencies that cannot be ignored by companies, governments and producers. The world market is under restructuring. Although in many segments the availability of natural resources is a necessary condition to growth, competitiveness is more and more determined by the capacity to answer to the consumers' demands and preferences. Moreover, in the future, competitiveness will depend on the capacity to anticipate demands and transform them in sources to aggregate value to the agribusiness products through technological innovations.

Agricultural subsidies in the US and Europe continue to restrict the growth potential of world agricultural production, particularly in countries like Brazil that have great potential to grow. Before the 2008 food crisis, what was the explanation for the persistence of protectionist programmes? If there is an evident loss of welfare, what is the logic that sustains the protectionist policies? As Zylbersztajn (2008) put it, the incentives for private groups to organise in defence of protection predominate over those of groups that would benefit from the reduction of protectionist policies.

Considering the above mentioned, it can be said that institutional issues are the main obstacle to increasing food production in countries such as Brazil, because in addition to limiting production itself, they inhibit investment in R&D, which constrains the future of world agriculture.

References

AgroStat (2011) Statistics. http://www.agricultura.gov.br. Accessed 30 Jan 2012

Alves E, Rocha DP (2010) Ganhar tempo é possível?. In: Gasques JG, Vieira Filho JER, Navarro Z (eds) A agricultura Brasileira: desempenho, desafios e perspectivas/organizadores. Ipea, Brasília

ANDA (2010) Estatísticas. http://www.anda.org.br/. Accessed 15 Feb 2010

ANFAVEA (2010) Estatísticas. http://www.anfavea.com.br/. Accessed 15 Feb 2010

Assad E, Silveira Pinto H (eds) (2008) Global warming and future Brazilian agriculture scenarios. Embrapa and Cepagri/Unicamp. http://www.agritempo.gov.br/climaeagricultura/download.html. Accessed 5 March 2012

Balsadi OVO (2007) Mercado de trabalho assalariado na agricultura brasileira no período 1992–2004 e suas diferenciações regionais. Tese (Doutorado), Instituto de Economia, Universidade Estadual de Campinas

Barros G (2008) Brazil: the challenges in becoming an agricultural superpower. http://www.brookings.edu/papers/2008/05_brazil_agriculture_barros.aspx. Accessed 15 Feb 2010

Buainain AM (2008) Reforma agrária por conflitos a gestão dos conflitos de terras no Brasil, in: Luta Pela Terra. In: Buainain AM (ed) Reforma Agrária e Gestão de Conflitos no Brasil, Coleção Instituições, Agricultura e Desenvolvimento Sustentável, 1st edn, vol 1. Editora Unicamp, Campinas, pp 17–128

Buainain A, Vieira Filho JE, Silveira JM (2005) Agricultural development in Brazil. Campinas, Instituto de Economia da Unicamp. Document prepared for the Seminario Internacional: la inovacion em el sector rural de la América del Sur, IFPRI. Lima, Peru

CEPEA/USP/CNA (2011) Agribusiness GDP—1994 to 2011. http://www.cepea.esalq.usp.br/pib. Accessed 5 Jan 2011

CNA (2008) Agronegócio é questão de Estado, por Kátia Abreu. http://www.cna.org.br/site/noticia.php?n=20686. Accessed 16 Jan 2009

CONSEPA (2011) OEPAS—Organizações Estaduais de Pesquisa Agropecuária. http://www.consepa.org.br/. Accessed 14 Jan 2011

Di Sabatto A, Buainain AM, Guanziroli C (2011) Dez anos de evolução da agricultura familiar: 1996–2006. In 49º Congresso da Sober (Sociedade Brasileira de Economia, Administração e Sociologia Rural). 24 a 27 de julho de 2011, Belo Horizonte, Minas Gerais. http://www.sobre.org.br. Accessed 30 Oct 2011

Embrapa (2011a) Information on Embrapa's web site. http://www.embrapa.br. Accessed 14 Jan 2011

Embrapa (2011b) Organizações Estaduais de Pesquisa Agropecuária—OEPAs. http://www.embrapa.br. Accessed 14 Jan 2011
Faccion CE (2010) Pesquisa agropecuária brasileira e as organizações estaduais de pesquisa agropecuária. Seminários do Programa de Pós-graduação em Agronomia/Fitotecnia, 2º semestre. http://www.prpg.ufla.br/ppg/fitotecnia/noticia_detail.php?id=15. Accessed 31 Jan 2011
FAOSTAT (2011) Statistics. http://www.faostat.fao.org. Accessed 5 Jan 2011
Fonseca M, Dal Pozand ME, Silveira JM (2004). Direitos de propriedade intelectual em biotecnologia: um processo de construção. In: Silveira JM et al (eds) Biotecnologia e recursos genéticos: desafios e oportunidades para o Brasil. Instituto de Economia/Unicamp/Finep, Campinas
Gasques JG, Rezende GC, Villa Verde CM, Salerno MS, Conceição JCPR, Carvalho JCS (2004) Desempenho e crescimento do agronegócio no Brasil. Texto para discussão nº 1.009/Ipea. http://www.desafios2.ipea.gov.br/pub/td/2004/td_1009.pdf. Accessed 15 Feb 2010
Gasques JG, Bastos ET, Contini E, Saab AA, Freire da Silva L (2007) Projeções do Agronegócio, Mundial e do Brasil. MAPA-AGE Assessoria de Gestão Estratégica. http://www.sober.org.br/palestra/6/1127.pdf. Accessed 18 Feb 2010
Gasques JG, Bastos ET, Bacchi MRP, Valdes C (2011) Produtividade e crescimento da agricultura brasileira. Nota Técnica de Produtividade do Ministério da Agricultura, Pecuária e Abastecimento
Hoffmann R, Ney M (2010) Evolução recente da estrutura fundiária e propriedade rural no Brasil. (preparação para capítulo de livro)
IBGE (2006) Censo Agropecuário—2006. http://www.ibge.gov.br. Accessed 15 Feb 2010
IBGE (2010) Segurança Alimentar 2004/2009. http://www.ibge.gov.br. Accessed 14 Jan 2011
IPEADATA (2011) Statistics. http://www.ipeadata.gov.br. Accessed 30 Jan 2012
Lopes M, Arcuri P (2010) The Brazilian Agricultural Research for Development (ARD) system. Paper presented at the international workshop on fast growing economies' role in global agricultural research for development. Beijing, February 2010
MAPA (2010) Acesso à informação. http://www.agricultura.gov.br/. Accessed 15 Feb 2010
MDA (2011a) Programa Nacional de Fortalecimento da Agricultura Familiar—Pronaf. http://www.mda.gov.br. Accessed 14 Jan 2011
MDA (2011b) Programa de Aquisição de Alimentos—PAA. http://www.mda.gov.br. Accessed 14 Jan 2011
MDS (2011) Bolsa Família. http://www.mds.gov.br/. Accessed 14 Jan 2011
NEAD/MDA (2008) Estatísticas do Meio Rural (versão 2008). http://www.mda.gov.br. Accessed 15 March 2010
PAM/IBGE (2010) Pesquisa Agrícola Municipal. http://www.ibge.gov.br. Accessed 30 Jan 2012
Silveira JMFJ, Borges IC, Buainain AM (2005) Biotecnologia e agricultura: da ciência e tecnologia aos impactos da inovação, 2nd edn, vol 19. São Paulo em Perspectiva, São Paulo, pp 101–114
Vieira Filho JE (2010) Capítulo 3: trajetória tecnológica e aprendizado no setor agropecuário. In: Gasques JG, Vieira Filho JE, Navarro Z (eds) A agricultura brasileira: desempenho, desafios e perspectivas. http://www.ipea.gov.br. Accessed 31 Jan 2011
Vieira Júnior PA (2006) Previsão dos atributos do clima e do rendimento de grãos de milho na região Centro-Sul do Brasil. Tese (Doutorado em Fitotecnia), Universidade de São Paulo, São Paulo
Zylbersztajn D (2008) Persistência de instituições ineficientes, O estado de São Paulo, 6 set. http://www.estadao.com.br. Accessed 6 Sept 2008

Chapter 3
The Role of Agriculture in China's Development: Performance, Determinants of Successes and Future Challenges

Jikun Huang and Scott Rozelle

3.1 Introduction

In the post-World War II era, development economists mostly agree that the role of agriculture and rural development is an integral part of the process of nation building and development (Johnston 1970; Johnston and Mellor 1961). Agriculture plays five important roles in the development of an economy: supplying high quality labour to factories, constructions sites and the service sector; producing low-cost food which will keep wages down for workers in the industrial sector; producing fibre and other crops that can be inputs to production in other parts of the economy; supplying commodities that can be exported to earn foreign exchange that can help finance imports of key technology packages and capital equipment; and raising rural incomes.

The goal of this chapter is to document the performance of China's agricultural sector during the People's Republic era, against the Johnston and Mellor criteria to assess how well the sector has done. In the next section, we will examine the performance of China's rural economy during the reform era. In Sect. 3.3, we will analyse the policies that have helped or hindered progress since the 1980s. In Sect. 3.4, we will discuss some of the future policy challenges.

3.2 The Role of Agriculture in China's Transition Era

The performance of China's agriculture sector improved remarkably during the reform period. The Rural Reforms span the late 1970s (1978, to be exact) until the 2000s. The ups and downs that characterised the performance of agriculture in the

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prereform period disappeared after 1978. Whatever metric of success there was in agricultural production in China during the 1950s, 1960s and 1970s was surpassed during the reform era and agriculture finally began to carry out its various roles in the development process. Compared to the early and mid-1970s when the value of gross domestic product of agriculture rose by 2.7% annually, the annual growth rate nearly tripled to 7.1% during the initial Reform period, 1978–1984, compared with 1.8% of population growth in the same period (Table 3.1), although during the later reform periods (1985–1995; and 1995–2000) the annual growth rates slowed (around 4% or so in real terms, which was about four times higher than population growth).

3.2.1 Revival of Agriculture and Solving China's Grain Problem

At least in the early reform period, output growth—driven by increases in yields—occurred in all subsectors of agriculture. Between 1978 and 1984, grain production in general increased by 4.7% per year. Production rose for each of the major grains—rice, wheat and maize. While the sown area did not change during this time, annual growth rate of yields for grains in general more than doubled between the late part of the pre-reform era and the early reform period.

The success of agriculture in playing its role of supplying abundant, inexpensive food can be illustrated by an examination of grain prices in China. During the Reform era, with the exception of price spikes in 1988 and 1995, the real price of rice, wheat and maize fell. When using a regression approach to measure the trends, grain prices fell in real terms between 33% (maize) and 45% (wheat) between the late 1970s and early 2000s. Coupled with rising incomes, falling grain prices have reduced the share of the consumption budget accounted for by grain from nearly 40% in the late 1970s to about 14% for rural households in 2004. In urban areas, grain accounted for more than 20% of total expenditure in the late 1970s and it has been less than 3% since 2003.

3.2.2 Beyond Grain: The Transformation of the Agricultural Sector

China's agricultural economy has steadily been remaking itself from a grain-first sector to one that is producing higher valued cash crops, horticultural goods and livestock/aquaculture products. Like the grain sector, cash crops, in general, and specific crops, such as cotton, edible oils and vegetables and fruit, also grew rapidly in the early reform period compared to the 1970s. Unlike grain (with the exception of land-intensive staples, such as cotton), the growth of the non-grain sector continued throughout the reform era. The rise in some sectors has been so fast that it almost defies description. For example, between 1990 and 2005 China added the equivalent of the production capacity of California (the world's most productive

Table 3.1 Annual growth rates (%) of agricultural economy by commodity and population, 1970–2005. (Sources: NSBC 1980–2007; MAO 1980–2007)

Commodity	Pre-reform	Reform period			
	1970–1978	1978–1984	1985–1995	1996–2000	2001–2005
Agricultural gross domestic product	2.7	7.1	4.0	3.4	3.9
Grain total					
Production	2.8	4.7	1.7	0.03	1.1
Sown area	0.0	−1.1	−0.1	−0.14	−0.7
Yield	2.8	5.8	1.8	0.17	1.8
Rice					
Production	2.5	4.5	0.6	0.4	−0.8
Sown area	0.7	−0.6	−0.6	−0.5	−0.8
Yield	1.8	5.1	1.2	0.8	0.0
Wheat					
Production	7.0	8.3	1.9	−0.6	−0.4
Sown area	1.7	−0.0	0.1	−1.6	−3.1
Yield	5.2	8.3	1.8	1.0	2.7
Maize					
Production	7.4	3.7	4.7	−1.3	5.6
Sown area	3.1	−1.6	1.7	0.8	2.7
Yield	4.2	5.4	2.9	−0.9	2.9
Total cash crop area	2.4	5.1	2.1	3.5	1.5
Cotton					
Production	−0.4	19.3	−0.3	−1.9	6.5
Sown area	−0.2	6.7	−0.3	−6.1	5.3
Yield	−0.2	11.6	−0.0	4.3	1.2

Table 3.1 (continued)

Commodity	Pre-reform	Reform period			
	1970–1978	1978–1984	1985–1995	1996–2000	2001–2005
Edible oil crop production	2.1	14.9	4.4	5.6	0.8
Vegetable area	2.4	5.4	6.8	9.5	3.1
Fruit					
Orchards area	8.1	4.5	10.4	2.0	2.4
Outputs	6.6	7.2	12.7	10.2	21.0
Meat (pork/beef/poultry)	4.4	9.1	8.8	6.5	4.9
Fishery	5.0	7.9	13.7	10.2	3.6
Population	1.8	1.4	1.4	0.9	0.6

Growth rates are computed using regression method. Growth rates of individual and groups of commodities are based on production data; sectoral growth rates refer to value added in real terms. Because vegetable production data are not available, only annual growth rate vegetable area is reported

Table 3.2 Changes in structure (%) of China's agricultural economy, 1970–2005. (Source: NSBC, Chinas' Statistical Yearbook (various issues) and China Rural Statistical Yearbook (various issues from 1980 to 2007))

	1970	1980	1985	1990	1995	2000	2005
Share in agricultural output							
Crop	82	76	69	65	58	56	51
Livestock	14	18	22	26	30	30	35
Fishery	2	2	3	5	8	11	10
Forestry	2	4	5	4	3	4	4

vegetable basket) every 2 years. It is interesting to note that the rapid growing cash crop sector is dominated by small farms with average farm sizes of less than 0.6 ha in recent years (Wang et al. 2009).[1] China also is moving rapidly away from crop-first agriculture. The rise of livestock and fishery sectors outpaces the cropping sector, in general, and most of the subcategories of cropping (Table 3.2). Clearly, the agricultural sector is playing a major role in providing more than subsistence; it is supplying oilseeds for the edible oil sector, horticultural products for the retail food sector and cotton for the textile sector.[2]

3.2.3 *Moving off the Farm*

The Reform era has brought even more fundamental, transformative changes when looking at a picture of the rural economy. While the average annual growth of agriculture averaged about 5% throughout the entire reform period, the growth rates of the economy as a whole and of the industrial and service sectors were faster (Table 3.3). In fact, since 1985, the growth of the industry and service sectors has been two to three times faster than that of agriculture. Because of the differences in sectoral growth rates, agriculture's share of GDP has fallen from 40% in 1970 to 12% in 2005 (Table 3.4). The shifts in the economy can also be seen in employment. Agriculture employed 81% of labour in 1970. By 2005, however, as the industrial and service sectors grew in importance, the share of employment in agriculture fell to 45%. By 1995, more than 150 million farmers were working off the farm (Rozelle et al. 1999). By 2000, the number rose to more than 200 million (Rozelle and Swinnen 2004).

[1] Wang et al. (2009) showed that small and poor farmers actively participate in the emergence of China's horticulture economy. Middle-stream markets are operated by hundreds of thousands of small wholesalers and brokers. Markets are very competitive. There is little penetration of modern retailers into rural wholesale markets and rural communities.

[2] The fall in cotton production during the later reform period has more to do with pest infestations than lack of incentives. Since the late 1990s, there has a been a revival of the cotton sector production-wise as the advent of insect resistant, genetically modified cotton has overcome this problem (Huang et al. 2002).

Table 3.3 Annual growth rates (%) of China's economy, 1979–2005. (Source: NSBC, Statistical Yearbook of China (various issues))

	Reform period			
	1979–1984	1985–1995	1996–2000	2001–2005
Gross domestic products	8.8	9.7	8.2	9.6
Agriculture	7.1	4.0	3.4	3.9
Industry	8.2	12.8	9.6	10.7
Service	11.6	9.7	8.2	10.2
Foreign trade	14.3	15.2	9.8	25.0
Import	12.7	13.4	9.5	25.5
Export	15.9	17.2	10.0	24.6
Rural enterprises output	12.3	24.1	14.0	NA
Population	1.40	1.37	0.91	0.63
Per capita GDP	7.1	8.3	7.2	9.0

Figure for GDP in 1970–1978 is the growth rate of national income in real terms. Growth rates are computed using regression method

Table 3.4 Changes in structure (%) of China's economy, 1970–2000. (Source: NSBC, China's Statistical Yearbook (various issues), and China Rural Statistical Yearbook (various issues))

	1970	1980	1985	1990	1995	2000	2005
Share in GDP							
Agriculture	40	30	28	27	20	15	12
Industry	46	49	43	41	47	46	48
Services	13	21	29	32	33	39	40
Share in employment							
Agriculture	81	69	62	60	52	50	45
Industry	10	18	21	21	23	22.5	24
Services	9	13	17	19	25	27.5	31

3.2.4 Domestic Market Integration

China in the 2000s may have one of the least distorted, domestic agricultural economies in the world. In a recent survey by the CCAP, with the exception of farmers that were renting village-owned orchards that had been planted in the 1980s and early 1990s, in 100% of the responses, unlike during the Socialist period in China, the farmer said that he/she made the planting decision and was not compelled by local officials (Rozelle et al. 2006). In another survey, every farmer stated that they purchased all of their chemical fertiliser on their own and that local officials had no role in the transaction (Zhang et al. 2005). All purchases were made from private vendors. On the procurement side, whereas it used to be that government parastatals were responsible for purchasing the output of China's farms, since the 1990s the majority of sales of grains and oilseeds and fibre crops and literally all purchases of horticulture and livestock products are to small, private traders (Huang et al. 2008; Wang et al. 2010). Indeed, even with the rise of supermarkets and processing firms that are catering to the retail needs of the urban population, a recent survey discovered that almost all purchases of fruit, vegetables, nuts and livestock products are by *first buyers*, individual entrepreneurs who are trading on their own account (Table 3.5). Even in the second link in the marketing chain (*second buyer*), private traders are still handling most of the produce.

The existence of millions of small traders that are competing with virtually no regulation has meant that China's markets have become integrated and efficient. Park et al. (2002), Huang et al. (2004) and Rozelle and Huang (2004, 2005) find that prices are transmitted across space and over time as efficiently and at levels of integration that meet or exceed those of the United States. Input prices for fertiliser are equally well integrated (Qiao et al. 2003). Although few authors have attempted to quantify the gains from market liberalisation, in the few papers that do exist, it is found that farmers have been gaining from increased allocative efficiency (deBrauw et al. 2004; Huang and Rozelle 1996; Lin 1991). The authors conjecture (without empirical basis) that the gains are due in part to increasing specialisation. The results of our survey show that indeed specialisation has been occurring in China's agricultural sector. Between 1995 and 2004, the percentage of villages that are specialising in an agricultural commodity has increased sharply and has done so in every province (Table 3.6). On average, throughout our sample from across China, 30 % of China's villages are specialising, up from 21 % in 1995. When examining the composition of the output of villages that are specialising, it is clear that the rise in the demand for horticulture and other speciality products is what is driving the specialisation. In our sample, fully 60 % of those villages that are specialising are producing either fruits (28 %) or vegetables (13 %) or other cash crops (28 %, for example, sugar cane, tobacco and cotton). There also are villages that specialise in livestock commodities, oilseed crops, forest products and other commodities.

3.2.5 Expanding Agricultural Trade

In the reform process, China has turned from a hermit country into one of the world's great trading nations, including in the area of agricultural trade. From 1980 to 2000, the total value of China's agricultural trade grew by about 6.0 % on an annual basis. Since 2000, it has more than doubled, making China the fourth-largest importer of agricultural commodities in the world (Gale 2006). However, China is more than an importer; since the reforms, in most years the level of agricultural exports has exceeded that of imports (Fig. 3.1). Perhaps more remarkable is the shift in the composition of trade that China has experienced over the past 25 years. According to custom statistics, the net exports of *land-intensive bulk commodities*, such as grains, oilseeds and sugar crops, have fallen; exports of higher-valued, more *labour-intensive products*, such as horticultural and animal products (includ-

Table 3.5 Supply and marketing channels of horticultural markets in greater Beijing Area, 2004. (Source: Wang et al. 2006)

	Modern supply chains			Traditional supply chains		Other supply chains		
	Supermarkets	Specialised suppliers	Processing firms	Small traders	Farmers sell in local periodic markets	Co-operatives	Consumers direct purchase from farmers	Others
Panel A: First-time buyers (%)								
Horticultural crops	0	2	2	79	8	0	7	2[a]
Vegetables	0	3	5	82	5	0	1	3[a]
Fruit	0	1	1	75	11	0	9	3[a]
Nuts	0	6	0	88	3	0	3	0[a]
Panel B: Second-time buyers (%)								
Horticultural crops	3	3	10	49	13	0	22[b]	
Vegetables	6	0	6	57	11	0	20[b]	
Fruit	1	2	9	46	16	0	26[b]	
Nuts	3	10	19	50	6	0	12[b]	

[a] *Others* (first-time buyers) includes purchases by agents of hotels or restaurants, gifts to other farmers or procurement by organised groups (such as enterprises for distribution to their workers)

[b] *Others* (second-time buyers) includes sales to other villages and sales to market sites that supply processing and other food firms

Table 3.6 Percentage of villages and sown area with specialisation by region. (Source: Huang and Rozelle 2005, FAO paper)

	Percentage of villages[a]		Percentage of sown area[b]	
	1995	2004	1995	2004
Average	21	30	14	24
Hebei	18	19	20	24
Henan	22	23	4	9
Shanxi	51	74	11	22
Shaanxi	4	5	23	32
Inner Mongolia	9	17	38	40
Liaojing	15	32	13	29

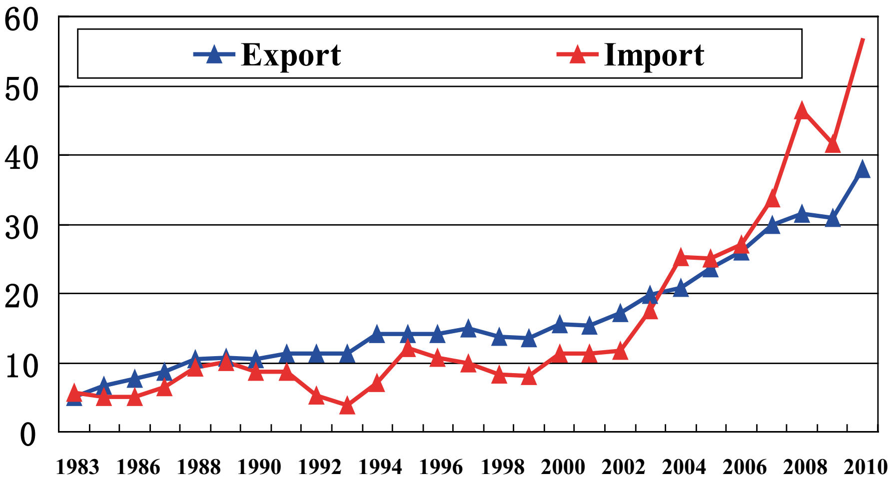

Fig. 3.1 Agricultural exports and imports (billion US$) 1983–2010

ing aquaculture) have risen. In other words, China has begun to export those commodities in which it has a comparative advantage and import those in which it does not have an advantage.

3.2.6 Small Farms and Emerging Co-operatives

One of the most conspicuous trends in production is for households to have smaller and smaller farm sizes. Between 1980 and 2000, the average size of land controlled by households has actually fallen, from 0.71 to 0.55 ha. Moreover, while the rate of growth of production and marketing co-operatives (called Farmer Professional Associations or FPAs) has risen in recent years, few villages and few farmers (percentage-wise) belong to them. According to Shen et al. (2005), only 7% of villages have FPAs, and, of the villages that have FPAs, only about one-third of farmers belong to them. As a result, as of 2005, in all of China, only about 2 % of farmers belonged to co-operatives, a level of participation that is far below almost all other East Asian nations (and many Western nations during their development years), where participation rates were almost 100 %. Between 2005 and 2008, there has been progress. According to a recent study by the CCAP, there has been a steady growth of co-operatives (Deng et al. 2009). By 2008, 22 % of villages had a co-operative and about 13 % of households belonged (5 % as formal members and 7 % as informal members).

3.2.7 Productivity Trends and Rural Incomes

Output per unit of land (or yields) all rose sharply (Lardy 1983). Trends in agricultural labour productivity, measured as output per farm worker, parallel those of yield. Several series of TFP estimates have been produced for China's agriculture (Fan 1991, 1997; Huang and Rozelle 1996; Jin et al. 2002; Lin 1992; McMillan et al. 1989; Wen 1993). The studies uniformly demonstrate that in the first years after reform (1978–1984), comprehensive measures of productivity (either constructed TFP indices or their regression-based equivalents) rose by 5–10 % per year. Although Wen (1993) worries that TFP quit growing in the post-reform period (1985–1989), Fan (1997) and Jin et al. (2002) demonstrate that during the 1990s, TFP continued to rise at a rate of around 2 % per year. A more recent study by Jin et al. (2010) shows that the record of TFP growth in China is remarkably consistent—especially after 1995.

In part due to rising productivity, and perhaps also due to the increasing (allocative) efficiency associated with specialisation, shifting to the production of higher value crops and livestock commodities and the expansion of off-farm work, rural incomes during the reforms have steadily increased (Table 3.7). Between 1980 and 2000, average rural per capita incomes have risen (in real terms) from 771 to 2347 Yuan.

The inequality between rural and urban areas also has a parallel with the rural economy; in relative terms the poorest of the rural poor are falling behind.

Table 3.7 Rural income per capita in China, 1980–2000 (in real 2000 Yuan). (Source: NBSC)

Income group	1980	1985	1990	1995	2000	2001	Annual growth rate, 1980–2001 (%)
Average	711	1248	1305	1702	2253	2347	6
Bottom decile (poorest)	312	448	442	493	579	578	3
Top decile (richest)	1530	2486	3253	4763	6805	7159	8

Importantly, although rises in income (and income inequality) are clearly related closely with the ability of rural households to gain access to off-farm employment (Riskin and Khan 2001), agriculture has been shown to play an inequality-mitigating role. Two factors are responsible for this (Rozelle 1996). First, agricultural income is distributed more evenly to begin with. Second, the poor are proportionately more involved in agriculture. Because of these two characteristics, it has been shown that increases in agriculture income lead to a lower Gini coefficient and other measures of inequality.

3.3 Building the Institutional Base and Policy Strategy of Reform: The Enabling Factors

Unlike in the transitional economies in Europe, leaders in China did not move to dismantle the planned economy in the initial stages of reform in favour of liberalised markets (Rozelle and Swinnen 2004). Policymakers only began to shift their focus to market liberalisation in 1985, after decollectivisation was complete. Even then, liberalisation was a start-and-stop process (Sicular 1995).

3.3.1 Price Policy Changes

Although early in the reforms China's leaders had no concrete plan to liberalise markets, they did take steps to change the incentives faced by producers that were embodied in the prices that producers received for their marketed surplus. Hence, perhaps one of the least appreciated moves of the early reformers was the bold decision of China's leaders to administratively increase the price of farm goods that were to be received by farmers (Lardy 1983; Sicular 1988a, b). Between 1978 and 1983, in a number of separate actions, planners in China increased the above quota price, i.e., the payment farmers received for voluntary sales beyond the mandatory delivery quotas, by 41% for grain and by around 50% for cash crops (Sicular 1988b). According to data from the State Statistical Bureau, the relative price of grain to fertiliser rose by more than 60% during the first 3 years after reform.

As during the pre-reform period, during the early transition era (the late 1970s and early 1980s), input prices—especially that of fertiliser—were still mostly controlled by the state's monopoly agricultural inputs supply corporation in China (Stone 1988, 1993). Although in short supply, the government controlled the price of fertiliser and other inputs (such as pesticides, diesel fuel, and electricity) as well as their distribution (Solinger 1984). Farmers, through their collective leadership, received low-priced fertiliser from the state, but almost all of it was inframarginal. In other words, the government-supplied, subsidised fertiliser was not sufficient to meet the needs of most farmers. Producers in the early reform periods typically purchased additional fertiliser from the state at a higher price or bought fertiliser on the fledgling markets (Ye and Rozelle 1994). Hence, unlike other transition and developing countries, at the margin, farmers in China were not able to purchase fertiliser at highly subsidised rates.

Empirical studies on China confirm the strong impact of these price changes on output during the first years of transition (Fan 1991; Fan and Pardey 1997; Huang and Rozelle 1996; Lin 1992). Lin (1992) finds that 15 % of output growth during the first 6 years of reform came from the rise in relative prices.

3.3.2 Property Rights Reforms for Cultivated Land

China's rural economic reform, first initiated in 1979, was founded on the household responsibility system (HRS). The HRS reforms dismantled the communes and contracted agricultural land to households, mostly on the basis of family size and number of people in the household's labour force. Although the control and income rights after HRS belonged to individuals, the ownership of land remained collective. China has recently passed a new land law, the Rural Land Contract Law (effective 1 March 2003), which seeks to greatly increase tenure security.

Above all, the government is searching for a mechanism that permits those that stay in farming to be able to gain access to additional cultivated land and increase their incomes and competitiveness. Even without much legal protection, over the past decade, researchers are finding that increasingly more land in China is rented in and out (Deininger and Jin 2005). In order to accelerate this process, the new Rural Land Contract Law further clarifies the rights for transfer and exchange of contracted land. The new legislation also allows family members to inherit the land during the contracted period. The goal of this new set of policies is to encourage farmers to use their land more efficiently and to increase their farm size.

There is little doubt that the changes in incentives resulting from property rights reforms triggered strong growth in both output and productivity. In the most definitive study on the subject, Lin (1992) estimates that China's HRS accounted for 42–46 % of the total rise in output during the early reform period (1978–1984). Fan (1991) and Huang and Rozelle (1996) find that even after accounting for technological change, institutional change during the late 1970s and early 1980s contributed about 30 % of output growth. Researchers also have documented impacts that go beyond output. McMillan et al. (1989) document that the early reforms in China also raised total factor productivity, accounting for 90 % of the rise (23 %) between 1978 and 1984. Jin et al. (2002) show that the reforms had a large effect on productivity, contributing greatly to a rise in TFP that exceeds 7 % annually.

3.3.3 Input Marketing Policies

The reforms in fertiliser, seed and other input markets follow China's gradual reform strategy (Rozelle and Swinnen 2004). In the first stage, reformers only implemented measures that provided incentives to sets of individuals and for less important commodities and did not alter the institutional structure that was set up to provide abundant and inexpensive food to the urban economy. Decollectivisation and administrative output price hikes improved incentives to farmers. Leaders, who remained responsible for meeting the same ambitious food sector goals, did little to the rest of the rural economy in the early 1980s, leaving machinery, fertiliser and the seed systems virtually unchanged, and heavily planned. Since the middle 1980s, market liberalisation was gradually implemented, starting with machinery, pesticides, and farm films. The meaningful liberalisation of strategically important inputs, such as fertiliser, occurred mostly in the early 1990s. The reform of the seed industry did not begin until the late 1990s.

3.3.4 Domestic Output Market Liberalisation Policies

Leaders in China did not dismantle the planned economy in the initial stages of reform in favour of liberalised markets (Rozelle 1996). Sicular (1988a, b, 1995), Perkins (1994) and Lin (1992) discuss how China's leadership had little intention of letting the market play anything but a minor supplemental guidance role in the early reforms period in the early 1980s. In fact, the major changes to agricultural commerce in the early 1980s almost exclusively centred on increasing the purchase prices of crops administratively executed by the national network of grain procurement stations acting under the direction of the State Grain Bureau (Sicular 1988b; Watson 1994).

An examination of policies and the extent of marketing activity illustrate the limited extent of changes in the marketing environment of China's food economy before 1985. Reformers did allow farmers increased discretion to produce and market crops in ten planning categories, such as vegetables, fruits, and coarse grains. Moreover, by 1984, the state only claimed control over 12 commodities, including rice, wheat, maize, soybeans, peanuts, rapeseed, and several other cash crops (Sicular 1988b). However, while this may seem to represent a significant move towards liberalisation, the crops that remained almost entirely under the planning authority of the government still accounted for more than 95 % of sown area in 1984. The record of the expansion of rural and urban markets confirms the hypothesis that market liberalisation had not yet begun by the early 1980s. Although agricultural commodity markets were allowed to emerge during the 1980s, their number and size made them a small player in China's food economy. In 1984, the state procurement network still purchased more than 95 % of marketed grain and more than 99 % of the marketed cotton (Sicular 1995). In all of China's urban areas, there were only 2000 markets in 1980, a number that rose only to 6000 by 1984 (deBrauw et al. 2004).

After 1985, however, market liberalisation began in earnest. Changes to the procurement system, further reductions in restrictions to trading of commodities, moves to commercialise the state grain trading system, and calls for the expansion of market construction in rural and urban areas led to a surge in market-oriented activity (Sicular 1995). For example, in 1980, there were only 241,000 private and semi-private trading enterprises registered with the State Markets Bureau; by 1990, there were more than 5.2 million (deBrauw et al. 2002). Private traders handled more than 30 % of China's grain by 1990, and more than half of the rest was bought and sold by commercialised state grain trading companies, many of which had begun to behave as private traders (Rozelle et al. 1999, 2000).

Even after the start of liberalisation in output in 1985, the process was still partial and executed in a start-and-stop manner (Sicular 1995). For example, after the initial commercialisation of the grain bureau, when grain prices rose in 1988, leaders halted the grain reforms. The policies were relaxed again in the early 1990s and retightened in the mid-1990s. Another round of liberalisation and retrenchment occurred in the late 1990s.

3.3.5 Investment in Agricultural Technology

Agricultural research and plant breeding in China during the reform era is still almost completely organised by the government. Reflecting the urban bias of food policy, most crop breeding programs have emphasised fine grains (rice and wheat). For national food security considerations, high yields have been the major target of China's research programme except for recent years when quality improvement was introduced into the nation's technology development plan. Although there have been several private domestic and joint venture investments in agricultural research and development, policies still discriminate against them.

While effective during the Socialist era, China's agricultural research system entered the 1980s and 1990s overburdened with staff that is poorly trained. One of the world's most decentralised systems, the nature of the system also promoted duplication of research effort and discouraged investments in basic research. As a consequence, a nationwide reform in research was launched in the mid-1980s. The reforms attempted to increase research productivity by shifting funding from institutional support to competitive grants, supporting research that was useful for economic development, and encouraging applied research institutes to support themselves by selling the technology they produced.

Since the mid-1990s, today the record on the reform of the agricultural technology system is mixed and its impact on new technological developments and crop productivity is unclear. Empirical evidence demonstrates the declining effectiveness of China's agricultural research capabilities (Jin et al. 2002). Our previous work found that while competitive grant programmes probably increased the effectiveness of China's agricultural research system, the reliance on revenue from commercialisation to subsidise research and make up for falling budgetary commitments weakened the system.[3] It is possible that imperfections in the seed industry partly contributed to the ineffectiveness of research reform measures in crop breeding.

[3] Findings based on a series of intensive interviews and survey data gathered from a wide range of agricultural ministry personnel, research administrators, research staff and others involved in China's agricultural research system.

3.3.6 Investment in Water Infrastructure

The investment by the state in water control—both irrigation and flood control—swamps the amount invested in agricultural research. As noted above, from the 1950s to the 1970s most of the state's effort was focussed on building dams and canal networks, often with the input of corvee labour from farmers. After the 1970s, greater focus was put on increasing the use of China's massive groundwater resources (Wang et al. 2005a). By 2005, China had more tube wells than any country in the world, except possibly for India. Although, initially investment was put up by local governments with aid from county and provincial water bureaus, by the 1990s the government was encouraging the huge shift in ownership that was occurring as pump sets, wells and other irrigation equipment went largely into the hands of private farming families (Wang et al. 1995b). At the same time, private water markets (whereby farmers pump water from their own well and sell it to other farmers in the village) were also encouraged. The main policy initiative after the mid-1990s in the surface water sector was management reform (with the goal of trying to make water use more efficient). Despite concerns, many reports have shown that the water table has continued to fall.

3.4 Future Policy Challenges

While we believe that four of the five roles of agriculture (the supply of labour, food, raw materials and exports) have either already succeeded or are no longer relevant, the final role—providing the 800 million rural population with income—has remained elusive.

3.4.1 Small Farms and Agricultural Modernisation

China needs to increase farm size to raise the incomes of those who were left in the agricultural sector during the industrialisation/urbanisation phase that was ongoing during the early 2000s. Since land cannot be bought or sold, this means that the expansion of farm size will have to depend on China's cultivated land rental markets. In the past (1980s and 1990s), at least, there were many restrictions on renting and the number of rental contracts was extremely small (Brandt et al. 2002). In fact, during the 1980s and mid-1990s less than 5 % of cultivated land was being planted under rental tenancy. However, in recent years (since the mid-1990s) there are indications that rental markets have emerged in a vibrant way. Unfortunately, in China's national statistic surveys, there is little (almost no) systematic information on the scope of their emergence. According to this survey, the share of cultivated land that is being rented out was only 7 % in 2000, but increased to 19 % in 2008. More land in coastal and southern China is being rented out than in inland areas or in northern China.

One of the main issues that policymakers face is that the nature of China's land tenure (based on the contracting of land use rights of collective land to individual households for a fixed number of years) is reducing the enthusiasm for renting. Even more so, would further reform and increased security for farm households stimulate rental activity and provide greater opportunity for increasing the scale of farming? In the coming years, property rights reform will be high on the priority list of potential reforms. These reforms are complicated and will certainly create great challenges. The willingness of farmers to rent out their land for the long term (or give it up entirely) depends on their access to alternative forms of insurance, such as unemployment insurance and social security. The willingness of policymakers to initiate policies to encourage land consolidation will also depend on whether they believe that there are sufficient social insurance protections for those that have left farming in case of downturns in employment. The nation is currently experimenting and slowly expanding rural health insurance, low-income welfare payments and social security for rural households. The current programmes, however, are still either funded at a relatively low level and/or only in the pilot stages and do not cover all of rural China. Hence, success in promoting farm size doubtlessly will also depend on success in promoting these forms of social insurance.

3.4.2 Groundwater Management

How serious is China's groundwater problem? Where is the policy challenge? Wang et al. (2009) have shown that indeed there is a water crisis in northern China. When using other measures of scarcity, a more nuanced picture emerged. According to data on the change in the groundwater table in communities over the past 10 years, in approximately one-half of China's groundwater-using communities, there was a decline in groundwater resources. In a small share of them (about 8 %), the groundwater table was falling rapidly (more than 1 m annually). But in up to half of China's communities in northern China there is no severe problem in groundwater resources. Therefore, we believe the best interpretation of northern China's water resources is that there *is* a water crisis in northern China. Hence, policies to address water scarcity problems should be implemented, but they also should be carefully targeted.

Perhaps our more important conclusion is that it is going to take a more active role of the government for China to be able to begin to solve the problems in the groundwater sector. Although the government in China has begun to make a number of responses to the groundwater shortages that are emerging in some areas, implementation has not been very effective.

3.4.3 Subsidies

China recently has moved from taxing agriculture to subsidising agriculture. In the late 1990s and early 2000s observers reported on the discontent in China's rural population, not least due to the heavy burden of fees and taxes (Esarey et al. 2000). After 2003, however, things changed a lot. The changes have occurred in both the direction of payments, the quantity of the transfers and the nature of payment. In the first year of the Hu Wen government (2003–2005) leaders abolished taxes and fees (Luo et al. 2007). In 2004, subsidies to farmers rose to 14.5 billion Yuan (Ministry of Finance, China 2005). By 2005 instead of the net flow being from rural households to the government's fiscal coffers, the flow reversed. Between 2004 and 2008 subsidies from the Ministry of Finance to the agricultural sector rose by more than 2.5 times. In 2007 government subsidies reached 51.4 billion Yuan. Between 2007 and 2008 subsidies registered the fastest absolute growth, rising to 95 billion Yuan, a rise of 85 % in 1 year (from a base that was already fairly high in 2007). Taxes were zero.

Beside changes in the volume of subsidies, the nature of subsidies also changed. According to the Ministry of Finance, most of the subsidy payments (more than 65 %) went directly to farmers, instead of as before to agricultural enterprises and government agencies. According to government sources, farmers received several types of subsidy payments. Among them, 'grain subsidy' (*liangshi butie*) and 'input subsidy' (*nongzi zhonghe butie*) are major subsidy payments.

What triggered this turnaround in the 5-year period between 2003 and 2008? Policy documents suggest that leaders began to increase subsidies for two fundamental reasons (Central People's Government, China 2008). On one hand, with the rapid rise in demand for a number of agricultural commodities and the systematic shifts in the structure of agriculture, the government, as it has for thousands of years, professed a concern for national food security (Central People's Government, China 2008). On the other hand, policy documents stated explicitly that the government intended the subsidies to help support agricultural incomes.

We find that agricultural subsidies in China are high on per unit of cultivated area basis. Moreover, almost all producers—grain and non-grain producers and the poor and the non-poor—receive the subsidies. The level of subsidies on per cultivated area basis is almost as high as in any other country in the world. However, subsidies are mostly being given to the land contractor (Huang et al. 2010). The tiller is not the target of the subsidies. And, most importantly (in part due to the way that subsidies are given), the subsidies appear to be non-distorting. We show that there is no evidence that grain and input subsidies are distorting producer decisions. We conclude that the income goals of the subsidy programme are taking on the most importance. China's grain and input subsidies should not be expected to have much of an impact on its national food security goals. As a consequence, despite the rise in subsidies, there is *no* evidence that China is *not* following through with their WTO promises in the area of subsidies since these are clearly non-distorting (green box type) policies.

3.4.4 Investment in Conventional Agricultural Technologies and Biotechnology

While decollectivisation played a key role in boosting productivity (Lin 1992) in the early stages of reform, this provided only a one-off boost to productivity. After 1985, the evidence suggests that technological advances have been the main engine of productivity growth (Huang and Rozelle 1996).

China's system of agricultural research faced great challenges by the late 1980s and early 1990s (Rozelle et al. 1997). After the mid-1990s, investment in R&D began to rise. Investment in government-sponsored R&D increased by 5.5% annually between 1995 and 2000 and by over 15% per year after 2000 (Shi et al. 2008). During the past decade, the increases in investment in rural research and development have been the most rapid of any large nation.

China's investment in plant biotechnology reveals that it believes future productivity gains can come from new technologies from these investments. Since the middle 1990s, the growth of China's agricultural biotechnology research investment has accelerated. The investment increased from US$ 33 million in 1995 to US$ 104 million in 2000 and nearly US$ 200 million (or 953 million donors in PPP) in 2003 (Huang et al. 2005).

Investment in agricultural biotechnology is expected to grow. In 2008, in addition to the current research programmes on agricultural biotechnology, the State Council approved a new and major 12-year 'Special Program' to support research on and the development of genetically modified (GM) crops and animals. The total budget was 26 billion Yuan (or US$ 3.8 billion). Half this budget will come from the central government and the other half will be co-funding from industry and local governments.

China's GM crop commercialisation has been impressive. China had approved the commercialisation of GM cotton, petunia, tomato, sweet pepper, poplar trees and papaya before 2006, and approved the commercialisation of Bt rice and phytase maize in 2009. Bt cotton area reached 3.8 million ha in 2008. Recent approval of Bt rice and phytase maize for commercialisation is a milestone in China's GM technology development, moving China's GM crops from fibre to major feed and food crops, which is expected to have significant implications for GM technology in the rest of the world. As Bt rice and phytase maize still need to go through regional varietal demonstrations and registration in the coming years, it is expected that they will be cultivated for large-scale production within 3–4 years.

3.4.5 The Emergence of Biofuels

China was one of the countries that invested in biofuels heavily in the early periods. Four large-scale state-owned bioethanol plants were constructed in 2001. The bioethanol production capacity of these plants, which mainly use maize as feedstock, reached 1.5 million t. In 2007, China set up another bioethanol plant based on cassava. China became the third largest producer of ethanol in the world in 2007.

However, the national leaders quickly saw the trade-off between producing energy and food security. As soon as prices began to inch up in late 2007 and early 2008, China immediately put a moratorium on all biofuel plants that used food or feed crops as feedstock. This, of course, brought the growth of the industry to a rapid stop. In response, the pro-bioenergy lobby did not go away, but, instead put their efforts into finding nontraditional feedstock that would not compete with food and feed. In 2008, China produced about 1.35 million t of ethanol and 0.2 million t of biodiesel. In the coming years, China plans on raising the target. Specifically, the government has announced a target for the biofuels industry. It wants to reach an annual production level of 10 million t of ethanol and 2 million t of biodiesel in 2020. By plan, the demand for feedstock crop will be met by cassava, jatropha, sweet sorghum and other crops that can be grown on marginal lands (Qiu et al. 2010).

While Qiu et al. (2010) have shown that China will be able to meet its biofuel production target in 2020, they are also careful to point out that the actual potential to expand beyond that is still tenuous. Several obstacles must be overcome before non-cereal-based and marginal land-based ethanol production can play a significant role in China's fuel supply. First, the cost to reclaim those marginal lands could be very high. Second, difficulties associated with collecting and transporting feedstock from the field to ethanol plants can be a big challenge. Third, the land quality of these marginal lands is much lower than that of cultivated lands, and the availability of water for these marginal lands is also a critical issue.

3.5 Concluding Thoughts on China's Transition Era Agricultural Policies

The scope of China's policy efforts during the transition era is impressive. Policy shifts were made in pricing and the organisation of production, marketing, investments, technology and trade. One of the most important characteristics of agricultural reform in China is the pace of reform. The sequencing of agricultural reform policies followed the gradualism strategy of China's more general, economy-wide reforms. In the initial stages of reform, leaders consciously restricted the promotion of market-based economic activity. Not until 1985, after the completion of HRS, did policymakers begin to encourage market activity for important commodities (e.g., grain), although initially market activity only occurred within the framework of China's renowned two-tier price system (Sicular 1988b). Leaders did not commit themselves to more complete market liberalisation until the early 1990s, more than a decade after the initiation of HRS. From this description, it is clear that China's reforms fall into two distinct stages: the incentive reforms that dominate the period from 1978 to 1984; and a period of gradual market liberalisation that begins in 1985 and extends through the 1990s. In addition, outside of agriculture other rural- and urban-oriented policies and other factors affected the sector.

When taken together, these policies have been shown to have a dramatic effect on China's agricultural sector. They have increased output of food, driven down prices and improved supplies of non-grain food and raw materials for industry. The mix of policies also has made producers more efficient and they have freed up labour and resources that are behind the structural transformation in the agricultural economy, specifically, and the rural economy, more generally.

The findings of the chapter are that although agriculture failed in the Socialist era during the Reform era—despite the cost to some parts of the rural population—agriculture has being playing a constructive role in many dimensions. Indeed, it is arguable that agriculture's responsibilities in three of its roles are largely fulfilled: Food is plentiful; industry is not being constrained by raw material shortages and China has some of the high holdings of foreign exchange reserves in the world. Moreover, the cropping sector, in particular, and the agricultural sector, more generally, are being transformed with remarkable speed as farmers with strong incentives are responding to market signals and shifting their productive energies more towards higher-value commodities in which China has a comparative advantage. The linkages between the rural and urban economies are also beginning to strengthen as more than 200 million people—in more than eight out of ten rural households—have found employment off the farm.

But, as anyone who has visited China's rural areas in recent years knows, China is not yet a developed nation and many of its rural areas are still backwards. We do not disagree with this, and, in fact, we believe that China currently is entering a new stage of agricultural development and it is one that is filled with as many new and demanding challenges as were being faced at the onset of the reforms. Farm sizes need to grow. Groundwater needs to be managed. The new subsidy programme needs to be shaped and solidified, and made into an institution that will foster agricultural development, not retard it. China's position on international trade liberalisation needs to be clarified. Leaders have to make decisions on the commercialisation or the regulation of biotech and biofuels. There are many other challenges, too.

References

Brandt L, Huang J, Li G, Rozelle S (2002) Land rights in China: facts, fictions, and issues. China J 47:67–97

Central People's Government of the People's Republic of China (2008) Guojia Liangshi Anquan Zhongchangqi Guihua Gangyao. The Central People's Government of the People's Republic of China

deBrauw A, Huang J, Rozelle S, Zhang L, Zhang Y (2002) The evolution of China's rural labor markets during the reforms. J Comp Econ 30(2):329–353

deBrauw A, Huang J, Rozelle S (2004) The sequencing of reforms in China's agricultural transition. Econ Trans 12(3):427–466

Deininger K, Jin S (2005) The potential of land rental markets in the process of economic development: evidence from China. J Dev Econ 78:241–270

Deng H, Huang J, Xu Z, Rozelle S (2009) Policy support and emerging farmer professional cooperatives in rural China. Working Paper, Center for Chinese Agricultural Policy, Chinese Academy of Sciences, Beijing

Esarey A, Bernstein TP, Lu X (2000) Taxation without representation in contemporary rural China. Harvard University Press, Cambridge

Fan S (1991) Effects of technological change and institutional reform on production growth in Chinese agriculture. Am J Agric Econ 73:266–275

Fan S (1997) Production and productivity growth in Chinese agriculture: new measurement and evidence. Food Policy 22:213–228

Fan S, Pardey P (1997) Research productivity and output growth in Chinese agriculture. J Dev Econ 53:115–137

Gale F (2006) Food consumption in China: feeding the dragon. Paper Presented at the 2006 Outlook Conference for US Agriculture, Arlington, VA, Feb 19, 2006

Huang J, Rozelle S (1996) Technological change: rediscovering the engine of productivity growth in China's agricultural economy. J Dev Econ 49:337–369
Huang J, Rozelle S (2005) Market development, commercialization and small farmers in China. Working Paper, Center for Chinese Agricultural Policy, Institute of Geographical Sciences and Natural Resource Research, Chinese Academy of Sciences, Beijing, China
Huang J, Hu R, Rozelle S, Pray C (2005) Insect-resistant GM rice in farmer fields: assessing productivity and health effects in China. Science 308:688–690
Huang J, Wu Y, Zhi H, Rozelle S (2008) Small holder incomes, food safety and producing, and marketing China's fruit. Rev Agric Econ 30(3):469–479
Huang J, Wang X, Zhi H, Huang Z, Rozelle S (2010) Subsidies and distortions in China's agriculture: evidence from producer-level data. Aust J Agric Resour Econ 55:1–19
Jin S, Huang J, Hu R, Rozelle S (2002) The creation and spread of technology and total factor productivity in China's agriculture. Am J Agric Econ 84(4):916–939
Johnston B (1970) Agriculture and structural transformation in developing countries: a survey of research. J Econ Lit 8:101–145
Johnston B, Mellor J (1961) The role of agriculture in economic development. Am Econ Rev 51:566–593
Lardy NR (1983) Agriculture in China's modern economic development. Cambridge University Press, Cambridge
Lewis WA (1954) Economic development with unlimited supplies of labor. Manch Sch 22:139–191
Lin J (1991) Prohibitions of factor market exchanges and technological choice in Chinese agriculture. J Dev Stud 27(4):1–15
Lin J (1992) Rural reforms and agricultural growth in China. Am Econ Rev 82:34–51
Lin J, Cai F, Li Z (1996) The China miracle: development strategy and economic reform. Chinese University Press, Hong Kong
Luo R, Zhang L, Huang J, Rozelle S (2007) Election, fiscal reform and public goods provision in rural China. J Comp Econ 35:583–611
McMillan J, Naughton B (1992) How to reform a planned economy: lessons from China. Oxf Rev Econ Policy 8:130–143
McMillan J, Walley J, Zhu L (1989) The impact of China's economic reforms on agricultural productivity growth. J Polit Econ 97:781–807
Ministry of Finance (2005) Various reports, website of Ministry of Finance, China. http://www.gov.cn/jrzg/2008-11/13/content_1148414.htm
Ministry of Finance (2006) Various reports, website of Ministry of Finance, China. http://www.gov.cn/jrzg/2008-11/13/content_1148414.htm
Ministry of Finance (2007) Various reports, website of Ministry of Finance, China. http://www.gov.cn/jrzg/2008-11/13/content_1148414.htm
Ministry of Finance (2008) Various reports, website of Ministry of Finance, China. http://www.gov.cn/jrzg/2008-11/13/content_1148414.htm
Perkins D (1994) Completing China's move to the market. J Econ Perspect 8(2):23–46
Qiao F, Lohmar B, Huang J, Rozelle S, Zhang L (2003) Producer benefits from input market and trade liberalization: the case of fertilizer in China. Am J Agric Econ 85(5):1223–1227
Qiu H, Huang J, Yang J, Rozelle S, Zhang Y, Zhang Y, Zhang Y (2010) Bioethanol development in China and the potential impacts on its agricultural economy. Appl Energy 87:76–83
Riskin C, Khan A (2001) Inequality and poverty in China in the age of globalization. Oxford University Press, New York
Rozelle S (1996) Stagnation without equity: changing patterns of income and inequality in China's post-reform rural economy. China J 35(Jan):63–96
Rozelle S, Huang J (2005) China's soybean economy: supply, demand and trade. Report for the American Soybean Association, Beijing, China
Rozelle S, Swinnen J (2004) Success and failure of reform: insights from the transition of agriculture. J Econ Lit XLII(June):404–456

Rozelle S, Pray CE, Huang J (1997) Agricultural research policy in China: testing the limits of commercialization-led reform. Comp Econ Stud 39(Summer 1997):37–71

Rozelle S, Li G, Shen M, Hughart A, Giles J (1999) Leaving China's farms: survey results of new paths and remaining hurdles to rural migration. China Q 158(June):367–393

Rozelle S, Park A, Huang J, Jin H (2000) Bureaucrat to entrepreneur: the changing role of the state in China's transitional commodity economy. Econ Dev Cult Change 48(2):227–252

Rozelle S, Huang J, Sumner D (2006) China's horticulture economy: supply, demand and trade. Report for the Western Growers American Soybean Association, Beijing, China

Shen M, Zhang L, Huang J, Rozelle S (2005) Farmer's professional associations in rural China: state dominated or new state-society partnerships? Working Paper, Center for Chinese Agricultural Policy, Institute of Geographical Sciences and Natural Resource Research, Chinese Academy of Sciences, Beijing, China

Shi K, Hu R, Huang J, Li S, Xu N (2008) The funding and sources of funding in China's public agricultural research system and their variations among regions after the recent reform. China Soft Sci 11:79–84

Sicular T (1988a) Plan and market in China's agricultural commerce. J Polit Econ 96(2):283–307

Sicular T (1988b) Agricultural planning and pricing in the post-mao period. China Q 116:671–703

Sicular T (1995) Redefining state, plan, and market: China's reforms in agricultural commerce. China Q 144:1020–1046

Solinger D (1984) Chinese business under socialism. University of California Press, Berkeley

Wang J, Huang J, Rozelle S (2005a) Evolution of tubewell ownership and production in the North China plain. Aust J Agric Res Econ 49(June):177–195

Wang J, Xu Z, Huang J, Rozelle S (2005b) Incentives to water management reform: assessing the effect on water use, productivity and poverty in the Yellow River Basin. Environ Dev Econ 10:769–799

Wang H, Dong X, Rozelle S, Huang J, Reardon T (2009a) Producing and procuring horticultural crops with Chinese characteristics: a case study in the Northern China. World Dev 37(11):1791–1801

Wang J, Huang J, Rozelle S, Huang Q, Zhang L (2009b) Understanding the water crisis in Northern China: what the government and farmers are doing. Water Res Dev 25(1):141–158

Watson A (1994) China's agricultural reforms: experiences and achievements of the agricultural sector in the market reform process. Working Paper 94/4, Chinese Economic Research Unit, University of Adelaide, Australia

Wen G (1993) Total factor productivity change in China's farming sector: 1952–1989. Econ Dev Cult Chang 42:1–41

Ye Q, Rozelle S (1994) Fertilizer demand in China's reforming economy. Can J Agric Econ 42(2):191–208

Zhang L, Li Q, Rozelle S (2005) Fertilizer demand in China: what is causing farmers to use so much fertilizer? Working Paper, Center for Chinese Agricultural Policy, Institute of Geographical Sciences and Natural Resource Research, Chinese Academy of Sciences, Beijing, China

Chapter 4
Agriculture, Food Security and Livelihoods in India: Performance, Issues and Challenges

S. Mahendra Dev

4.1 Introduction

Agriculture plays a pivotal role in the Indian economy. Although its contribution to gross domestic product (GDP) is now around one-sixth, it provides employment to 56 % of the Indian workforce. Thus agriculture not only contributes to overall growth of the economy but also reduces poverty by providing livelihoods and food security to the majority of the population in the country and thus it is the most inclusive growth sector of the Indian economy. The global experience of growth and poverty reduction shows that GDP growth originating in agriculture is at least twice as effective in reducing poverty as GDP growth originating outside agriculture (WDR 2008). The 12th Five-Year Plan's (2012–2017) approach paper also indicates that agricultural development is an important component of a faster, more inclusive sustainable growth approach.

It may be noted that Indian agriculture is the home of small and marginal farmers—their share in holdings being more than 80 %. Therefore, the future of sustainable agriculture growth and food security in India depends more on the performance of small and marginal farmers.

According to the FAO (2002), food security exists when all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. Food security has three components, viz. availability, access and absorption (nutrition), and they are interconnected. There are concerns about the progress in availability, access and nutrition in the country. India has the highest number of poor people and the highest number of children suffering from undernutrition in the world.

Against this background, this chapter examines the performance, issues and challenges in agriculture and food security in India. It is organised as follows: Section 2 presents the performance in agriculture, while Sect. 3 looks at performance in

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food security. Section 4 examines issues and future challenges for achieving higher growth in agriculture and enhanced food security in India.

4.2 Performance of Agriculture

In terms of growth, the performance of agriculture in the postindependence era has been impressive compared with the preindependence period. The all-crop output growth of around 2.57 % per annum in the postindependence period (1949–1950 to 2007–2008) was much higher than the negligible growth rate of around 0.4 % per annum in the first half of the previous century. As a result, India achieved significant gains in food grains and nonfood grain crops.

The highest growth rate of GDP from agriculture and allied activities of 3.9 % per annum in recent years was recorded in the period 1992–1993 to 1996–1997 (Table 4.1). If we look at decadal averages, the 1980s recorded the highest growth rate of more than 3 % per annum. In the postreform period, it declined to 2.76 % per annum. The deceleration in the growth rate of GDP from agriculture between the first half of the 1990s and the later period is glaring. It is disquieting to note that during 1997–1998 to 2004–2005, agriculture growth was only 1.6 % per annum (Table 4.1). Fortunately, it recorded a growth of 3.5 % per annum from 2004–2005 to 2010–2011. Significant fluctuation in growth of agriculture is a matter of concern (Fig. 4.1).

One of the paradoxes of the Indian economy is that the decline in the share of agricultural workers in total workers has been much slower than the decline in the share of agriculture in the GDP. For example, the share of agriculture and allied activities in the GDP declined from 57.7 % in 1950–1951 to 15.7 % in 2008–2009 (Table 4.2). The share of agriculture in total workers, however, declined slowly from 75.9 % in 1961 to 56.4 % in 2004–2005 (Table 4.2).

Table 4.1 Growth rates in agriculture GDP: all India. (Source: National Accounts Statistics (various years). Central Statistical Organisation, Government of India)

Period	Growth rate (% per annum)
1950–1951 to 1964–1965	2.51
1867–1868 to 1980–1981	2.20
1980–1981 to 1990–1991	3.07
1992–1993 to 1996–1997	3.85
1992–1993 to 2001–2002	2.76
1997–1998 to 2004–2005	1.60
2004–2005 to 2010–2011	3.47

GDP is in 1980–1981 constant prices from 1950–1951 to 1980–1981; in 1993–1994 constant prices for the period 1980–1981 to 2004–2005; in 2004–2005 constant prices for the period 2004–2005 to 2010–2011. Quick estimates for 2009–2010 and advanced estimates for 2010–2011

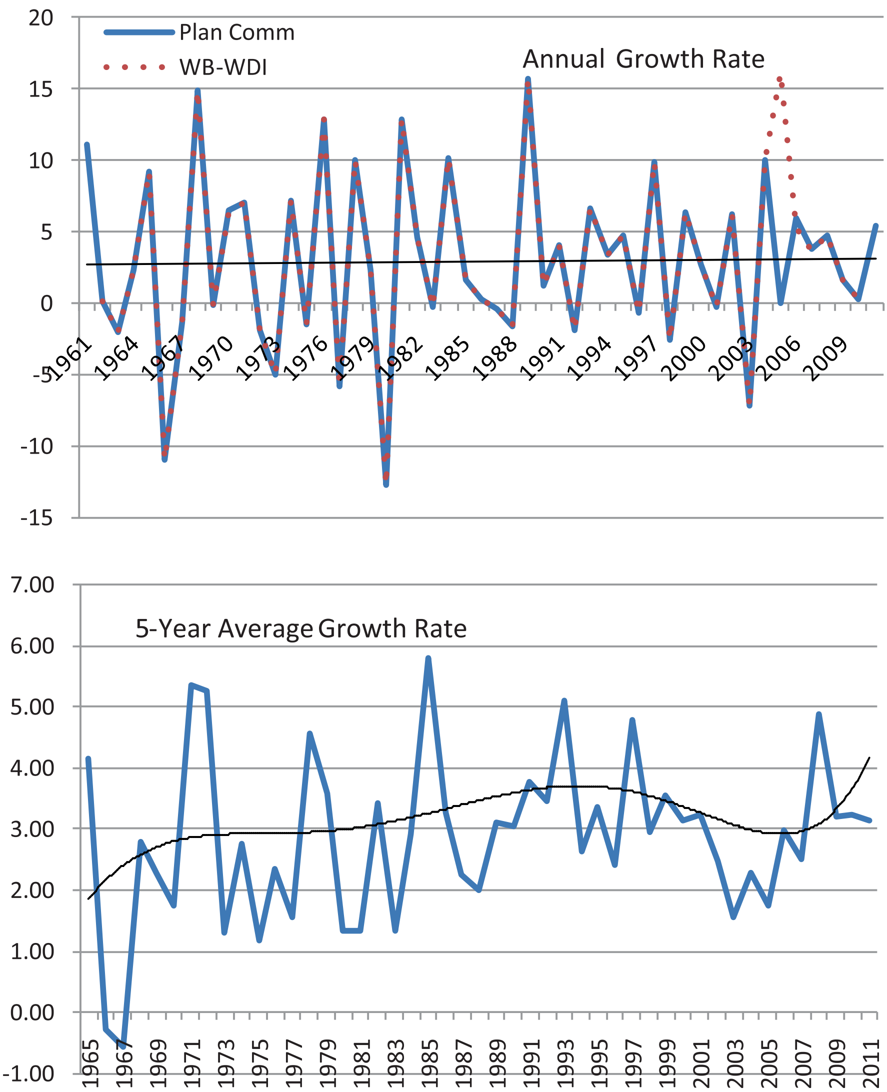

Fig. 4.1 GDP growth in agriculture in India. (Source: Madhur 2011)

There has been significant of diversification production over time. The share of high-value commodities such as fruits and vegetables, livestock and fishery products in total value of agricultural output has increased from 35.2 % in 1980–1981 to 48.9 % in 2009–2010 (Chand and Parappurathu 2011).

Table 4.2 Share of agriculture in GDP and employment: all India. (Source: National Accounts Statistics of India: 1950–1951 to 2002–2003; Economic and Political Weekly Research Foundation, December 2004, Mumbai; Brochure on the New Series of National Accounts, Base Year 2005; Sundaram (2001))

Year	Share in GDP (%)		Share in employment (%)
	Agriculture, forestry and fishing	Agriculture[a]	
1950–1951	57.7	50.2	–
1960–1961	53.0	47.3	75.9
1980–1981	39.7	35.8	–
2004–2005	18.9	15.9	56.4
2008–2009	15.7	13.3	–

[a] Crop production and livestock

4.2.1 *Performance at the State Level*

The performance of agricultural growth in terms of net state domestic product during the period 1999–2000 to 2008–2009 shows that, as one expects, there is significant regional variation across states. Gujarat recorded the highest growth rate of 11.5% followed by Chhattisgarh (6.1%) and Andhra Pradesh (5.2%) (Table 4.3). States such as Madhya Pradesh, Rajasthan and Maharashtra showed more than 4% growth in agriculture, but many states show low growth rates (Table 4.3) Therefore, there is a lot of potential for these low-growth states to catch up with medium- and high-growth states.

Table 4.3 Per annum growth rates of net state domestic product in agriculture at state level: 1999–2000 to 2008–2009. (Source: Chand and Parappurathu 2011)

State	Growth rate (%)	State	Growth rate (%)	State	Growth rate (%)
Jharkhand	−0.9	Uttarakhand	2.2	Madhya Pradesh	4.1
Karnataka	0.4	Himachal Pradesh	2.4	Rajasthan	4.3
Assam	0.8	Punjab	2.4	Maharashtra	4.7
Kerala	1.0	Bihar	2.5	Andhra Pradesh	5.2
Uttar Pradesh	1.6	Jammu & Kashmir	3.4	Chhattisgarh	6.1
Tamil Nadu	1.8	Haryana	3.5	Gujarat	11.5
West Bengal	2.0	Orissa	3.6	–	–

Growth rates are based on 2-year moving averages

Table 4.4 Countrywise yield of paddy in 2008. (Source: Agricultural Statistics at a glance 2010)

Country	Yield (kg/ha)
Egypt	9731
USA	7672
China	6556
Japan	6488
Vietnam	5223
Indonesia	4895
Brazil	4229
Bangladesh	3995
Philippines	3770
Pakistan	3520
India	3370
Thailand	2973
World	4309

Table 4.5 Gap in potential and realised yield for rice (yield in tonnes per hectare). (Source: Department of Agriculture & Co-operation; quoted in CACP 2011)

State	Yield in front-line demonstrations	Yield in farmers' fields	Yield gap (%)
Assam	2.55	1.53	66.7
Bihar	4.15	1.51	174.8
Chhattisgarh	3.13	1.45	115.9
Uttar Pradesh	5.20	2.18	138.5

4.2.2 Yield Gap

There is significant yield gap between India and developed countries. For example, the paddy yield in India is less than the world average, and almost half that of China (Table 4.4). Within India, there is a large gap between potential and realised yields. As shown in Table 4.5, the yield gap is 175 % in Bihar, 139 % in Uttar Pradesh and 116 % in Chhattisgarh.

4.2.3 Total Factor Productivity in Agriculture

In the development literature, the assumption is that productivity in agriculture is lower than in the nonagriculture sector. Here we look at the Indian evidence on total factor productivity growth (TFP) in agriculture and nonagriculture. The evidence shows that TFP growth was almost identical (1.13 % per annum) in both sectors during the 50-year period 1950–2000 (Krishna 2006). The subperiod data indicate that TFP growth in agriculture was the highest in the 1980s at 1.89 % per annum,

Table 4.6 Total factor productivity (TFP) in agriculture and nonagriculture. (Source: Sivasubramonian 2004)

	1950–1951 to 1960–1961	1960–1961 to 1970–1971	1970–1971 to 1980–1981	1980–1981 to 1990–1991	1990–1991 to 1999–2000
Agriculture					
Growth rate in GDP (%)	3.03	2.31	1.50	3.43	2.97
Growth rate in TFP (%)	1.65	0.88	−0.35	1.89	1.68
Percentage of TFP share in GDP growth	54.5	38.1	−23.3	55.1	56.6
Nonagriculture					
Growth rate in GDP (%)	5.34	5.30	4.38	6.77	7.14
Growth rate in TFP (%)	0.88	0.89	0.01	1.98	2.04
Percentage of TFP share in GDP growth	16.5	16.8	0.22	29.3	28.6

but declined to 1.68 % in the postreform period (Table 4.6). On the other hand, the nonagriculture sector's TFP growth was higher than agriculture's in the 1980s and increased marginally in the postreform period. One interesting finding is that despite lower growth in GDP, the TFP contributes more than 50 % to GDP in agriculture, whereas in nonagriculture its contribution to GDP was less than 30 % during the 1980s and 1990s. It shows the importance of TFP for agriculture in the past two decades.[1]

A comparison of TFP in agriculture in Brazil, China, Indonesia and India during the period 1961–2009 shows that Brazil and China recorded the highest rates of growth followed by Indonesia. India is a distant fourth with lower growth (Lele et al. 2012). For example, China recorded more than 150 % rise compared to 60–70 % increase of TFP in India during 1961–2009 (Fig. 4.2).

4.2.4 Agricultural Trade

Economic reforms along with trade liberalisation in 1991 led to the expansion of exports and imports in agriculture. We examine here the changes in the postreform period. The share of India in world agriculture exports has increased from 0.97 %

[1] A recent study by Chand et al. (2011) shows that TFP declined in the recent period for some crops and rose for other crops.

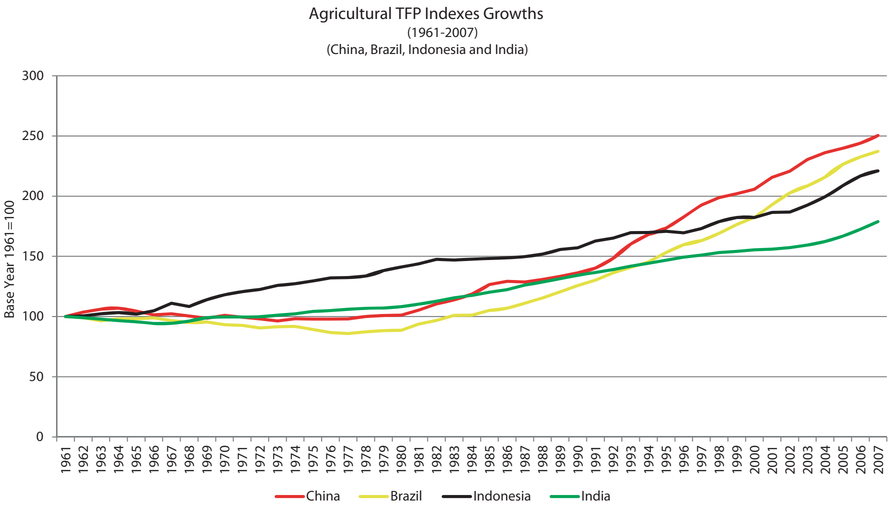

Fig. 4.2 Agricultural TFP indexes growths (1961–2009). (Source: cited in Lele et al. 2012)

Table 4.7 Indicators of agricultural trade in India. (Source: Columns 2, 3, 5 and 6 estimated from WTO data)

	India's share in world agriculture trade, values in US$ (%)		Share of agri. trade in agri GDP	Share of agriculture in India's total merchandise trade, values in US$, percentage shares	
Year	Exports	Imports	Share in %	Exports	Imports
1993	0.97	0.33	5.55	19.32	6.62
2000	1.08	0.67	7.43	14.04	7.75
2006	1.32	0.81	8.74	10.22	4.47
2010	1.70	1.22	8.91	10.55	5.33

in 1993 to 1.70 % in 2010 (Table 4.7). Similarly the share of India in world agricultural imports increased from 0.33 to 1.22 % during the same period. The share of agriculture trade in agriculture GDP in India has also improved over time. On the other hand, the share of agricultural trade in total merchandise trade declined in both exports and imports (Table 4.7). This could be due to exports of higher value products in the nonagricultural sector in recent years.

The composition of exports in India shows that in 2010 the major agricultural exports were in textile fabrics, cereals and cereal preparations, vegetables and fruits, fish and fish preparations, coffee, tea, feeding stuff for animals, and meat and meat preparations. In the same year, the major imports in terms of their high shares were fixed vegetable oils and fats, vegetables and fruits, crude rubber, cork and wood, and pulp and waste paper. Tables 4.8 and 4.9 provide the respective changes in the composition of exports and imports.

Table 4.8 Composition of India's exports, values in US$ (thousands), percentage shares. (Source: Estimated from UN-COMTRADE database)

SITC Rev 2 codes	Description	1993	2000	2006	2010
00	Live animals chiefly for food	0.04	0.02	0.08	0.05
01	Meat and meat preparations	2.64	4.53	5.61	8.06
02	Dairy products and birds' eggs	0.16	0.54	1.33	0.81
03	Fish, crustaceans, molluscs, preparations	19.37	23.14	13.55	10.66
04	Cereals and cereal preparations	10.60	11.59	13.83	14.16
05	Vegetables and fruit	13.10	15.38	13.41	10.36
06	Sugar, sugar preparations and honey	1.41	1.33	5.68	4.86
07	Coffee, tea, cocoa, spices, manufactures	15.54	14.70	10.03	9.78
08	Feeding stuff for animals	17.96	8.07	10.19	9.16
09	Miscellaneous edible products and preparations	0.41	0.76	0.80	0.73
11	Beverages	0.30	0.28	0.34	0.56
12	Tobacco and tobacco manufactures	3.53	2.98	2.93	3.89
21	Hides, skins and fur skins	0.02	0.00	0.13	0.02
22	Oil seeds and oleaginous fruit	2.03	3.72	2.98	4.04
23	Crude rubber	0.08	0.12	1.35	0.62
24	Cork and wood	0.01	0.06	0.15	0.13
25	Pulp and waste paper	0.01	0.02	0.01	0.00
26	Textile fibres (except wool tops)	5.39	1.87	9.60	16.40
29	Crude animal and vegetable materials	4.98	6.88	5.32	2.21
41	Animal oils and fats	0.00	0.03	0.10	0.08
42	Fixed vegetable oils and fats	2.16	3.41	2.03	2.83
43	Animal/vegetable oils/fats	0.27	0.55	0.57	0.57
	Total	100	100	100	100

The SITC codes that constitute 'Agriculture' are: (SITC 0 + 1 + 2 − 27 − 28 + 4)

Table 4.9 Composition of India's imports, values in US$ (thousands), percentage shares. (Source: Estimated from UN-COMTRADE database)

SITC Rev 2 codes	Description	1993	2000	2006	2010
00	Live animals chiefly for food	0.06	0.01	0.03	0.05
01	Meat and meat preparations	0.00	0.00	0.01	0.02
02	Dairy products and birds' eggs	0.37	0.35	0.28	1.03
03	Fish, crustaceans, molluscs and their preparations	0.09	0.12	0.32	0.33
04	Cereals and cereal preparations	5.17	1.03	4.34	0.91
05	Vegetables and fruit	27.47	13.41	21.16	18.25
06	Sugar, sugar preparations and honey	0.40	1.39	0.29	5.83
07	Coffee, tea, cocoa, spices, manufactures	1.26	1.56	2.56	2.43
08	Feeding stuff for animals	1.42	0.66	1.06	1.06
09	Miscellaneous edible products and preparations	4.07	1.26	0.61	0.49
11	Beverages	0.20	0.24	0.99	0.92
12	Tobacco and tobacco manufactures	0.14	0.11	0.32	0.15
21	Hides, skins and fur skins	2.07	1.37	0.79	0.53
22	Oil seeds and oleaginous fruit	0.24	0.08	0.32	0.31
23	Crude rubber	7.23	3.97	6.74	9.20
24	Cork and wood	9.26	11.88	10.68	7.92
25	Pulp and waste paper	10.52	7.04	7.58	6.21
26	Textile fibres (except wool tops)	20.85	17.02	9.36	5.71
29	Crude animal and vegetable materials	2.24	1.52	1.90	1.42
41	Animal oils and fats	0.04	0.05	0.04	0.03
42	Fixed vegetable oils and fats	3.80	33.48	27.19	35.99
43	Animal/vegetable oils/fats	3.10	3.43	3.43	1.21
Total		100	100	100	100

The SITC codes that constitute 'Agriculture' are: (SITC 0+1+2−27−28+4)

4.2.5 Role of Small Farmers

4.2.5.1 Structure of Land Holdings

India is a land of small farmers. As shown in Table 4.10, the share of marginal and small farmers accounted for around 81 % of operational holdings in 2002–2003 compared to 62 % in 1960–1961. Similarly, the area operated by small and marginal farmers has increased from about 19 to 44 % during the same period. *Thus, the small holding character of Indian agriculture is much more prominent today than before.*

4.2.5.2 Farm Size, Output and Productivity

In terms of production, small and marginal farmers also make a larger contribution to the production of high-value crops. They contribute around 70 % to the total production of vegetables, 55 % to fruits against their share of 44 % in land area (Birthal et al. 2011). Their share in cereal production is 52 and 69 % in milk production. *Thus, small farmers contribute to both diversification and food security.*

There has been debate in India on the relationship between farm size and productivity. The results of the National Sample Survey (NSS) 2003 Farmers' survey has empirically established that small farms continue to be produce more in value terms per hectare than medium and large farms. The estimates show that the value of output per hectare was ₹ 14,754 for marginal farmers, ₹ 13,001 for small farmers, ₹ 10,655 for medium farmers and ₹ 8783 for large farmers. *It shows that from the efficiency point of view, small holdings are equal or better than large holdings.*

Table 4.10 Changes in percentage distribution of operate holdings and operated area. (Source: National Sample Survey Land Holdings 8th, 17th, 26th, 37th, 48th, 55th Rounds, Central Statistical Organisation, Government of India)

Land class	Percentage distribution of farm holdings				Percentage distribution of operated area			
	1960–1961	1981–1982	1991–1992	2002–2003	1960–1961	1981–1982	1991–1992	2002–2003
Marginal	39.1	45.8	56.0	62.8	6.9	11.5	15.6	22.6
Small	22.6	22.4	19.3	17.8	12.3	16.6	18.7	20.9
Small and marginal	*61.7*	*68.2*	*75.3*	*80.6*	*19.2*	*28.1*	*34.3*	*43.5*
Semimedium	19.8	17.7	14.2	12.0	20.7	23.6	24.1	22.5
Medium	14.0	11.1	8.6	6.1	31.2	30.1	26.4	22.2
Large	4.5	3.1	1.9	1.3	29.0	18.2	15.2	11.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Marginal 0.01–1.00 ha, *small* 1.01–2.00 ha, *semimedium* 2.00–4.00 ha, *medium* 4.01–10.00 ha, *large* above 10 ha

4.2.5.3 Small Holders and Livelihoods

The sustainability of small farmers is crucial for livelihoods in rural areas and for the entire country. It is true that small holdings have higher productivity than medium and large farms. However, the monthly income and consumption figures across different size classes of land holdings show that marginal and small farmers have dissavings compared to medium and large farmers. According to NSS 2003 data, the monthly consumption of marginal farmers was ₹ 2482 but their monthly income was ₹ 1659. It shows that they have dissavings of ₹ 823. The small farmers dissaved ₹ 655. On the other hand, for large farmers, monthly income and consumption were ₹ 9667 and 6418, respectively, with savings of ₹ 3249. The need for an increase in productivity and incomes of small holdings and the promotion of nonfarm activities for these farmers is obvious.

4.3 Performance in Terms of Food Security: Availability, Access and Absorption

4.3.1 Availability

Attaining self-sufficiency in food grains at the national level is one of the big achievements in the postindependence period. After remaining a food-deficit country for about two decades after independence, India has become largely self-sufficient in food grain production at the macro level. There were hardly any imports after the mid-1970s except occasionally. Food grain production increased from about 50 million t in 1950–1951 to around 242 million t in 2010–2011 and it is expected to be more than 250 million t in 2011–2012.

4.3.1.1 Per Capita Availability of Food Grains

The per capita net availability of food grain increased only about 10 % over the past 56 years if we compare 1951 and 2009 (Table 4.11). However, the net availability declined if we compare 1961 (469 g/day) with 2009 (444 g). In other words, the significant increase in food grains has not been able to keep pace with the increase in population. During the period 1951–2009, per capita availability of pulses declined significantly. On the other hand, per capita availability of sugar and edible oils has increased over time.

Consumption patterns have been shifting to noncereal food like edible oils, fruits, vegetables, dairy, poultry, meat and fish. There is a need to increase the production of these foods to meet the increasing demand. The projections show that India will be self-sufficient in rice and wheat even in 2030 or beyond.

Table 4.11 Net availability of food grains and other commodities. (Source: Economic Survey 2010–2011, Government of India)

Year	Per capita net availability per day (g)			Edible oil (kg)	Vanaspati (kg)	Sugar (Nov–Oct) (kg)
	Cereals	Pulses	Total food grains			
1951	334.2	60.7	394.9	2.5[a]	0.7[a]	5.0[a]
1961	399.7	69.0	468.7	3.2	0.8	4.8
1971	417.6	51.2	468.8	3.5	1.0	7.4
1981	417.3	37.5	454.8	3.8	1.2	7.3
1990	435.3	41.1	476.4	5.3	1.1	12.3
1991	468.5	41.6	510.1	5.5	1.0	12.7
1992	434.5	34.3	468.8	5.4	1.0	13.0
1993	427.9	36.2	464.1	5.8	1.0	13.7
1994	434.0	37.2	471.2	6.1	1.0	12.5
1995	457.6	37.8	495.4	6.3	1.0	13.2
1996	442.5	32.7	475.2	7.0	1.0	14.1
1997	466.0	37.1	503.1	8.0	1.0	14.6
1998	414.2	32.8	447.0	6.2	1.0	14.5
1999	429.2	36.5	465.7	8.5	1.3	14.9
2000	422.7	31.8	454.4	9.0	1.4	15.6
2001	386.2	30.0	416.2	8.2	1.3	15.8
2002	458.1	35.4	494.1	8.8	1.4	16.0
2003	408.5	29.1	437.6	7.2	1.4	16.3
2004	426.9	35.8	462.7	9.9	1.2	16.1
2005	390.9	31.5	422.4	10.2	1.2	15.5
2006	412.8	32.5	445.3	10.6	1.1	16.3
2007	407.4	35.5	442.8	11.1	1.1	16.8
2008	394.2	41.8	436.0	11.4	1.2	17.8
2009	407.0	37.0	444.0	12.7	1.3	18.8

[a] Pertains to the year 1955–1956

4.3.2 *Access*

To achieve food security it is also important that the poor have sufficient means to purchase food. The purchasing power of the poor to buy food can be ensured in two ways. One way is to have an employment-intensive pattern of growth that can provide remunerative work to the poor and enhance their power to purchase food. Another way is to increase income and subsidise food through social protection programmes like the public distribution system (PDS) and employment programmes.

The incidence of poverty in a region may give some indication of the extent to which food is accessible to households. Based on the Tendulkar Committee's methodology (Planning Commission 2009), the poverty ratio at the all-India level was 37.2% in 2004–2005 (Table 4.12). The rural and urban poverty ratios were 42 and 26%, respectively, in the same year.

Table 4.12 Poverty ratios based on Tendulkar's expert group methodology. (Source: Planning Commission 2009)

Year	Head count ratios (%)		
	Rural	Urban	Total
1993–1994	50.1	31.8	45.3
2004–2005	41.8	25.7	37.2

The PDS is one instrument to ensure household level food security. The percentage of consumption obtained from PDS to total consumption provides some idea about the role of PDS in catering to the needs of the population. PDS consumption constituted only 11 % of the total per capita consumption in rural India. But the 2009–2010 NSS survey shows that the working of the PDS has improved in many states. A detailed survey conducted in May–June 2011 covered more than 100 randomly selected villages from Andhra Pradesh, Bihar, Chhattisgarh, Himachal Pradesh, Jharkhand, Orissa, Rajasthan, Tamil Nadu and Uttar Pradesh. The survey reveals two important findings: (a) evidence of a major revival of the PDS across the country (even in states like Odisha and Uttar Pradesh)—the main exception being Bihar (b) where PDS works, people much prefer food to cash transfers.

4.3.3 Nutrition

The prime minister of India recently commented that it was a national shame to have half of our children suffering from malnutrition. National Family Health Survey (NFHS) data show that the proportion of underweight children declined only marginally from 47 % in 1998–1999 to 45.9 % in 2005–2006, although stunting among children declined much more (Table 4.13). International studies have shown that the rate of decline of child undernutrition tends to be around half the rate of growth of per capita GDP (Haddad et al. 2003). Compared to this finding, the rate of decline in malnutrition is much lower than per capita income growth in India.

The nutritional status of children is summarised in Box 1. It shows that three out of four Indian children are anaemic, and it increased between 1998–1999 and 2005–2006. Only 23.4 % are breastfed within the first hour of birth.

Table 4.13 Trends in child malnutrition (0–3 years of age). (Source: GOI 2009)

Nutritional parameter	1992–1993 NFHS-1	1998–1999 NFHS-2	2005–2006 NFHS-3
Stunted	52.0	45.5	38.4
Wasted	17.5	15.5	19.1
Underweight	53.4	47.0	45.9

Box 1. Nutritional Status of Children

- Three out of four children in India are anaemic.
- Every second newborn has reduced learning capacity due to iodine deficiency.
- Underweight children (0–3 years) are 46 % in NFHS-3, a marginal decrease from 47 % in NFHS-2.
- Children under 3 with anaemia are 79 % (NFHS-3), an increase from 74.2 % in NFHS-2.
- Only 23.4 % are breastfed within the first hour of birth and 46 % are exclusively breastfed for a month (NFHS-3)

Source: GOI 2009

4.4 Issues and Future Challenges in Policies and Institutions Focus on Four 'I's: Incentives, Investment, Infrastructure and Information

4.4.1 Agriculture

The agriculture sector has many problems. Growth decelerated from 3.5 % during 1981–1997 to 2 % during 1997–2005. Agricultural growth was only around 2.5 % during the 9th and 10th Plan periods and 3.2 % for the 11th Plan period. Further scope for increase in net sown area is limited. Land degradation in the form of depletion of soil fertility, erosion, and water logging has increased. There has been a decline in the surface irrigation expansion rate and a reduction in the groundwater table. Risk and vulnerability have increased. Disparities in productivity across regions and crops persist. Long-term factors like steeper declines in per capita land availability and shrinking of farm size are also responsible for the slow performance of agriculture.

The 12th Five-Year Plan aims to achieve 4 % growth in agriculture. The Plan wants to focus on small and marginal farmers and resource-poor areas. It also wants to shift the focus on cereals from Punjab and Haryana to the eastern sector. On the supply side it focuses on incentives, institutions and infrastructure. It also advocates the promotion of the rural nonfarm sector to improve food security and livelihoods.

There are three goals of agricultural development: (a) achieve 4 % growth in agriculture and raise incomes by increasing productivity (land, labour), diversifying to high-value agriculture and the rural nonfarm sector; (b) share growth (equity) by focusing on small and marginal farmers, lagging regions, women etc.; and (c) maintain sustainability of agriculture by focusing on environmental concerns.

What policy reforms are needed to achieve these goals? The following factors need focused attention in the short and medium term. All these factors relate to the four 'I's: Incentives, investment, institutions and information. These are: (a) price policy for incentives; (b) tackling inflation; (c) investment in infrastructure; (d) land issues; (e) irrigation and water management; (f) research and extension; (g) credit; (h) diversification; (i) institutions; and (j) information.

4.4.1.1 Incentives: Price Policy and Food Management

The major underlying objective of the Indian government's price policy is to protect both producers and consumers. Currently, the food security system and price policy consist of three instruments: procurement prices/minimum support prices (MSP), buffer stocks and the PDS. There is a need to provide remunerative prices for farmers in order to maintain food security and increase their incomes.

One criticism of procurement policy is that it is limited to a few crops and a few states. Our field visits to different states reveal the following farmers' perceptions about agricultural prices. The cost of cultivation is increasing due to an increase in input prices. In particular, agricultural wages have increased due to the National Rural Employment Guarantee Scheme (NREGS) in several states. They want to mechanise due to labour shortages during the peak season. Farmers respond to prices as shown by an increase in yields of wheat in Punjab and other states with a significant increase in the MSP. Farmers have to undergo distress sales due to lack of procurement in states like Bihar, parts of Uttar Pradesh, Madhya Pradesh, and Orissa. If rice production is to be shifted to the eastern region, rural infrastructure including procurement centres has to be improved. The production of pulses can be enhanced in several states with higher MSPs and procurement.

There is a need for reforms in buffer stock operations and the targeted public distribution system (TPDS). Buffer stock operations are becoming expensive. As the FCI gets full reimbursement for its procurement, handling and storage costs, the scope to improve efficiency by reducing operating costs needs to be examined. Similarly, there are significant leakages in the PDS. There can be more efficient food management practices in procurement, buffer stock and PDS. Policy reforms are needed here. The private sector can be involved in storage and other activities with regulations.

4.4.1.2 Tackling Food Inflation

It is known that consumption patterns have been changing and there has been diversification in Indian diets. The predominance of cereals in the typical household diet gives way to a greater balance and a consequent increase in the demand for proteins—pulses, milk, meat, fish and eggs—as well as vegetables and fruit. As a result, the demand for proteins has increased significantly. It is no surprise that these items have been the primary causes of food inflation in the recent period. Table 4.14 shows that inflation for three major pulses (*urad*, *arhar* and *moong*) was nearly 50 %, although it showed negative inflation in recent months. Similarly, inflation for milk, eggs, meat fish, fruits and vegetables was very high. It is known that food inflation hurts the poor and has an adverse impact on food and nutrition security.

Table 4.14 Food inflation for major groups and subgroups: 2007–2008 to first quarter of 2011–2012 (year-on-year changes). (Source: Ministry of Finance, Government of India)

	2007–2008	2008–2009	2009–2010	2010–2011	2011–2012 (average of April–July)
All commodities	4.7	8.0	3.8	9.6	9.5
Primary articles	8.3	11.1	12.7	17.7	12.9
Food articles	7.0	9.1	15.3	15.6	8.9
Food grains	6.9	11.0	14.5	4.8	2.3
Cereals	9.5	11.9	12.6	5.3	5.0
Rice	11.02	14.8	12.3	5.9	2.6
Wheat	7.3	9.9	12.8	3.0	0.4
Maize	6.3	6.8	10.2	10.1	1.9
Pulses	−2.8	7.5	22.4	3.2	−8.18
Urad	−16.5	0.0	43.0	19.0	−9.23
Arhar	16.4	14.4	48.8	−4.5	−16.3
Moong	−11.9	6.1	55.4	19.9	−21.4
Fruits and vegetables	11.5	8.2	9.7	16.4	16.0
Milk	5.1	7.6	18.8	20.1	8.0
Eggs, meat and fish	3.2	7.7	20.8	25.5	9.1

What are the factors for higher food inflation in India in the past 2.5 years? Both domestic and global factors are responsible for the rise in food prices, but domestic factors like supply shortages play a more important role than global factors. Food inflation does not seem to be a transitory phenomenon and it seems to be a structural problem now. In particular, protein (pulses, milk, eggs, meat and fish) inflation seems to be more due to structural problems than transitory factors. There is a need for agricultural policies to improve the supply of protein-rich foods and a diversified diet to contain food inflation.

4.4.1.3 Investments in Agriculture

One major reform needed in the agriculture sector relates to reduction in subsidies and an increase in investments. Agricultural subsidies are fiscally unsustainable and encourage misuse of resources, leading to environmentally malignant developments. There is a trade-off between subsidies and investments. Public investment declined from 3.4 % of agricultural GDP in the early 1980s to 1.9 % in 2001–2003. At the same time subsidies increased from 2.9 to 7.4 % of agricultural GDP (GOI 2007a). An increase in public and private investment is crucial for enhancing agricultural growth. Fortunately, gross capital formation in agriculture as a percentage of agricultural GDP has increased from 12 % in 2004–2005 to 21 % in 2008–2009. Public sector investment has increased significantly during this period. However, other measures are needed to make the investment in agriculture more effective.

4.4.1.4 Land Issues

Some argue that small size of farm is responsible for the low profitability of agriculture, but the experience of China and other East Asian countries shows that it is not a constraint. On the land market, the Report of the Steering Committee recommended the following: 'Small farmers should be assisted to buy land through the provision of institutional credit, on a long term basis, at a low rate of interest and by reducing stamp duty. At the same time, they should be enabled to enlarge their operational holdings by liberalising the land lease market. The two major elements of such a reform are: security of tenure for tenants during the period of contract; and the right of the landowner to resume land after the period of contract is over' (GOI 2007a). Basically, we have to ensure land leasing and create conditions including credit, whereby the poor can access land from those who wish to leave agriculture. There are some emerging land issues, such as an increase in demand for land for nonagricultural purposes including special economic zones, and the displacement of farmers, tribals and others due to development projects. Land alienation is a serious problem in tribal areas. There is a need for careful land acquisition.

4.4.1.5 Institutions for Irrigation and Water Management

Water is the leading input in agriculture. The development of irrigation and water management is crucial to raise living standards in rural areas. The major areas for reform in irrigation are: stepping up and prioritising public investment, raising the profitability of groundwater exploitation and augmenting groundwater resources, rational pricing of irrigation water and electricity, involvement of user farmers in the management of irrigation systems and, making groundwater markets equitable (Rao 2005). In a recent study, Shah et al. (2009) indicated that the impact of the drought of 2009 is expected be less severe than the drought of 2002 due to groundwater recharge in the past few years. Groundwater can be exploited in a large way in the eastern region. Watershed development and water conservation by the community are needed under water management. New watershed guidelines based on the Parthasarathy Committee's recommendations were accepted by the Central Cabinet in March 2009. Implementation has to be stepped up in order to obtain benefits in rainfed areas. The National Rainfed Area Authority has a major responsibility in matters relating to water conservation and watershed development. An integrated approach is needed for water resource management in the country. An appropriate strategy should integrate institutional approaches with market principles.

4.4.1.6 Research, Extension and Technology Fatigue

The yield growth for many crops declined in the 1990s. Technology plays an important role in improving yields. The National Commission on Farmers indicates that there is a large knowledge gap between the yields in research stations and actual yields in farmers' fields. The yield gaps given by the Planning Commission (GOI 2007b) range from 5 to 300% depending on the crop and the State.

The issue of technology fatigue in agriculture is well known now. There is a need to shift away from individual crop-oriented research focused essentially on irrigated areas towards research on crops and cropping systems in the dry lands, hills, tribal and other marginal areas (Swaminathan 2007). In view of the high variation in agro-climatic conditions in such unfavourable areas, research has to become increasingly location-specific with greater participation or interaction with farmers. Private sector participation in agricultural research, extension and marketing is becoming increasingly important especially with the advent of biotechnology and the protection being given to intellectual property. However, private sector participation tends to be limited to profitable crops and enterprises undertaken by resource-rich farmers in well-endowed regions. Therefore, public sector research has to increasingly address the problems facing resource-poor farmers in the less endowed regions. The new agricultural technologies in the horizon are largely biotechnologies. There has been a revolution in cotton production due to the success of *Bacillus thuringiensis* (Bt) cotton in this decade.[2] Similarly, there is a need to strengthen extension. The Agricultural Technology Management Agency (ATMA) launched a scheme in 2005 to support state governments' efforts to revitalise extension. This scheme gives an opportunity to improve the extension system. The returns to investment on research and extension will be much higher on agricultural growth compared to other investments.

4.4.1.7 Credit

According to the expert group on Financial Inclusion only 27% of farmers have access to institutional credit. It is true that there have been some improvements in the flow of farm credit in recent years. However, the government has to be sensitive to the four distributional aspects of agricultural credit: (a) not much improvement in the share of small and marginal farmers; (b) a decline in credit–deposit (CD) ratios of rural and semiurban branches; (c) an increase in the share of indirect credit in total agricultural credit; and (d) significant regional inequalities in credit.

4.4.1.8 Diversification into High-Value Agriculture

There has been diversification of Indian diets away from food grains to high-value products like milk and meat products and vegetables and fruits. Since the risk is high in diversification, necessary support in infrastructure and marketing are needed. The price policy should also encourage diversification. The government wants a second 'green revolution' by diversifying agriculture in the crop sector and allied activities. To promote holistic growth of the horticulture sector through area-based

[2] On biotechnology in Indian agriculture.

regionally differentiated strategies, the National Horticulture Mission (NHM) was launched during the 10th Plan. The impact has to be strengthened further to improve productivity in the horticulture sector.

The true benefits of diversification will come if greater emphasis is given to allied activities like animal husbandry and fisheries. The livestock sector contributes 5.4% to GDP and 22.7% to total output from the agriculture sector. Ownership of livestock is more equitable than that of land and women play a significant role in animal husbandry.

4.4.1.9 Institutions for Marketing, Particularly for Small Holders

For farmers, particularly for small and marginal farmers, marketing their products is the main problem apart from credit and extension. In recent years, there has been some form of contract arrangements in several agricultural crops such as tomatoes, onions, potatoes, chillies, gherkins, baby corn, cotton, wheat, basmati rice, groundnuts, flowers such as roses, and medicinal plants. There is a silent revolution in institutions regarding noncereal foods. New production–market linkages in the food supply chain are: spot or open market transactions, agricultural cooperatives and contract farming (Joshi and Gulati 2003).

One of the most successful producer organisations is the Indian dairy cooperative which in 2005 had a network of more than 100,000 village-level dairy cooperatives with 12.3 million members (Birthal et al. 2008).

Contract farming in India is neither backed up by law nor by an efficient legal system. This is the single major constraint on the widespread use of contract farming in India. The legal system can be improved with legislative measures.

There is a need to revamp some of the legal hurdles for agro processing and the Agricultural Produce Market Committee (APMC) Act. Several state governments have already amended their APMC Acts allowing varying degrees of flexibility. However, several states are yet to notify the relevant rules that would make the amendment fully operational. These steps should be speedily completed to boost the promotion of direct marketing, contract farming, and setting up of markets in the private and cooperative sectors.

The most important problem for small farmers is output price fluctuations. There is a large gap between producer prices and consumer prices. The real challenge lies in organising small and marginal farmers for marketing and linking them to high-value agriculture. Thus, a group approach is needed to get the benefits from marketing.

Supermarkets and Supply Chains Small farmers can benefit from the emerging supermarkets and value chains. The presence of supermarkets in retail trade is rapidly expanding in emerging economies. Reardon and Minten (2011) examine the patterns and dynamics of diffusion of modern food retail in India. They emphasised three surprises in the rise of modern food retail in India: (1) that has occurred since the 1960s with waves of government, cooperatives and then private retail; (2) that the private retail wave has been extremely fast in particular in its second phase, in the past 6 years, when it grew at 49 % per year on average, some five times faster than the fast growth being experienced in the GDP; (3) that the rise of private retail chains has been unique or rare in its drivers (in its great majority by domestic capital, not foreign investment), and 'early' (compared with the prior experience in other developing countries) in its penetration of the food markets of the poor, of small cities and even rural areas, of fresh product markets, and its use of diverse formats to help toward the above ends (Reardon and Minten 2011, p. 20).

In India, the expansion of modern retail has the potential to spark investment in marketing efficiency and processing that yields benefits to both producers and consumers. In cases where small producers have been able to integrate into the supply chains, supermarkets have offered enhanced security and considerably higher margins than traditional clients, such as wholesalers and grocery stores. However, there is scope for exploitation in contract farming and supermarkets if the rules are not framed properly.

Women's Collectives Women's cooperatives, producer women's groups and other forms of group efforts, where they do not already exist, should be promoted to overcome the constraints of small and uneconomic land holdings, to disseminate agricultural technology and other inputs, and to market produce (Agarwal 2010). There has also been greater emphasis on women's collectives. For example, the Deccan Development Society (DDS), an NGO, enables women from landless families to access various government schemes to establish claims on land, through purchase and lease. There are 'four critical steps that ensured local food security in an experiment by the DDS in Andhra Pradesh where the 'sangams'—women's collectives (i) improved 6000 acres of degraded land; (ii) dalit women took cultivable land on lease; (iii) organised their own public distribution of grains with accent on coarse cereals consumed by 65 % of our rural population, built grain banks at village level; and (iv) made systematic collection and preservation of seed varieties.' (Krishnaraj 2006, p. 5386).

Information Technology The declining costs of information and communications technology (ICT) are giving small farmers greater access to information. Mobile phone coverage in India is expanding at breakneck speed. Nokia sold several lakh mobile phone handsets, and new subscriptions average 6 million a month, many in rural areas. Computers are now being linked through mobile phone networks to greatly expand the scope of information. By linking communication technologies to market exchanges in commercial centres, even small farmers can overcome the enormous informational asymmetries that limit their bargaining power in traditional supply chains. The revolution in mobile phones is helping small farmers get information about crop prices, input prices and other related information on agriculture.

4.4.1.10 Emerging Challenge: Climate Change

Climate change is a reality and India has reason to be concerned about it. The majority of the population depends on climate-sensitive sectors like agriculture, forestry and fishery for their livelihood. The adverse impact of climate change in the form of declining rainfall and rising temperatures and thus the increased severity of drought and flooding would threaten food security and livelihood in the economy. For example, a rise in temperature would affect wheat yields.

India has prepared a document, namely, the National Action Plan on Climate Change. It provides a direction for changes at the national level in policy, planning and public–private partnerships and lays out a global vision for modifying longer time trends for sustainable development. Successful adaptation coupled with mitigation holds the key to food security and livelihoods for the 21st century and beyond in India.

4.4.2 Improving Access to Food and Nutrition

Access to food can be increased through employment due to growth in labour-intensive sectors and/or by having social protection programmes. The problem of malnutrition is much broader than access to food. India has almost double the levels of many African countries. It needs a multidisciplinary approach by covering diet diversification including micronutrients, women's empowerment, education, health, safe drinking water, sanitation and hygiene.[3]

India has government programmes such as the PDS, nutrition programmes like midday meals, and the Integrated Child Development Services (ICDS) to improve food and nutrition security. NREGS and self-employment programmes can also increase access to food and nutrition.

National Food Security Bill The National Food Security Bill is supposed to help improve food access and nutrition. The bill seeks to provide 7 kg of rice, wheat and coarse grains at ₹ 3, 2 and 1/kg, respectively, to each person in a priority household every month. In rural India, up to 75 % of the people will be covered, with at least 46 % under priority households (which is the same as 'below the poverty line' families in the existing public distribution system). Up to 50 % of people will be covered in the urban centres, with at least 28 % under the priority category.

Social protection programmes in India helped improve incomes and protect the population, particularly the poor, from shocks. However, there are numerous gaps and inefficiencies in the social protection programmes.

4.4.2.1 Agriculture and Nutrition Linkages

The Indian economy has done well in terms of economic growth in the postreform period that started in 1991. However, the reduction in malnutrition among children has been very slow compared to the rapid economic growth in the postreform period. This puzzle of higher economic growth and lower decline in malnutrition shows that many other factors like inequalities across regions and social groups, access to adequate health services, clean drinking water, hygiene, women's empowerment,

[3] On the policies relating to food and nutrition security, see Gulati et al. (2011).

caring capacity and practice, intrahousehold food security, governance etc. determine the changes in nutritional status. Thus, a multisectoral approach is needed to tackle the problem of malnutrition.

However, *one part of the above puzzle relates to the role of the agricultural sector*. Agriculture is the single most important sector that influences nutritional levels in the country because of several linkages. Gillespie and Kadiyala (2011) provide seven pathways that link agriculture with nutrition: (a) as a source of food; (b) as a source of income; (c) agricultural policy and food prices; (d) expenditure patterns: how income derived from agriculture is actually spent; (e) women's status and intrahousehold decisions and resource allocation; (f) women's ability to manage young childcare; and (g) women's own nutritional status.

Dev and Kadiyala (2011) focus on three key entry points: inclusive agricultural growth, improving the quality of the diet and empowerment of women. It is true that agricultural initiatives alone cannot solve the nutrition crisis in India, but they can play a much bigger role towards that end than they have done thus far.

4.5 Conclusion

Agriculture development is important for raising food security and livelihoods. There are three goals of agriculture: (i) achieving 4% growth in agriculture; (ii) equity in terms of higher growth in lagging regions, small and marginal farmers and women; and (iii) sustainability. Both demand-side and supply-side measures are needed.

There are six deficits in Indian agriculture: (a) investment, credit and infrastructure deficit; (b) land and water management deficit; (c) research and extension (technology) deficit; (d) market deficit; (e) diversification deficit; and (f) institutions deficit. The focus has to be on the four 'I's: incentives, investment, institutions and information. A group approach among farmers should be encouraged so that they can get inputs at cheaper rates and market the output at higher prices.

The central government's four special programmes, viz. National Food Security Mission (NFSM), Rastriya Krishi Vikas Yojana (RKVY), National Horticulture Mission (NHM) and ATMA would be useful, if implemented properly, in improving growth and equity in agriculture.

The medium and long-term measures relating to the supply side can also improve drought-proofing and derisking agriculture. Similarly, the rural non-farm sector has to be developed. In spite of these measures, agriculture will always be subject to shocks in the form of volatility in global agricultural prices and natural calamities like droughts, floods and temperature changes. Therefore, there is a need to put in place social protection programmes and drought/flood management practices including crop insurance to take care of risks or shocks in agriculture.

The government is thinking of a big push in education and health in the 12th Five-Year Plan. A similar big push is needed for supply-side measures for agriculture. Similarly, demand factors also have to be addressed. Given the short run and structural long-term problems in agriculture, the government should push core issues to make cultivation viable and profitable. There is a need to concentrate on delivery systems also. India's large numbers of farmers can benefit if there are right policies and effective implementation.

The key to ensuring long-run food security lies in targeting cereals productivity to increase significantly faster than the growth in population, so that adequate land becomes available for other agricultural uses. Measures are also needed to improve access to food and nutrition.

Nutrition is not anybody's baby and greater efforts are needed for the convergence of various departments like, agriculture, women and health. We can be more optimistic about the convergence of health and nutrition, but much more can be done about agriculture–nutrition linkages. A beginning can be made to sensitise policy makers and implementers. Once it is recognised, the results may be faster than in the past 65 years.

Ultimately, success depends on political commitment. If the centre is committed to improving food and nutrition security, it can do much more. But state-level experiences show that political commitment at the state level can play an important role in the success of programmes and policies (e.g. the Tamil Nadu experience).

Finally, agriculture alone cannot sustain the livelihoods of 56 % of the workers in India. There is a need to shift people to nonagriculture to raise labour productivity in agriculture. The development of the rural nonfarm sector is important here to absorb the workers in agriculture and improve the incomes and food security of the population.

References

Agarwal B (2010) Rethinking agricultural production collectives. Econ Polit Wkly 45(17):64–78

Birthal PS, Jha AK, Tiongco MM, Narrod C (2008) Improving farm to market linkages through contract farming: a case study of small holder dairying in India. IFPRI discussion paper 00814, Washington, DC

Birthal PS, Joshi PK, Narayanan AV (2011) Agricultural diversification in India: trends, contribution to growth and small farmer participation. ICRISAT, Mimeo, Mumbai

CACP (2011) Price policy for Kharif 2011–2. Commission for Agricultural Costs and Prices, Ministry of Agriculture, New Delhi

Chand R, Parappurathu S (2011) Historical and spatial trends in agriculture: growth analysis at national and state level in India. Paper presented at the workshop on Policy Options and Investment priorities for accelerating agricultural productivity and development in India, organised by IGIDR and IHD, India International Centre, New Delhi, November 10–11

Dev SM, Kadiyala S (2011) Pro-nutrition agriculture in India: entry points and policy options. India Health Beat 5(8):1–4

FAO (2002) The state of food insecurity in the world 2001. FAO, Rome

Gillespie S, Kadiyala S (2011) Exploring the agriculture-nutrition disconnect in India, 2020 Conference Brief 20. Leveraging agriculture for nutrition and health, Feb 2011

GOI (2007a) Report of the steering committee on agriculture for 11th five-year plan. Planning Commission, Government of India, New Delhi
GOI (2007b) Agricultural strategy for the eleventh plan: concerns and way ahead. Planning Commission, Government of India, New Delhi
GOI (2009) Eleventh five-year plan, 2007–2012. Planning Commission, Government of India, New Delhi
Haddad L, Alderman H, Appleton S, Song L, Yohannes Y (2003) Reducing child malnutrition how far does income growth take us? World Bank Econ Rev 17(1):107–131
Joshi PK, Gulati A (2003) From plate to plough: agricultural diversification in India. Paper presented at the Dragon and Elephant: a comparative study of economic and agricultural reforms in China and India, New Delhi
Krishna KL (2006) Some aspects of total factor productivity in Indian agriculture. In: RadhaKrishna R, Rao SK, Dev SM, Subba Rao K (eds) Essays in honour of CH Hanumantha Rao. Academic Foundation, New Delhi
Krishnaraj M (2006) Food security, agrarian crisis and rural livelihoods: implications for women. Econ Polit Wkly 41(52):5376–5388
Lele U, Agarwal M, Timmer P, Goswami S (2012) Patterns of agricultural productivity growth and distribution, poverty reduction and structural transformation. Paper presented at the workshop on policy options and investment priorities for accelerating agricultural productivity growth, New Delhi, 9–11 Nov 2011
Madhur, G (2011) India: accelerating agricultural productivity growth—policy and investment options. Mimeo, World Bank, Washington, DC
Planning Commission (2009) Expert group to review the methodology for estimation of poverty (Chaired by S. D. Tendulkar). Planning Commission, GOI, New Delhi
Rao CHH (2005) Agriculture, food security, poverty and environment. Oxford University Press, New Delhi
Reardon T, Minten B (2011) Surprised by supermarkets: diffusion of modern food retail in India. J Agribus Dev Emerg Econ 1(2):134–161
Shah T, Gulati A, Hemant P, Shreedhar G, Jain RC (2009) Secret of Gujarat agrarian miracle after 2000. Econ Polit Wkly 44(52):45–55
Sivasubramonian S (2004) The sources of economic growth in India: 1950–1951 to 1999–2000. Oxford University Press, New Delhi
Sundaram K (2001) Employment and poverty in 1990s, further results from NSS 55th round, employment-unemployment survey, 1999–2000. Econ Polit Wkly 36(32):3039–3049
Swaminathan, MS (2007) Agriculture cannot wait: new horizons in Indian agriculture. Academic Foundation, National Academy of Agricultural Sciences, New Delhi
WDR (2008) World development report 2008. World Bank, Washington, DC

Chapter 5
Dimensions of Food and Livelihood Security of Agricultural Trade: The Case of Malaysia

Tengku Ariff Tengku Ahmad

5.1 Introduction

Developing countries in general need markets in other higher income countries for them to generate more rapid economic growth, create wealth and prosper. The growth of the Asian Tigers consisting of South Korea, Taiwan, Hong Kong and Singapore can be mostly attributed to the markets of the North. Much of the earlier 'take-off' growth of South Korea and Taiwan was mainly due to the special treatment that they received from developed countries, especially the USA, in terms of market access, technology and general preferences. As is well known, this planned assistance was to strengthen the two countries to counter the threat from socialist China, North Korea and the Soviet Union during the era of the Cold War. The opening of markets of the developed countries to these countries plus outward-looking policies helped propel these two countries into becoming the high-income economies they are today.

While the economies of South Korea and Taiwan in the early part greatly depended on agriculture (Taiwan's strategy of 'fostering industry through agriculture while supporting agriculture through industry'), specifically by encouraging agricultural production and exports, albeit through selective protective measures and support, the story of the highly open economies of Hong Kong and Singapore were quite different. These economies were able to leap from the backwaters of a low-end economy in the 1960s to become high-income economies in just about 40 years. They had and continue to depend on free trade in goods and services, as well as an open and conducive investment environment to prosper, moving from being merely trading ports into manufacturing and subsequently to global services. Freer markets seemed to be their recipe for growth and prosperity.

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The central question now is: Is free or freer trade the panacea for growth for all developing countries to enable them to transform into high-income economies? What about food and livelihood securities? There have been examples where high dependence on external sources for food has threatened the security of nations, causing social discontent, riots and even the downfall of governments due to the inability of the system to deliver affordable basic food to their people because of 'sudden external shocks'. Examples of these shocks include the Asian financial crisis of 1997/1998 and the food and fuel crisis of 2008. The IMF observed that increases in food prices hit poorer countries hardest, posing serious economic and political problems around the world. Developing countries too were not spared. Widespread social unrest was reported in Mexico, Haiti, Morocco, Egypt, Indonesia and many other countries (Baker 2008). Then, there is the question of the traditional industries that have been providing employment for many that might be jeopardised in the face of foreign competition. Then, how can a nation address this apparent paradox of the need to pursue openness to international trade and investments for economic growth while at the same time being able to fulfill its strategic needs of food and social security and to protect the welfare of its people during times of turbulence, when the supply of basic food cannot be assured? The answer and the modality of development, of course, cannot be the same for all, as certainly 'one size cannot fit all'. This chapter examines the question of the dual dimensionality of agricultural trade policies in Malaysia to maintain domestic production and self-sufficiency levels of strategic food crops for national food security while at the same time encouraging the exports of horticultural and industrial crops to enhance the income of farmers for livelihood security, wealth creation and economic growth.

This chapter first describes the Malaysian economy and its agriculture as well as its changing structure over the years. It then traces the evolution of Malaysia's agricultural and trade policies, where policy efforts, though directed towards economic growth, were also balanced with programmes that were 'social and strategic' in nature to address income and food security as well as social equity issues in the economy. Next, the chapter analyses the economic and trade performance of Malaysia, especially with respect to agricultural development and trade, using traditional indicators such as growth in GDP and exports and also other indicators of social and strategic achievements including those related to poverty alleviation and food and income security. The last two sections examine the case and effects of different policy regimes for palm oil, an export-oriented industry, which was 'unprotected', and the paddy and rice industries, which are highly protected in Malaysia. Finally, a number of policy reform options are proposed to more prudently address issues of food and livelihood security as well as economic growth for Malaysia.

5.2 The Malaysian Economy and Its Agriculture

Malaysia registered a respectable average annual growth of 5.5 % for the period of 1991–2010 (Fig. 5.1). This was despite the economic downturns experienced during the period including the Asian financial crisis of 1998, the global economic

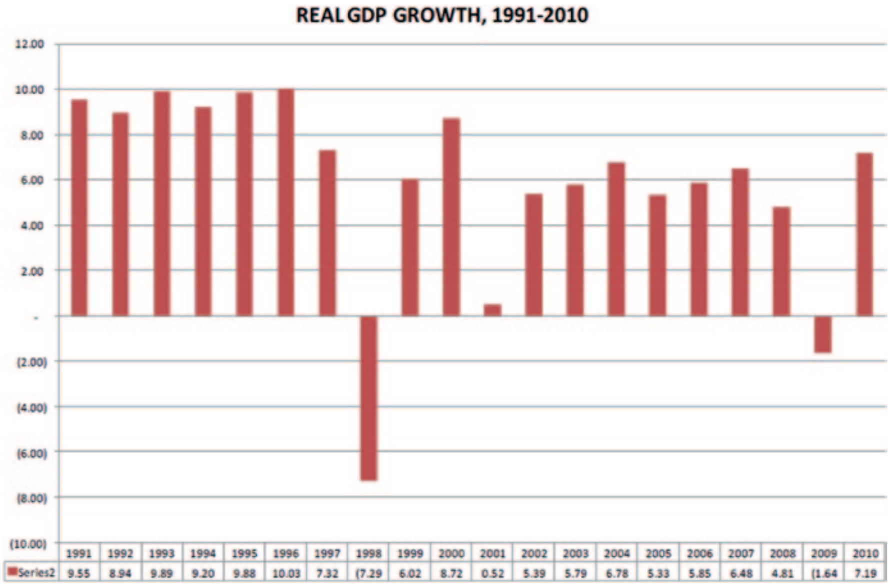

Fig. 5.1 Malaysia GDP growth, 1991–2010

slowdown of 2000/2001 and the food and fuel crisis of 2008/2009. Analysts contributed this strong growth to the prudent fiscal and monetary policies and the adoption of a market-oriented and outward-looking approach to economic development.

5.2.1 Structural Composition of the Economy

When the country gained its independence from the British in 1957, the economy was predominantly based on primary commodities. Agriculture, mainly rubber and timber as well as tin mining, contributed to more than 50 % of the country's GDP. The contribution by manufacturing was less than 10 %. In the 1960s, diversification programmes were pursued to expand its agriculture base and it successfully ventured into palm oil and cocoa. Palm oil is now the leading contributor to agricultural output and has often been dubbed the 'golden crop' of the country due to its continuous and enormous contribution to revenues, exports and wealth and income security for many. However while cocoa was an initial success, output had dwindled due to labour shortages and problems with pests and diseases.

In the early 1980s, Malaysia embarked on programmes to industrialise the economy to lessen its dependence on agriculture and primary commodities. In 1985, the Industrial Master Plan was launched where programmes to promote and develop specific industries were formulated. With appropriate incentives and supported by heavy investments in basic infrastructure, manufacturing became the leading sector of the economy in 1987, contributing to almost 23 % of GDP, while that of agriculture fell to 21.7%. Two decades on, manufacturing now accounts for 32.2% of GDP, while the contribution from agriculture has fallen to only 7.8%. The remainder is mostly from services. This change in the structure of the economy marks the successful transformation of Malaysia from the one that depended on the lower end of the economic value chain to a much higher value economy.

5.2.2 Malaysian Agriculture

For the first three decades of the country's economic history since independence, agriculture was the core sector of the Malaysian economy. It is not an understatement to say that the success and robustness of the economy today was build on the strength of its agriculture in the beginning, providing revenues through agricultural export and corporate taxes of plantation companies to finance national development and the development of other sectors of the economy. Now it still functions as a cushion to absorb external shocks to the economy. Despite its much smaller fraction, it is viewed as a strategically important sector that is directly linked to universally important issues concerning food security, social equity and welfare.

5.2.3 Composition of Malaysian Agriculture

Malaysian agriculture can be primarily grouped into the agro-industrial subsector (comprising oil palm, rubber, cocoa and timber), the food subsector (comprising

Table 5.1 Share industrial and food crops to agricultural GDP. (Source: Economic planning unit)

Item	1985	1990	1995	2000	2005	2010
	Percentage					
Industrial crops	72.1	73.5	71.0	59.1	60.6	56.4
Rubber	19.2	13.8	10.6	10.0	10.5	9.0
Oil palm	30.5	35.8	42.1	31.4	36.7	36.6
Sawlogs	17.7	15.6	13.9	16.4	13.0	10.0
Cocoa	4.7	8.3	4.4	1.3	0.4	0.5
Food commodities	25.3	24.1	26.2	40.9	39.4	43.6
Paddy	4.7	4.0	4.1	3.2	3.4	3.6
Fruits	2.5	2.7	2.9	–	–	–
Vegetables	3.2	2.9	3.1	–	–	–
Fisheries	11.1	10.4	11.2	13.4	12.6	14.1
Livestock	3.8	4.1	4.8	8.1	8.1	9.0
Other agriculture	2.6	2.4	2.8	16.2[a]	15.2′	16.9′
Total	100.0	100.0	100.0	100.0	100.0	100.0
Share of agriculture to GDP(%)	*20.8*	*18.7*	*13.5*	*8.9*	*8.2*	*7.8*

[a] Includes fruits and vegetables

paddy, fruits and vegetables, livestock and fishery) and the miscellaneous group (consisting of tobacco, pepper, coconuts, sugarcane, cassava, sweet potato, maize, tea and coffee as well as other smaller industries, such as floriculture and aquarium fish).The structural composition of the agricultural sector has changed significantly over the past two decades. Where previously agro-industrial crops dominated agricultural GDP, the situation now is somewhat balanced. During 1985–1995, the contribution of industrial crops to agricultural value-added was more than 70%, with the food crop and the miscellaneous subsectors accounting for only 30% (Table 5.1). In 2010, the percentages were 56.4 and 43.6, respectively. The agricultural base had to a certain extent been successfully broadened.

5.3 Agricultural Policy

Agricultural policies were generally designed to balance the economic, social and political objectives of the State that saw a combination of fairly liberal policies for many of the agricultural industries while instituting high protectionist measures for some industries.

5.3.1 Earlier Policies

The legacy of plantation crops such as rubber and oil palm started with the colonisers before independence. Since then this subsector has been the pillar of Malaysian agriculture. Relative to other subsectors, plantation crops received more emphasis in terms of budget allocation and development programmes as well as other government support during the early phases of agricultural development. The only other subsector that received special emphasis is paddy and rice. This is due to the importance of this subsector for food security and poverty alleviation, where the incidence of poverty was highest amongst all agricultural subsectors.

Policies and programmes in the early stages of development were mainly designed to enhance the income of agricultural producers in order to reduce the incidence of poverty in agriculture and to minimise intersectoral disparity and inequity between agriculture and non-agriculture. Hence, agricultural development strategies in the 1960s and 1970s mainly focused on the objectives of reducing poverty, providing rural employment and enhancing agricultural incomes. Earning and saving foreign exchange was also emphasised.

Plantation crops for export, mainly rubber, oil palm and cocoa, were actively promoted while a number of the food subsectors were protected to insulate producers and to save foreign exchange in line with the import substitution strategy during this period. Some of these support and protection measures are in existence to this day.

The introduction of the National Agricultural Policy (NAP 1984) marked the beginning of the liberalisation of the agricultural sector. Productivity, efficiency and competitiveness were the main focus of the policy. Development efforts in this sector were consequently geared towards modernisation and commercialisation of the

Table 5.2 Share of exports by sector, Malaysia, 1980–2005. (Source: Ministry of trade and industry, Malaysia 1996)

Sector	1980	1990	1995	2000	2005
Agriculture	48.5	22.3	13.1	6.1	7.0
Mining	26.4	18.3	5.8	7.2	9.8
Manufacturing	20.6	58.8	79.6	85.2	80.5
Others	9.3	0.6	1.5	1.5	2.7

sector. Downstream and value-added agricultural industries were emphasised and encouraged by providing highly attractive incentives, such as tax breaks and export rebates. Tariffs on agricultural products were reduced and many were abolished to make imports of raw materials cheaper to reduce the input costs of downstream industries.

This was followed by the National Agricultural Policy 2 (NAP2), 1992–2010, which basically continued and further strengthened the policies in NAP1. During this period of the 1990s, when the global economy was in a 'bull-run' spurred by manufacturing demand from developed countries, Malaysia's share of manufactured exports rapidly rose from 58.8% in 1990 to almost 80% in 1995, where it remained in the 2000s. The share of agriculture meanwhile dropped from 22.3% to just 13.1% during this period, and to 7% in 2005 (Table 5.2). It was during this period that the governments of many developing countries, Malaysia included, neglected agricultural development. Budgetary allocation, human resources and infrastructure development as well as other important requisites for agricultural growth were no longer given emphasis. This period of the 'roaring nineties' (Stiglitz 2003) made Malaysia complacent on the importance of growing its own food. The popular mantra then was 'We can always buy what we want'.

5.3.2 Recent Policy Developments

The Asian financial crisis of 1998 was a wake-up call for the government on the importance of not being too dependent on imports for food. Domestic food prices escalated, resulting from higher import costs as the domestic currency seriously depreciated. Riots in a neighbouring country due to food shortages and unaffordable prices led to the fall of the government. In Malaysia, social discontent was rising. This development led the Malaysian government to review the National Agricultural Policy, which gave birth to the Third National Agricultural Policy (1998–2010).

5.3.2.1 The Third National Agricultural Policy (1998–2010)

In the NAP3, as it is popularly known, policies, strategies and initiatives to transform and revitalised the sector were specified. The importance of food production and self-sufficiency level (SSL) was re-emphasised and 'meeting national food requirements' was the first of the five strategic thrusts of the NAP3. Another important strategy was to enhance and strengthen the requisite foundation of agricultural development, especially for the food subsector. This includes among others, physical infrastructure, finance, human resources and technology.

5.4 Malaysia's Trade Policy

Trade policies in Malaysia closely followed the sectoral development policies where the national development agendas were embedded.

5.4.1 Components of Malaysia's Trade Policy

Being a trade-oriented economy, external trade is of great importance to the development of the Malaysian economy and Malaysia places high importance on a strong, open and viable trading system (GATT 1993). Malaysia's trade policies are intended to improve market access for goods and services, promote the global competitiveness of its exports, expand and diversify trade with existing trade partners and explore new markets (WTO 2010).

5.4.1.1 Trade Regime for Agriculture

Overall, Malaysia has a liberal trade regime with low tariffs for most products. The simple average applied MFN tariff was 7.4% in 2009, while about 60% of the products are duty free. As early as 1985, the Food and Agriculture Organization of the United Nations (FAO) observed that even for the so-called 'protected subsectors' in Malaysian agriculture, such as the fruit industry, which attracted a tariff of RM 661 per ton for many imported fruit types, the tariff was still among the lowest in the region (FAO 1985). The present tariffs on agricultural imports are generally low, averaging 2.8% in 2009 (WTO 2010), down from 3.2% in 2005 and from 10.4% in 1993. The lowering of the tariffs was in fact a necessity that benefits downstream agricultural value-adding activities through the imports of cheaper raw materials and intermediate agricultural products.

5.4.1.2 Protected Agricultural Industries

As was previously mentioned, the government protected a number of agricultural industries for strategic and socioeconomic reasons. In many cases, these protection were in industries where there still existed large numbers of poor farming households. The 'infant industry' argument was also used to justify some of these supports during those times. The industries involved were paddy and rice, specific livestock subsectors, tobacco and tropical fruits, coffee and cabbages. It is in these subsectors that most of the non-*ad valorem* tariffs and non-tariff measures are still maintained. This includes import licensing and tariff rate quotas (TRQs).

5.5 Agricultural Growth, Trade and Non-trade Concerns (NTCs)

Economic theory in standard economic textbooks has shown that there are gains to be made from free trade. These gains were supposed to be translated into better economic growth and higher national income that would filter to the masses through the work of the 'invisible hand'. However, in reality, governments all over the world need to grapple with their social obligations to ensure that economic growth is accompanied by better incomes for society's poorest. This usually comes in the form of protection of industries that these people are involved in to protect their income and livelihoods. In Malaysia, too, policies and programmes to address these NTCs, consisting mainly of food security and self-sufficiency as well as poverty eradication, are given high emphasis.

5.5.1 Agricultural Growth and Trade

The mixed policies in agriculture—a liberal trade regime for most products and carefully managed support and protection for some subsectors—that were practiced by Malaysia seemed to be returning fairly good payoffs. Agricultural growth for more than four decades had been positive for almost all of the years, except for a few 'inescapable' years during a recession and/or regional as well global economic crisis. Even during these trying times, growth quickly bounced back into the positive. Table 5.3 shows the agricultural sector growth rates for 1960–2010. Agricultural growth rates were higher during the early phases and slower in the later years. As can be seen, agriculture really started to decelerate in the 1990s, where the emphasis was on industrialisation with less focus on agriculture.

Table 5.3 Agricultural GDP growth. (Source: Calculation from Malaysia plans, various issues)

Period	Growth rate%
1961–1970	7.0
1971–1980	5.0
1981–1990	4.1
1991–1995	1.8
1996–2000	1.2
2001–2005	3.0
2006–2010	3.0

Table 5.4 Growth in agricultural exports (%). (Source: Calculated from FAOSTATS)

Period	Growth rate %
1981–1995	4.9
1996–2000	−6.9
2001–2005	12.3
1996–2005	2.7
2006–2009	12.0
1981–2009	*6.0*

During the Asian financial crisis of 1997/1998, Malaysia was only country among the affected countries that did not seek IMF assistance to weather the crisis. This was, in part, due to the strength of agricultural exports, particularly palm oil that acts as an economic buffer to save the country from an economic melt-down. However, consumers paid the price for the government's indifference to agricultural development and food security during the prior years, which resulted in sudden increases in food prices due to imported inflation. Subsequent re-investments and prioritisation of food production began to show positive outcomes as agricultural GDP growth increased to 3 % for the 2001–2005 and 2006–2010 periods.

Malaysia recorded steady, robust growth in agricultural trade of more about 6 % per annum for the 35-year period of 1981–2009 (Table 5.4). The only negative growth period was for the period of 1996–2000, where severe depreciation of the Ringgit to the US dollar (by more than 50 %) caused a decline in export earnings expressed in that currency. Overall, the agricultural trade data showed an overall 'healthy' trend with an expected simultaneous rise in exports and imports, a reflection of better export earnings and higher standards of living. Again, as in agricultural GDP, growth in agricultural trade showed that Malaysia's policy of enhancing liberalisation in trade was in the right direction.

5.5.2 Self-Sufficiency

Food security is an important policy objective for Malaysia. Although the emphasis on this issue had been softened during the 'roaring years', two major crises within a span of 10 years have jolted the complacency and perception of many that the food security issue in a country like Malaysia, where food can easily be imported, is just conceptual in nature. The 2008 food and fuel episode had shown that in a situation of global food shortages, traditional food exporters might not want to sell their food in anticipation of their own needs and security, irrespective of the state of wealth of the buyer nation. Food security in the Malaysian context is always linked with 'comfortable levels' of self-sufficiency. Despite the opening of its agriculture markets, Malaysia encourages the domestic production of food to enhance self-sufficiency.

The government usually sets targets for levels of food self-sufficiency to be achieved for every Malaysia Five-Year Plan. However, targets set for most food

Table 5.5 Self-sufficiency in major food commodities, 1985–2010. (Sources: Malaysia Plans—various issues, Third National Agricultural Policy 1998–2010, World Trade Organisation 2010: Malaysian Trade Policy Review)

	1985	1990	1995	2000	2005	2006	2007	2010
Crops								
Rice	74	79	76	70	72	69	72	71
Vegetables	81	93	72	95	74	89	89	41
Fruits	102	94	89	94	117	107	105	66
Livestock								
Beef	43	30	19	15	21	22	25	29
Mutton	9	la	6	6	9	9	9	11
Pork	103	117	104	100	97	97	97	102
Poultry	109	115	111	113	125	125	121	128
Poultry eggs	103	109	110	116	109	109	111	115
Milk	4	4	4	3	5	5	5	5
Food fish	95	91	92	86	91	90	93	102

commodities were soft targets except for rice. The self-sufficiency levels for rice were reviewed from time to time based on domestic and international scenarios. The NAP3 (1998–2010) set a minimum target of 65 % self-sufficiency for rice. However, of late, increasing concern on the issue of food security has prompted the government to set a self-sufficiency target of 70 % for the Tenth Malaysia Plan (2011–2015).

The self-sufficiency levels for other major commodities can be seen in Table 5.5. There appear to be no significant changes in the level or in the pattern of self-sufficiency for each of the specific commodities over the years. Thus, even as the domestic market continues to open up, either due to unilateral initiatives or to satisfy international trade agreements, and domestic demand is increasing due to population growth and other factors, Malaysia was still able to face competition and to at least maintain self-sufficiency levels for its major foods.

5.5.3 Poverty Alleviation, Eradication and Livelihood Security

Poverty alleviation and eradication have always been a top development agenda, where economic and social prosperity for all is considered a must for society. The social riots in 1969 that took place in Malaysia were actually the result of social discontent between the ‘haves and haves not’ that translated into racial riots. Since then the government has taken affirmative action, driven by a number of comprehensive programmes that are targeted to alleviate and eradicate poverty throughout the country. This included increasing budgetary allocations for rural development, establishing rural and agriculture-related development institutions, providing physical infrastructure and implementing a diversified range of agricultural development programmes. Poverty eradication, or what can be termed today as livelihood security, and equity distribution and not maximum economic growth was the core strategy in nation building.

Many of the above strategies to eradicate poverty and address equity distribution presented themselves in the form of agricultural policies and programmes in the various subsectors of the agricultural sector. The majority of the policy instruments used to support and protect rice production originated from the need to enhance the income of paddy farmers who were mainly poor. Similarly, the extensive development and cultivation of oil palm by government development agencies were targeted at the landless poor. The development of these two subsectors, both targeted for the poor, eventually transformed into two entirely different 'industrial policy entities'.

5.5.3.1 Achievements in Poverty Alleviation and Eradication

Rural poverty in 1970 was at a high of 58.7%. The incidence of poverty in the paddy subsector was at 88.1%, fishermen (73.2%), rubber smallholders (64.7%) and coconut smallholders (52.8%) (Table 5.6). Poverty in agriculture declined from 68.3% in 1970 to 21.1% in 1990. While significant reductions in incidences of poverty were observed, poverty remained high in paddy farming, rubber production and among fishermen. Aggressive new land expansion for organised oil palm smallholders resulted in significant declines in the incidence of poverty in oil palm, from 30.3% in 1970 to only 8.2% in 1980. By 1984, oil palm smallholders were no longer identified as a significant group to be related with poverty. The cultivation of oil palm certainly played a dominant role in enhancing the income of the rural population and in the alleviation of poverty among agricultural smallholders.

Data subsequent to 1990 on the incidence of poverty by subsector were no longer published by the government. However, the incidence of poverty in the rural areas could be used as a proxy for the incidence of poverty in the agricultural sector (Table 5.7). The incidence of poverty in rural areas declined from 21.8% in 1990 to only 13.9% in 2004. Overall, Malaysia is a success story in poverty alleviation and

Table 5.6 Incidence of poverty by agricultural sub-sector. (Source: EPU, various issues)

Year/sector	1970	1975	1980	1984	1990
Rubber smallholders	64.7	59.0	40.0	43.4	24.1
Oil palm smallholders	30.3	9.1	8.2	n.a*	n.a
Coconut smallholders	52.8	50.9	47.1	46.9	27.1
Paddy farmers	88.1	77.0	73.0	57.7	39.0
Other agriculture	91.8	78.0	64.3	34.2	n.a
Fishermen	73.2	63.0	52.0	27.7	27.7
Estate workers	40.1	47.0	38.0	19.7	19.7
Total in agriculture	*68.3*	*63.0*	*49.3*	*23.8*	*21.1*

*n.a: not available

Table 5.7 Incidence of poverty in rural and urban households, 1990–2004. (Source: EPU various issues)

Year/sector	1990	1995	1999	2004
Rural	21.8	18.5	18.4	13.9
Urban	7.5	4.5	3.8	2.9
Total	17.1	10.8	10.4	6.9

in lessening income inequality, and it was able to do so simultaneously with rapid economic growth, with one reinforcing the other.

5.6 A Tale of Two Industries

The palm oil and paddy industries in Malaysia are two good contrastive examples: one with outward-looking policies that are grounded in competiveness and international trade to flourish and the other with inward-looking policies that heavily depended on government support and subsidies to exist. The palm oil industry evolved into a global leader, while the paddy and rice industry continues to grapple with inefficiencies and structural issues that increasingly require government intervention to this day.

5.6.1 The Malaysian Palm Oil Industry

The palm oil industry is the largest agricultural enterprise in Malaysia. It has evolved from just producing crude palm oil (CPO) to a more diversified industry, consisting of milling, refining and manufacturing of various food and non-food products, such as cooking oil, soaps and oleochemicals. The oil palm, dubbed the 'golden crop' of the country, has witnessed phenomenal growth since the 1960s. Since its introduction, this crop has permanently changed the landscape of agriculture in this country, by replacing most of the rubber areas and through new area development. From about 640,000 ha in 1975, oil palm now covers an area of almost 5 million ha, with both smallholders and private estates and more than 35 million t of palm oil products are exported with a value estimated at more than US$ 5 billion (Table 5.8).

5.6.1.1 Policies and Programmes in the Palm Oil industry

Policy measures for palm oil are primarily aimed at increasing productivity and quality, as well as expanding export markets. Three main institutions are involved in implementing these policy objectives: the Palm Oil Registration and Licensing Authority (PORLA), Palm Oil Research Institute of Malaysia (PORIM) and Malaysian Palm Oil Promotion Council (MPOPC). The former two have been merged to become the Malaysian Palm Oil Board (MPOB).

Table 5.8 Area under oil palm, 1975–2010. (Source: Malaysian palm oil board)

Year	Peninsular	Sabah	Sarawak	Total
1975	568,561	59,139	14,091	641,791
1980	906,590	93,967	22,749	1,023,306
1990	1,698,498	276,171	54,795	2,029,464
1995	1,903,171	518,133	118,783	2,540,087
2000	2,045,500	1,000,777	330,387	3,376,664
2005	2,298,608	1,209,368	543,398	4,051,374
2010	2,505,071	1,423,653	1,007,054	4,975,774

MPOB's general function is to ensure the orderly development of the palm oil industry. It issue licences to those involved in the production, transportation, storage, export and sale of palm oil and its products. Generally, the regulatory activities of MPOB are for the quality control of palm oil and its products. It also undertakes research and development (R&D) to improve productivity, value-added, quality and all other aspects of the industry's output. The MPOPC was established in 1990 to undertake public relations and market promotion of palm oil, mainly in the export markets. The organisation also facilitates joint-venture programmes. The activities of MPOB and MPOPC are funded from a compulsory cess collected from the industry. Apart from the cess collected from the industry to finance R&D, promotion and regulatory activities, palm oil is also subject to export duties. During the early years, these duties were aimed at providing revenues for the government. However, recently export duties for most palm oil products have been abolished. Duties are only imposed on exports of CPO to encourage local processing of palm oil into higher value-added products.

5.6.1.2 Organised Smallholder Schemes

The main mechanism for the establishment of an organised smallholder scheme was through the creation of the Federal Land Development Authority (FELDA), which was formed on July 1, 1956. With an initial working capital of merely RM 10 million, the first FELDA rubber scheme was developed, which only involved 1620 ha of land. A year later, five more schemes were developed (TunkuShamsul and Thong 1988). FELDA's involvement in oil palm began in 1961 with an initial area of 375 ha. Under an aggressive management, oil palm under FELDA schemes expanded rapidly over the years (Table 5.9). In 2011, FELDA had almost 700,00 ha under its care. Other government institutions also organised their own smallholder development schemes. These include state government agencies, the Rubber Industry Smallholder Development Authority (RISDA) and the Federal Land Consolidation and Rehabilitation Authority (FELCRA).

FELDA's model of land development was basically to provide centralised administration and management. Settlers were brought into the land schemes and were only given subsistence payment until the first crop harvest. Credit facilities and a

Table 5.9 Distribution of oil palm planted area by category: 2006 and 2007. (Source: Malaysian palm oil board)

Category	2006		2010	
	Hectares	%	Hectares	%
Private estates	2,476,135	59.45	3,035,222	61
Govt. schemes				
FELDA	669,715	16.08	696,608	14
FELCRA	159,780	3.83	149,273	3
RISDA	81,169	1.95	99,515	2
State schemes	323,520	7.77	298,546	6
Smallholders	454,896	10.92	696,608	14
Total	*4,165,215*	*100.00*	*4,304,913*	*100.00*

wide range of support services as well as community services were provided that aimed at aiding the rapid adaptation and change of the settlers. The development and initial operational costs were repaid by the settlers over an extended period of years from the revenues received. After all the costs had been recovered, ownership of the land was transferred to the smallholders. From its humble beginnings, FELDA has now diversified into downstream portfolios like milling, refining, kernel crushing, marketing, engineering transport, trading and security. Either on its own or through strategic alliances, these economic ventures turned FELDA into a highly integrated conglomerate and it is now one of the largest and most profitable government-linked companies in the country with domestic and international business operations.

Waves of urbanisation have brought facets of new development in some FELDA schemes. Due to the close proximity to the development corridors of the country, schemes like Sungai Buaya (in the northern part of Kuala Lumpur), Bukit Cherakah (on the fringe of Kuala Lumpur), Sendayan and LBJ (both bordering Kuala Lumpur International Airport) were being re-developed into residential and industrial satellites. This resulted in a drastic boom in the land prices of these schemes. Many of the earlier settlers and families are now millionaires from the sale of their land.

5.6.2 The Malaysian Paddy and Rice Industry

The paddy and rice industry is a highly subsidised and regulated industry in Malaysia. Policy measures and interventions consist of a web of policy measures that are aimed at protecting the incomes of rice farmers as well as ensuring that rice prices are affordable to consumers, particularly the urban poor. Policy instruments used to regulate the price of paddy and rice include single-desk trading, which allows BERNAS to be the sole legitimate importer of rice. In addition, the government also provides input and price subsidies, exercises price controls and gives the gamut of institutional support, including R&D, extension services, irrigation, farm management and others.

5.6.2.1 Paddy and Rice Policies in Malaysia

Table 5.10 provides a summary of the major policy interventions and instruments used in the paddy and rice sector. Much of this support has been increased from time to time to ensure that farmers received reasonable incomes from paddy farming. For example, income price support started at RM 168 per ton in 1980. At that time, this support was meant to increase farmers' income to above RM 300 per month (the national poverty income line at the time) to alleviate the high incidence of poverty among paddy farmers. In 1990, the amount was increased to RM 248.10 per ton and cost the government about RM 450 million annually. A fertiliser subsidy scheme meant to increase productivity has also increased over time. As reported by the WTO, the cost of this subsidy increased from RM 186 million in 2004 to almost RM 271 million in 2008. A summary of the major interventions can be seen in Table 5.10.

In spite of all the interventions in the industry, at almost all points of the supply chain productivity gains were modest, the industry remained internationally uncompetitive, and its contribution to the national economy remained small. It is a classic example of an industry trapped in a web of unproductive policy interventions from which it is becoming increasingly difficult to escape.

Table 5.10 Major policy interventions in the Malaysia paddy and rice sector. (Source: TengkuAriff and AriffinTawang 1999)

Policy instruments	Objectives of the intervention
Input intervention	
Fertiliser subsidies	To encourage farmers to use fertiliser in the earlier years, reduce the cost of production, and increase income
Credit facilities	To finance double-cropping of paddy and purchase of inputs. The interest rate was raised from 0 to 4% in 1986
Irrigation investment	To realise the double-cropping goal, and hence increase production and income. It involved huge capital investment totalling RM 4.2 billion during the period 1956–1996 (14% of total allocation for agricultural development); water charges are either negligible or free)
Paddy marketing and processing	
Floor price in the form of Guaranteed minimum price (GMP)	Income support programme by supporting paddy prices Current price is RM 55.00 and RM 51.69/100 kg for long-and medium-grade paddy, respectively Income support programme, to the amount of RM 248/ton
Price subsidy (bonus payment)	Monopoly by BERNAS in rice trading to ensure fair price to both producers and consumers
Rice marketing and pricing	
Rice marketing	Consumer protection, based on cost-plus pricing. The price is set by the government
Rice pricing	

5.7 Lessons Learnt and the Way Forward

The above two cases clearly show that integration of domestic industries into the international trading system is a better way to develop an industry and deal with the food security needs of the country based on the concept of self-reliance instead of self-sufficiency. In the former, the more important objective is society's capability to secure needed food, irrespective of whether the food was imported or domestically produced. With good levels of income and a consistently stable international trading system, the concept of self-reliance is more feasible to pursue compared to self-sufficiency. However, disruptions to the international trading system do occur occasionally, and the middle ground of physical stockpiling can be a more viable option compared to attempting to be self-sufficient.

For the palm oil sector, the government should continue its market-based policies that have worked so well for the industry. More funds should be invested in R&D for continued enhancement of productivity through superior planting materials and more environmentally friendly production practices, including in downstream processing. The industry could also competitively benefit from higher labour productivity through increasing automation and mechanisationin the process of production.

The case of the two industries also show that although both palm oil and rice have been able to contribute to the nation's strategic and social objectives—poverty alleviation, food security and political stability—while the palm oil industry did it by contributing to the wealth of the nation, the attainment of the strategic objectives in the paddy and rice sector, on the other hand, came with extremely high opportunity costs that actually partially eroded the wealth that has been acquired through palm oil.

5.7.1 Further Policy Options in Agriculture

Recommendations for further policy options in Malaysian agriculture are divided into 'sector-wide strategies' for general agricultural development and specific policy options to reduce economic loss in the paddy and rice industry.

5.7.1.1 Sector-Wide Strategies

It was mentioned earlier in this chapter that being a nation whose growth and income was spurred and highly dependent on international trade, Malaysia needs to intensify its outward-looking policies and expand them to the whole of the agricultural sector. The following are specific market-based sector-wide recommendations that should see a more consolidated and competitive agricultural sector in the long run (Table 5.11).

Table 5.11 Recommendations for agricultural development

	Recommendation	Description
1.	Focusing on specific food segments	The country needs to select and decide on the specialised products that it wants to excel in, and the market segments that it wants to focus on. For example, in the fruit market, it is unlikely that Malaysia will be able to excel internationally in marketing all fruit types
2.	Nurture and further develop agricultural industries with signs of international competitiveness	Efforts need to be geared towards further developing agricultural industries that have shown signs of competitiveness. Examples are those with expanding domestic industry and increasing exports, such as fruits like papaya, watermelon and fresh pineapple
3.	Build and provide a strong support foundation for the industry to grow	These include requisite economic foundation providers, such as credit, institutional support, quality control, required information and infrastructure and incentives
4.	Intensify market-driven R&D for specialised products to service specific market segments	The generation of new knowledge through R&D would be able to create specialised agricultural and food industries that can make Malaysia become internationally competitive

5.7.1.2 Tackling Economic Loss in the Paddy and Rice Industry

In a perfectly competitive hypothetical world, where Malaysia hypothetically produced only palm oil and paddy, economics would dictate that Malaysia devote all its resources to produce palm oil and import all the rice its needs from the wealth obtained from exports of palm oil. However, under the current state of distortions in international trade coupled with the possibility of international market failures as experienced during the recent food crisis, one would question whether this is a pragmatic option.

Malaysia has spent substantial amounts to ensure a comfortable level of self-sufficiency for its staples. Yearly direct support of price and fertiliser support currently amounts to about RM 600 million annually. The cost of ‘feeling secured’ at SSL of 65 % for rice comes at a reasonable high price. A study by Tengku Ariff and Ariffin Tawang (1999) showed that total liberalisation of the paddy and rice sector, including relaxing all border measures as well as direct domestic support, would increase total economic welfare by almost RM 460 million. However, this gain in economic welfare would compromise the SSL of rice and the ‘comfort’ associated with SSL and food security. In relation to this, another study estimated that a complete liberalisation of the rice industry, including dismantling all import barriers and eliminating all direct support to the industry, would reduce SSL to about only 25 % (TengkuAriff and Mad Nasir 2005).

In which scenario would a nation be more comfortable? Spending to the tune of RM 600 million annually and having an SSL of 70 % or zero spending but seeing a plunge of rice SSL from the current 70 % to only 25 %? The neo-classical economic approach would require opting for the former, but the issue would not only be politically unpopular but would also raise the question of whether the approach would make 'development sense'. It is certainly a national dilemma considering the uncertainty surrounding international rice supply during times of crisis. The 2007/2008 food crisis taught food-importing nations, especially developing ones 'a decisive lesson', that a nation cannot be dependent on other nations for its food at all times. At the height of the 2007/2008 food crisis, Vietnam, China and Cambodia banned exports of rice, while Thailand restricted its exports. India also banned its rice exports except for Basmati rice. The price for Thai White Rice, the benchmark for the world price of rice, shot up from about US$ 300 to more than US$ 1000/metric ton. Rice-importing countries, including Malaysia, were at times unable to source their rice through the open market and had to resort to government-to-government (G-G) arrangements to secure rice. The multilateral trading system that was supposed to protect the interests of importers as well as exporters appears to have failed in times of crisis. This was comparable to a market failure where buyers could only buy products at high, distorted prices due to collusions, monopoly and other distorted practices. Under these circumstances, Malaysia can consider the following strategies or initiatives for a 'cheaper' long-term strategy for national food security (Table 5.12).

Table 5.12 Strategies for the rice and paddy industry

	Strategy	Description
1.	Producing versus security stockpiling	RM 600 million of direct support expended to maintain about 70 % SSL
		A combination of production and 'food security stock' (25 % production and 45 % stockpiling) of rice for 70 % SSL would cost only RM 90 million annually.[a] However, total import costs would balloon to RM 1875 million from the current RM 750 million, an increase of RM 1125 million
2.	Increasing productivity	Increase in yield for the past 25 years had grown at only 1.3 % per year. Increase in production was largely attributed to increases in cropping intensively, which is no longer an option due to sustainability issues
		The high subsidies have discouraged innovation, slowed farm consolidation for better economies of scale and retarded higher growth in productivity. Reforms in the industry would allow the evolution of larger and more efficient farms
		A key programme that is needed is farm enlargement and consolidation which is coupled with a producer retirement programme. It could be modelled on the 'producer retirement schemes' of developed countries
		Improving aging infrastructure, including irrigation and drainage

[a] Economic Planning Unit (2004), Prime Minister's Department, Malaysia

5.8 Conclusion

Malaysia is a trading nation and has consistently been in the world's top-20 trading nations for the past decade. Its ratio of exports and imports over GDP is more than 100 %. The country is now aspiring to become among the world's top-10 trading nations by the year 2020. In agricultural trade, Malaysia is also among the top-20 exporters. However, more than 80 % of these exports comprised 'industrial commodities' (palm oil, rubber, cocoa and sawn logs), with palm oil alone accounting for between 45 and 50 % of total agricultural exports. The balance of trade for food commodities,on the other hand, has always been in the negative with expanding deficit. As such, historically, the food sector, which is less efficient than the industrial commodity sector, is protected, based on reasons of 'national interests' such as food and income security of the small rural producers. Political calls for a more protective agricultural sector continued to be made. This is not only true of Malaysia but for other countries as well, both developed and developing. These calls usually gain momentum and intensity resulting from negative economic developments such as a financial crisis and the more recent food and fuel crisis. The Asian financial crisis of 1997/1998 and the more recent global food and fuel crisis of 2008 affected the real incomes of the urban poor while higher agricultural input prices, brought about by spiralling fuel prices, caused hardship for small farmers. This re-ignited protectionist sentiments against freer trade. Pre-emptive measures by the government to avoid social discontent included increasing subsidies and providing 'one-off' support to the affected groups. However, this approach cannot be sustainable in the long run.

Despite the seemingly imperative national need to continue subsidising and supporting the agricultural sector, it is not only necessary but also crucial for Malaysia to continue liberalising the sector. Being a small economy that is highly dependent on trade for economic growth, it needs to leverage its more competitive industries with its trading partners. This might mean 'sacrificing' the very agricultural industries that it is supposed to protect for food and income security as well as for other strategic national reasons. On the other hand, developing international advantage is always the best way to ensure the sustained food and livelihood security of the nation. In moving forward, reforms towards market-based instruments need to be instituted for the agricultural sector to meaningfully contribute to the wealth and welfare of the nation.

References

Baker JL (2008) Impacts of financial, food and fuel crisis on the urban poor, urban development unit. The World Bank. http://www.worldbank.org/urban. Accessed Jan 2012

Economic Planning Unitva (various issues) Malaysia five-year plans. Prime minister's department, Putrajaya

Economic Planning Unit Malaysia, Prime Minister's Department (2004) A review of the Malaysian paddy and rice industry. Putrajaya

FAO (1985) Situation and prospects of international trade in fruits and vegetables in ASEAN countries, RAPA monograph 3185. Bangkok
GATT (1993) An analysis of the proposed Uruguay round agreement, with particular emphasis on aspects of interest to developing economies. Geneva
NAP (1984) Cabinet Commmittee for Agriculture Policy, Kuala Lampur, Malaysia: Government Printers
NAP3 (1998) The third national agricultural policy. Ministry of agriculture, Kuala Lumpur
Stiglitz J (2003) The roaring nineties—seeds of destruction. Penguin Books, London
TengkuAriff A, Ariffin T (1999) The effects of trade liberalization on agriculture in Malaysia: commodity aspects. CGPRT working paper No 46. CGPRT, Bogor
TengkuAriff A, Mad Nasir S (2005) Review of the paddy and rice industry in Malaysia. A study for the economic planning unit. Prime minister's department, Malaysia
TunkuShamsul B, Thong LB (1988) FELDA: Three decades of Evolution, FELDA Publication, Kuala Lumpur
WTO (2010) Malaysian trade review. http://www.wto.org/english/tratop_e/tpr_e/tp325_e.htm. Accessed on Nov 2014

Chapter 6
Agriculture, Food Security and Livelihoods of the Mexican Population Under Market-Oriented Reforms

Antonio Yunez-Naude

6.1 Introduction

In the 1980s, the Mexican governments began to apply market-oriented policies. With respect to food, agriculture and the rural sector, the reforms ranged from constitutional changes to enhance private property rights in rural communal lands to the elimination of price supports granted to farmers producing staple crops. Policy changes included agricultural trade liberalisation: in 1985, Mexico joined the General Agreement on Trade and Tariffs (GATT), and in January 1994, the implementation of the North American Free Trade Agreement (NAFTA) began. Parallel to economic reforms a huge social programme to alleviate rural poverty began to be implemented.

The objectives of this chapter are threefold: (1) to evaluate the effect of reforms and NAFTA in agricultural production and food security on the rural economy and the livelihoods of the population of Mexico with special attention to maize (the major staple food of Mexico), (2) to reflect on the future of food security and the livelihoods of Mexicans, and (3) to draw lessons from the Mexican experience for other 'emerging economies'.[1]

This chapter is divided into six sections. In the next section, a summary of the main market-oriented reforms applied to agriculture is presented, pointing out their expected effects. Section 6.3 presents the tendencies of agricultural trade and production, with special attention to what are called in Mexico basic crops (major grains and oilseeds) produced in the country. In Sect. 6.4, we study the structure of crop production and its changes, assessing the role of agriculture by farm size in food security and the livelihoods of the Mexican population. The last two sections

[1] Due to data restrictions, the livestock sector is not treated systematically in the chapter; it is considered in Yunez-Naude (2010).

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are reflexive: in Sect. 6.5, hypotheses are proposed that explain why, contrary to expectations, the production of grains—non-competitive crops under NAFTA—has not collapsed. Based on our research, this chapter ends in Sect. 6.6, presenting policy options for the Mexican State and drawing lessons that the Mexican experience can provide to other emerging economies on food security and livelihoods.

6.2 Reforms and Expected Effects

As in other countries, market-oriented policy reforms in the Mexican economy began in the early 1980s. The Mexican agricultural sector was included in the late 1980s and its reforms deepened during the first half of the 1990s to prepare the sector for NAFTA. In the mid-1980s, government support prices to farmers producing what we call basic crops (barley, beans, maize, rice, sorghum, wheat, and oilseeds) were abolished, as well as subsidies for agricultural inputs and for credit. In addition, the banking system was re-privatised, public infrastructure to support the marketing of basic crops was sold or abolished and the Constitutional Article related to land property rights was reformed (Table 6.1; see also Yunez-Naude 2003).

The land or *ejidal* reform allowed individual property rights to *ejidatarios*; those peasants benefited from the process of rural land distribution and re-distribution implemented after the Mexican Revolution of 1910 during the application of the Agrarian Reform from the 1930s to1991. Before the reform, *ejidatarios* had to use the acquired land for production purposes, but were not allowed to sell or rent it, and not even to conduct business in association with the private sector. Individual beneficiaries of land distribution could and did pass their land to their children, who became *ejidatarios* themselves. With the land reform of 1992 the above restrictions could disappear if the Ejido Assembly approves it. The official expectation was that the Ejidal Reform would promote private property rights on land and ownership security in the rural sector of Mexico and, with it, the development of the land market, an increase in agricultural plot sizes and agricultural productivity, as well as greater access to private credit and investment.

In January 1994, NAFTA began with the following expectations. Based on the abolition of price supports to Mexican agricultural producers and the fact that the USA is Mexico's major trade partner, producing and exporting agricultural goods in which Mexico is non-competitive (basic crops, especially maize, the major staple in Mexico). NAFTA was expected to provoke price convergence in agricultural products, i.e. by liberalising domestic prices of basic crops and, with NAFTA, Mexico would follow closely US prices and, hence, its imports of these crops from its northern partner would rise. Neither the increase of food dependency caused by raising imports of grains and oilseeds, nor agricultural subsidies to US farmers worried Mexico's Government officials; their expectation was that lower basic crop prices and economic growth would enhance food security in Mexico and the livelihoods of its population. With respect to agricultural products in which Mexico is competitive (fruits and vegetables), US (and Canadian) liberalisation of import restrictions

Table 6.1 Liberalisation process of Mexico's food sector. (Source: Own)

Policy	Main policy changes	Year(s)
Mexico joins GATT and food imports restrictions began to be reduced	Substitution of import licensing for tariffication of agricultural goods (tariffs ranging from 0 to 20%)	1986–1994
Sale of food state enterprises	Privatization of state food storage facilities and state enterprises selling seeds and fertilisers at subsidised prices	1988/1989
	Abolition of state enterprises selling coffee, sugar and tobacco	
'Ejidal' reform (land property rights reform)	Ending of agricultural land distribution to peasants	1992
	Liberalisation of agricultural land property rights	
Elimination of price supports to farmers producing food staples (in 1999 the state trading enterprise providing this subsidy was abolished)	Domestic prices of staples determined taking into account international prices	1989 to date
	Creation of Support Services for Agricultural Marketing (ASERCA) in 1991, a marketing support agency granting subsidies to commercial staple crops' producers and buyers	
	Creation of PROCAMPO in 1994, a direct income transfer program to all producers of staples	
North American free trade agreement (NAFTA)	Prohibits the use of import licenses and applies tariffication principles	Jan. 1994–2008
	'Free' trade in 15 years. Sensitive agricultural products were subject to tariff rate quotas for a transitional period of up to 15 years	
	Interventions are allowed in the three countries for agricultural subsidies, import restrictions on phytosanitary grounds and rules of origin and for packing	
Alliance for the countryside	Group of programs to promote agricultural and rural productivity, including small farmers	1995–2007

under NAFTA would increase Mexico's export of these goods. Added to the Ejidal Reform, trade liberalisation would hence improve resource allocation, efficiency and agricultural productivity in Mexico.

These changes would imply the transformation of Mexican agriculture, leading in the short to medium run to an increase in rural migration to the USA. However, in the longer run, this tendency would tend to disappear with the expected rapid growth of the Mexican economy.

Parallel to economic liberalisation, domestic 'transitional' policies were implemented with the creation of Support Services for Agricultural Marketing (ASERCA is its Spanish acronym), a government institution that has being providing subsidies to commercial producers and buyers of basic crops, and, through *Procampo*'s direct income transfers to all farmers producing these crops before NAFTA began to be implemented. ‘Alliance for the Countryside’ was the third major programme the Mexican government implemented from 1995 to 2007. It consisted of government supports to enhance rural productivity (Table 6.1).

Specific public policies and institutions aimed at reducing rural poverty—and, implicitly, food access to the poor—were created in parallel with the above reforms. In the early 1990s, the Ministry for Social Development was created and in 1997 a programme for Rural Education, Health and Nutrition (now called *Oportunidades*) began to be implemented. *Oportunidades* is a conditional cash-transfer programme aimed at reducing poverty in the short run while promoting human capital formation in the medium to long run.

Politically, the process of agricultural reform and liberalisation went smoothly until the beginning of the present century, when the political party that had ruled Mexico for 70 years lost power and when massive protests against the agricultural components of NAFTA emerged. The basic concern in these protests was the increasing imports of maize from the USA and the argument that with them Mexico was losing food security and sovereignty. The way to solve the conflict was by the creation of the Law for the Sustainable Development of the Rural Sector (LDRS, Spanish acronym; see Dyer and Dyer 2003) in 2002. Amongst other purposes, this Law includes the promotion of food security in Mexico, translated in practice by increasing public expenditure in the rural sector. However, it was not until 2005/2006 that food security purposes began to be implemented in a more concrete manner by the strategy called Special Programme for Food Security (PESA).

6.3 Tendencies: Agricultural Prices, Trade and Production, Food Dependency, Migration, Land Property Rights, Poverty and the Economy of Rural Households

Contrary to expectations, agricultural growth in Mexico has been poor and per capita agricultural GDP rates of growth have been negative before and after the reforms (the exception is the period of 2005–2008; Table 6.2). However, and as we will discuss, these trends do not necessarily mean that food security in major staples has sharply decreased.

As expected, since the deepening of reforms to agriculture, farm-gate prices of major grains declined until around 2006; the exception was the period of the macroeconomic crisis of Mexico in 1995/1996 (Fig. 6.1). Since the tendency is similar to that for international prices of these crops, the trend in Mexico suggests the presence of the ‘law of one price’ during reforms. We tested this hypothesis empirically and the results show that, indeed, domestic Mexican producers’ prices of basic crops increased their convergence with US prices (see World Bank 2005; Yunez-Naude and Barceinas 2003; Yunez-Naude and Serrano 2009).

Table 6.2 Total and agricultural GDP, and per capita agricultural and processed foods (GDP/2002 pesos). (Sources: Own estimations. GDP based on Bank of Economic Information Website (Banco de Información Económica or BIE) and Population based on INEGI's data)

	Production				Per capita	
	GDP (%)	Field crops and pastures (%)	Livestock (%)	Processed foods and beverages (%)	Agriculture (%)	Processed foods and beverages (%)
1980–1988	−0.41	0.92	−2.77	1.97	−1.93	0.11
1989–1993	4.06	2.28	−1.40	5.41	−0.92	3.13
1994–1998	1.60	−2.48	0.53	1.59	−3.21	0.00
1999–2004	4.60	−0.66	2.86	4.02	−0.80	2.79
2005–2008	4.38	8.11	0.78	3.21	3.87	2.03

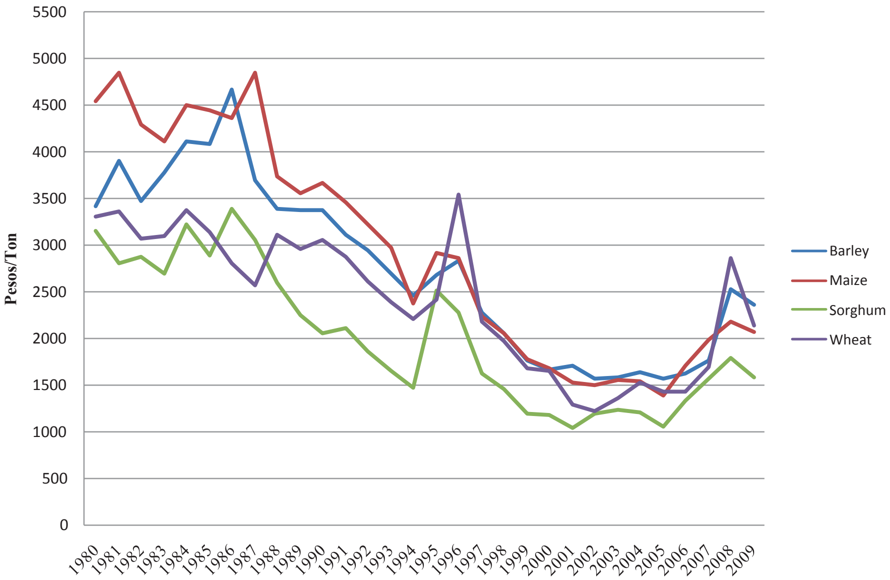

Fig. 6.1 Mexico. Producer price of selected grains (base 2002 = 100). (Source: SAGARPA-SIACON website, deflacted using Bank of Mexico consumer price index)

Before and after NAFTA, the weight of the USA in Mexico's total and agricultural trade has been greater than 80 %. During NAFTA, both food exports to and imports from the USA increased (Fig. 6.2).[2] Of particular interest in this chapter are imports of field crops and of maize in particular, because maize has been the major crop and staple food of Mexico produced by commercial and family farmers.

[2] For example, in 1990, Mexico was the sixth largest importer of US agricultural products, while in 2008 Mexico reached the second place, just behind Canada. A detailed presentation of the effects of NAFTA in the agriculture of Mexico is in Yunez-Naude (2011).

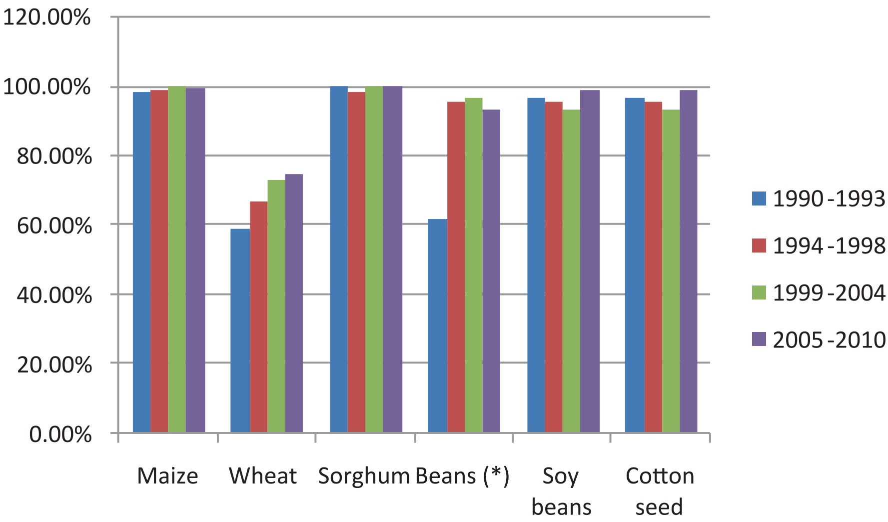

Fig. 6.2 Weight of USA in Mexico's value of imports (constant dollars). (*) Includes kidney beans and white pea beans. (Source: http://www.comtrade.un.org and http://www.imf.org/)

As expected, during the NAFTA era, production of Mexico's competitive crops (fruits and vegetables) has grown, whereas production of basic/non-competitive crops declined (oilseeds, rice and wheat) or grew (barley, beans, maize and sorghum; Table 6.3). Growth of domestic production of these four non-competitive crops was unexpected, especially the sharp increase in maize production; the reasons for this unexpected trend are discussed in Sect. 6.5 below.

Food dependency caused by increasing imports of basic grains from the USA has been a concern as well as an argument for state intervention by critics of liberalisation. We venture an answer to this question by calculating the ratios of non-competitive field crop imports to domestic production. Table 6.4 shows that 'food dependency' has clearly increased for major oilseeds (particularly soy beans), and this is not the case for all grains. The ratio of imports to domestic production remained practically unchanged for maize and sorghum, and it declined for beans and increased a little for barley.

Rural labour out-migration has increased continuously, both to urban Mexico and to the USA. During NAFTA, the rate of rural international migration has been higher with respect to domestic migration (Fig. 6.3).

In relation to the Land/Ejidal Reform, official information shows that expected effects have not been quite realised. After 17 years of its implementation land fragmentation increased, i.e. *minifundia* has grown and private property rights of former *ejidal* lands for agricultural production have not grown (Panel 1 of Table 6.5).

Measured in terms of access to a basket of basic foods, poverty indices of Mexicans increased in the first half of the 1990s, and increased sharply during the mid-nineties when Mexico suffered a severe macroeconomic crisis. Food poverty decreased from

Table 6.3 Domestic production of major crops: 1980–2008 (thousands of metric tons). (Sources: Mexico Ministry of Agriculture's website: 1980–2005 SIACON; 2006 onwards SIAP)

		1980–1988	1989–1993	1994–1998	1999–2004	2005–2009
Grains and beans	Rice	553.2	390.0	412.5	280.6	282.1
	Beans	1038.4	1053.1	1242.0	1189.5	1071.8
	Maize	12,296.8	14,978.9	18,145.1	19,513.8	21,859.6
	Wheat	4044.7	3913.9	3577.2	3010.5	3647.7
	Barley	524.2	519.5	452.2	779.7	716.6
	Sorghum	5449.3	4644.5	5373.4	6183.1	5989.4
Oilseeds	Sesame seed	68.4	37.7	26.1	33.2	26.6
	Cotton seed	749.1	345.4	613.6	274.9	374.3
	Saflower	257.5	98.9	138.7	159.2	90.8
	Soy beans	638.1	676.8	220.7	117.1	126.1
Fruits[a]		8.4	9.7	11.7	14.1	15.5
Vegetables[b]		3.4	4.6	5.2	6.7	7.2

[a] Fruits include avocado, peach, strawberry, guava, citrus, mango, apples, melon, papaya, pineapple, banana and water melon
[b] Vegetables include tomato, carrot, garlic, broccoli, pumpkin, onion, chayote, peas, chili, coriander, brussel sprouts, cauliflower, asparagus, cucumber and peppers

Table 6.4 Weight of imported volume on total domestic production: 1985–2006. (Source: Ministry of Agriculture http://www.siap.sagarpa.gob.mx/AnxInfo/)

	1985	1990	1995	2000	2001–2006
Grains[a]	027	0.30	0.22	0.48	0.48
Oilseeds	1.05	0.57	3.36	11.21	11.23
Rice	0.37	0.58	1.03	1.85	2.68
Beans	0.20	0.26	0.02	0.07	0.08
Maize	0.22	0.28	0.14	0.30	0.29
Wheat	0.11	0.09	0.31	0.69	1.01
Barley	0.07	0.23	0.14	0.22	0.25
Sorghum	0.52	0.48	0.50	0.88	0.60
Sesame seed	0.00	0.22	0.11	0.26	0.50
Cotton seed	0.00	0.00	0.00	0.00	0.00
Saflower	0.20	0.15	0.23	2.09	1.69
Soy beans	1.61	0.88	11.12	38.27	32.54

[a] Includes beans

1997 to 2006 and is rising again, mainly due to the rise in international food prices. In addition, the gap between rural and urban poverty has not decreased (Fig. 6.4).[3]

[3] Income inequality prevails and remains high in Mexico: the Gini coefficient was 0.53 in 1992 and 0.51 in 2005; see the website of the National Council for the Evaluation of Social Policy

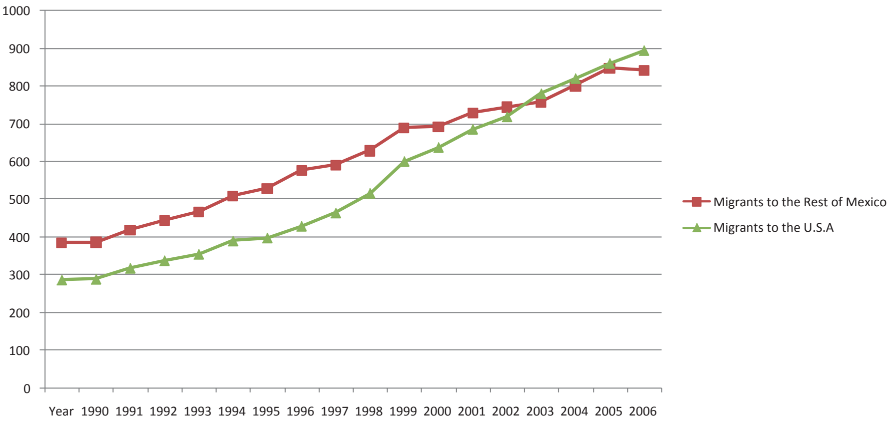

Fig. 6.3 Number of rural migrants: 1990–2007 (No expansion factors were applied to the survey results). (Sources: National Survey of Rural Households (ENHRUM, Sapnish acronym). PREC-ESAM website)

Table 6.5 Structure of property rights, size and weights of rural agricultural units of production (AUP): 1991 and 2007. (Source: Agricultural Censuses: 1990 and 2007, provided by the National Institute of Statistics, Geography and Informatics (INEGI, Spanish acronym)

(1) Land property rights	*Millions of hectares (ha)*		*Distribution in total land (%)*			
	1991	2007	1991	2007		
Ejidal	30.03	37.01	28.28	33.35		
Communal	4.34	3.78	4.09	3.41		
Private	70.49	69.67	66.39	62.79		
Public	1.32	0.49	1.24	0.44		
(2) Size of AUP	*Average size (ha)*		*Distribution in total AUP (%)*		*Distribution in total ha (%)*	
	1991	2007	1991	2007	1991	2007
Up to 2 ha	1.12	1.09	34.56	44.47	4.71	6.10
From 2 to 5 ha	3.41	3.46	25.35	24.21	10.55	10.51
From 5 to 20 ha	8.78	9.23	31.25	23.16	33.52	26.84
From 20 to 50 ha	20.51	25.26	5.27	5.10	13.22	16.16
From 50 to 100 ha	42.64	51.68	1.77	1.74	9.24	11.32
From 100 to 1000 ha	104.11	130.58	1.67	1.25	21.22	20.45
From 1000 to 2500 ha	351.45	517.82	0.09	0.05	3.70	3.06
More than 2500 ha	710.86	1724.79	0.04	0.03	3.84	5.55

(CONEVAL, Spanish acronym). The results of our research on changes in poverty and inequality from 1990 to 2005 are consistent with the above (see Yunez et al. 2010).

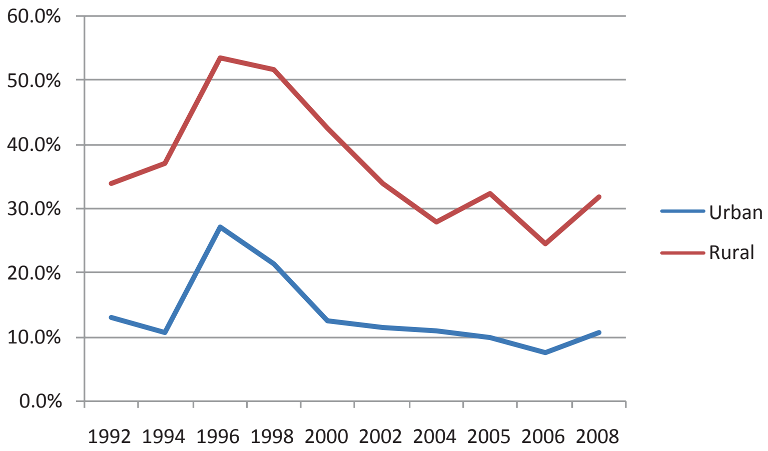

Fig. 6.4 Changes in food poverty (weights in total rural and urban populations). (Source: Coneval website. http://www.coneval.gob.mx)

That some of the expected effects of the reforms have not happened does not mean that Mexico's agricultural sector and rural economy are not changing; in fact, both are undergoing transformations. Today Mexico produces more agricultural GDP with a similar quantity of workers than in the early 1990s. For example, from 1993 to 2008, the annual average rate of growth of 'primary production' (agriculture, plus fisheries and hunting) measured in 2002 pesos was 1.2 %, whereas the number of persons employed in the sector declined by 0.9 % during the same period.[4] The agricultural supply chain is being transformed by an increasing concentration of food trade in the hands of a few large retailers, intermediaries and basic foods processors. Meanwhile, the economy of Mexican rural households is changing. For example, the share of independent farming income in total rural households' income decreased from more than 31 % in 1992 to 10 % in 2004, whereas that of waged non-farm labour increased from 20 % to almost 35 % during the same period (Table 6.6).

Table 6.6 Changes in the composition of income sources of rural households: 1992–2004. (Source: CONEVAL website)

	Non-farm waged labour	Independent farming	Private transfers	Public transfers
1992	20.0	31.2	11.0	1.3
1994	23.9	24.0	12.3	2.5
1996	24.9	24.3	9.9	4.0
1998	26.0	20.8	12.5	4.1
2000	27.3	17.5	14.3	5.0
2002	26.7	15.9	15.1	7.5
2004	34.2	10.0	9.9	9.1

[4] Based on own estimations using data on GDP from the same source as Table 6.3, and data on employment from FAO's website and from the Statistical Annex of the President of Mexico's 2011 Address to the Congress.

6.4 Structure of Crop Production and Changes: 1991–2007

The livelihoods of Mexico's rural poorest population highly depend on agricultural staple production, which was and is still done by highly heterogeneous farmers in Mexico. At one extreme are a considerable number of subsistence rural households producing maize, beans and rearing small animals for their families' own consumption on small plots of land, while at the other extreme, there are market-oriented large farmers; in the middle, there are farmers producing agricultural goods for both their families' own consumption and for the market. This heterogeneity must be considered in any study of food security and on the livelihoods of the Mexican population. This approach is also fundamental to reflect on the future of agriculture of Mexico and to propose lessons that the Mexican experience can provide to other emerging and less-developed countries.

6.4.1 Structure and Evolution of Mexican Agricultural Production

Data from the Mexican Agricultural Censuses of 1991 and 2007 (AGC in what follows) provide information to describe the structure and evolution of agriculture by farm size ('units of agricultural production' or AUP in AGC terms).[5]

From 1991 to 2007, the average size of Mexico's AUP declined from 8.18 to 7.96 hectares (ha in what follows) and average farm size slightly decreased for plots of less than 2 ha, remained practically unchanged for plots between 2 and 5 ha, and increased for the remaining plots (Panel 2 of Table 6.5). This table also indicates the prevailing high heterogeneity in Mexico's agrarian structure. For example, the number of small AUP (up to 5 ha of land) accounted for almost 60 % of total AUP in 1991 and for 68 % in 2007, but had just around 16 % of total area in both years. By contrast, big AUPs (more than 50 ha) constitute just over 3 % of total AUP, but cover around 40 % of total ha.

The AGC provides additional information about the persistence of agricultural heterogeneity in Mexico. Indeed, as AUP size decreases, more family, non-waged labour is used for agricultural production and more crops are used for family consumption. For example, production of crops for own consumption in 2007 was as high as 61 % in farms with up to 2 ha, and this weight sharply decreases as farm size increases (details in Taylor et al. 2011). With respect to property rights in agricultural lands, the average size of *ejidal* plots decreased by 1 ha, from 8.5 to 7.5 (Robles 2010).

Thus, contrary to expectations about the effects of economic liberalisation and the Land/ *Ejidal* Reform, fragmentation has increased. In addition to the prevalence of *minifundia*, formal credit access has decreased. As the AGC data shows, the number of farms with access to credit declined by almost 77 % from 1991 to 2007.

[5] The AGC for 2007 does not cover all major crops, such as rice, soy beans and other oilseeds.

6.4.2 Crop Production by Farm Size

Based on the heterogeneity of agricultural production, it is relevant to study the evolution of food production by farm size in order to examine the role played by agriculture during NAFTA and the reforms on food security and the livelihoods of Mexicans. For this, we use again the AGC data of 1991 and 2007, focusing on the most important crops cultivated in the country in terms of area planted by AUP. We stress here and in Sect. 4.3 below on production by small and medium-sized farming because we consider that production on these farms of some of the selected crops has been fundamental in the livelihoods of Mexicans, especially for the country's rural households that are the poorest segments of Mexico's population. In addition, production under small and medium-sized farms could be important in the future for improving the role of agriculture in Mexico's economic development.

Notwithstanding the prevailing high heterogeneity in the structure of land distribution by AUP per size (Table 6.5, Panel 2) and differentiation on inputs used (Taylor et al. 2011), volume of production of major basic crops has increased in all farm sizes (the exceptions are beans and wheat, whose production declined in all AUP but in the biggest AUP; Panel 1 of Table 6.7). In addition, yields between farms of different sizes have not been highly different in major basic grains and beans production, and neither has their growth from 1991 to 2007 (Panel 2 of Table 6.7).[6]

Consistent with the figures presented in Table 6.3, the AGC data shows that the volume of maize production sharply increased during the past years; it increased by 2.9 times between 1991 and 2007. This sharp growth was experienced by all farm sizes, but much more in the largest ones (Panel 1 of Table 6.7). In addition to increasing yields (Panel 2 of Table 6.7), the growth of maize production in AUP with more than 20 ha has been based on the extension of harvested area with the grain. This is reflected by the sharp rise from 1991 to 2007 in the participation of these AUP in both maize production and in harvested area: from 35 to 50 % (Panel 3.1 of Table 6.7) and from 37 to 39 % (Panel 3.2 of Table 6.7), respectively. Notwithstanding that maize production and yields also increased in the remaining AUP, their participation in total production and total harvested area decreased from 1991 to 2007 (hypotheses about the reasons for the evolution of maize production are discussed in Sect. 6.5 below).

Total production of beans in small and medium-sized AUP decreased slightly during 1991–2007. However, the weight of AUPs with less than 5 ha of land on total AUP participation and harvested area has remained, indicating that, as for maize, small farmers still grow beans for their own consumption (Table 6.7).

Cultivation of grains other than maize is for the market. The AGC data show that physical production of sorghum increased sharply from 1991 to 2007 in all farm sizes. However, most of this cash crop is grown by medium-sized and big farmers. During the same period, the volume of production of barley almost doubled, and this increase is explained by the rise of its production amongst all farm sizes.

[6] The exception is yields in maize as in 2007 they were much higher in the bigger farms. However, from 1991 to 2007 yields have grown sharply in all farm sizes.

Table 6.7 Structure of production by farm size of major basic crops. (Source: Agricultural Censuses: 1990 and 2007)

AUP	Barley		Beans		Maize		Sorghum		Wheat	
	1991	2007	1991	2007	1991	2007	1991	2007	1991	2007
Volume of production (thousands of metric tons)										
Up to 2 ha	8.2	20.8	62.9	53.7	1071.4	2396.2	33.3	167.9	30.8	44.6
From 2 to 5 ha	40.6	88.7	158.8	115.8	1705.8	3853.0	295.5	766.8	271.3	193.1
From 5 to 20 ha	116.6	237.6	573.4	383.2	3887.2	8796.9	1356.8	2930.1	1258.9	683.5
From 20 ha	229.0	378.2	484.5	580.3	3563.8	15,102.6	2005.0	9085.4	1914.7	2693.0
Total	*394.3*	*725.3*	*1279.6*	*1133.0*	*10,228.3*	*30,148.8*	*3690.6*	*12,950.2*	*3475.7*	*3614.3*
Yields (volume of production per cropped area)										
Up to 2 ha	1.05	2.37	0.31	0.45	1.04	2.09	3.32	6.91	2.24	4.53
From 2 to 5 ha	1.08	2.59	0.34	0.48	0.96	2.39	3.21	5.73	3.27	5.44
From 5 to 20 ha	1.24	2.72	0.44	0.56	1.11	3.21	2.36	5.84	3.47	5.63
From 20 ha	1.41	2.80	0.56	0.65	1.56	4.52	2.02	6.50	3.58	5.62
Distribution of AUP by size in total production and harvested area										
Production										
Up to 2 ha	2.08 %	2.86 %	4.92 %	4.74 %	10.48 %	7.95 %	0.90 %	1.30 %	0.89 %	1.23 %
From 2 to 5 ha	10.30 %	12.23 %	12.41 %	10.22 %	16.68 %	12.78 %	8.01 %	5.92 %	7.81 %	5.34 %
From 5 to 20 ha	29.56 %	32.76 %	44.81 %	33.82 %	38.00 %	29.18 %	36.76 %	22.63 %	36.22 %	18.91 %
From 20 ha	58.07 %	52.15 %	37.86 %	51.22 %	34.84 %	50.09 %	54.33 %	70.16 %	55.09 %	74.51 %
Harvested area										
Up to 2 ha	2.50 %	3.15 %	7.00 %	5.74 %	12.29 %	12.54 %	0.57 %	1.19 %	1.37 %	1.43 %
From 2 to 5 ha	12.46 %	12.77 %	15.71 %	11.94 %	20.59 %	17.73 %	5.41 %	5.47 %	8.36 %	5.37 %
From 5 to 20 ha	31.81 %	32.83 %	46.07 %	35.68 %	40.67 %	31.23 %	34.38 %	24.72 %	36.64 %	18.65 %
From 20 ha	53.22 %	51.25 %	31.23 %	46.64 %	26.45 %	38.50 %	59.63 %	68.62 %	53.63 %	74.55 %

Finally, the AGC data indicates that production of wheat slightly increased from 1991 to 2007, and that almost all of its production comes from medium and bigger farmers. However, the weight on total volume of wheat production of medium-sized farms (5–20 ha) declined during the period, whereas the contribution of bigger farms increased (Table 6.7).

Sugarcane and oranges are two of the major perennials produced for the market in Mexico in all farm sizes in the lowlands and tropical regions of Mexico. The study of the evolution of these two types of plantations from 1991 to 2007 is helpful to illustrate the structure, productivity, and tendencies in the production of cash agricultural products relevant for small and medium farmers and for the livelihoods of Mexico's population.[7]

The AGC data show that the volume of sugarcane productionincreased by more than 32 % from 1991 to 2007. Most of the sugarcane is produced in medium-size farms: for both years, more than 92 % of AUPs cultivating this crop had less than 20 ha of land, producing between 75 % in 1991 and 71 % in 2007 of the total sugarcane produced in Mexico (Taylor et al. 2011).

From 1991 to 2007, the volume of production of oranges increased almost 2.4 times. As in the case of sugarcane, most oranges are produced in small and medium-size farms: for both 1991 and 2007, more than 86 % of AUPs cultivating this crop had less than 20 ha of the land, producing 67 % in 1991 and 62 % in 2007 of the total volume of oranges produced in Mexico. Yields in orange production have sharply increased similarly in all farm sizes (Taylor et al. 2011).

The tendencies described above on production and yields allow us to propose that notwithstanding the economic reforms and trade liberalisation, not only production of basic corps has prevailed in Mexico but also the production by small farms of maize, barley and other cash agricultural goods—such as sugarcane and oranges—has remained and supported crop production and the livelihoodsof Mexico's population. If we add that medium-sized farmers have also played a role in this respect, we can argue that small and medium-size farming have survived NAFTA and reforms, and practically without government supports as discussed in Sect. 6.5 below.

6.4.3 Productivity and Efficiency in Agricultural Production of Rural Households

As discussed in the previous section, yields in the production of major basic grains and cash crops have grown during the period of reforms in all farm sizes, and therefore, agriculture has helped to support the livelihoods of Mexicans and food availability in the country. Based on panel data for 2002 and 2007 from the National Rural Households Survey for Mexico (ENHRUM, Spanish acronym), the results of

[7] Coffee is another major cash crop of small and medium-sized farmers. Coffee has been excluded here because data provided by the AGC are insufficient to study its evolution during the period under consideration.

on-going econometric research on productivity and efficiency in agricultural production of Mexican rural households by farm size allow us to extend the study on the role and changes of agriculture in food production and livelihoods in Mexico to the case of rural farmers (agricultural households located in communities of less than 2500 inhabitants; see DAS website).

Our results support the hypothesis proposed in the literature that there is an inverse relationship between farm size and productivity (the ENHURM sample splits evenly at a farm size of 3.0 ha, with the average size of small farms being 1.3 ha and that of bigger farms 8.1 ha). According to our results, other things being equal, a 1 % increase in farm size is associated with a 0.49 % reduction in output value per hectare and a 0.58 % reduction in labour-days per hectare.

In addition, we are studying empirically if the inverse relationship between farm size and productivity implies that small farms are more efficient than large farms. By defining the production efficiency frontier in terms of per-hectare output, we directly link productivityand efficiency and test for the existence of an inverse relationship between farm size and efficiency and for changes in this relationship over time using a pooled fixed effects stochastic frontier regression. The results of the stochastic frontier analysis when we allow for differences in technology between large and small farms (i.e. when the farm-size dummy variable is interacted with all inputs in the model: land, labour and purchased inputs) show that the marginal returns to labour are significantly lower on large farms. This is the only statistically significant difference in the efficiency frontiers between small and large farms (details in Taylor et al. 2011).

In summary, our results indicate that there is an evidence of an inverse relationship with respect to both productivity and efficiency on Mexican farms of rural households. Small farms enjoy a productivity advantage with respect to labour and large farms are significantly more inefficient than small farms. We find no evidence that the efficiency frontier is changing over time.

Overall, our findings suggest that despite the increasing importance of off-farm income of rural households members (Table 6.6) and far-reaching transformations of the agricultural policy and the supply chain, small farmers in rural Mexico continue to enjoy both a productivity and efficiency advantage with respect to larger farmers in rural Mexico, and so remain a relevant component in food production and in the livelihoods of the population of Mexico.

6.5 Towards an Interpretation of the Changes in the Rural Economy of Mexico with Special Reference to Maize Production

It is evident that during the period of economic liberalisation the rural sector of Mexico has experienced considerable transformations in some respects and no significant changes in others. With respect to the latter, after more than 20 years of reforms and more than 15 years of NAFTA implementation, production of non-competitive crops remains (this is especially so in the case of maize).

So, notwithstanding the high increase in maize imports from the USA during the reforms and up to 2006 the reduction of producer maize prices during NAFTA, production in Mexico of this grain has increased. To study the reasons explaining these events is relevant because, being the major staple in Mexico produced by all farmers, maize is closely related to questions of food security and livelihood in emerging economies.

We propose that in order to enquire about the factors explaining the evolution of the maize sector of Mexico one has to consider heterogeneity in its production and use, as well as the characteristics of public agricultural and rural policies that have accompanied the market-oriented reforms.

Maize in Mexico has been produced by all farmers, independent of their farm size and market orientation. These farms, including rural households, produce maize for their own consumption while engage in other family activities to diversify their income sources: production of cash crops, livestock, migration and remittances, local non-farm as well as farm wage work, etc. Whereas commercial producers of maize respond directly to price changes, family farmers may not, i.e. subsistence maize producers are price inelastic, either because of the presence of high transaction costs, or because they react in apparently unexpected ways to changes in maize output market prices. For the first hypothesis, see de Janvry et al. (1995). With respect to the second hypothesis, using a microeconomic computable general equilibrium model (MCGE), Dyer et al. (2006) found for a typical Mexican village that a maize market price shock is indirectly transmitted to subsistence producers through interactions in factor markets. They concluded that a drop in the market price of maize reduces local wages and land rents, stimulating maize production by subsistence households. (They also found that the real income of subsistence households falls.)

For the case of commercial medium and large maize farmers, we propose the following three hypotheses to explain its increasing production during NAFTA and the reforms: some of these farmers have reacted to price reductions by increasing productivity per yields (e.g. medium-sized farmers); others have changed their land use for other purposes; and the remaining have been isolated from US competition through government supports. No time series are available to test these three hypotheses. However, the AGC data presented in Table 6.7 do not contradict them.

With respect to government supports, income subsidies for marketing from ASERCA (target income, or *Ingreso Objetivo*) have been channelled to commercial maize farmers, mostly in the northwest of Mexico and those with access to irrigation. Excluding *Procampo*, around 70 % of ASERCA's budget has been used to support the income of farmers with surplus basic crops (between 430 and 600 million USD per year). 50 % of this subsidy goes to this type of maize producer, of which 70 % is for farmers in a single north-western state, Sinaloa. There is empirical evidence showing that the target income programme has promoted maize production by its beneficiaries. Hence, the programme is coupled and has isolated some maize surplus producers from US competition. The same applies to farmers in the north of Mexico receiving target income to market their sorghum and wheat production (see Sumner and Balgatas 2007).

In addition to target income*, Procampo's* direct income and decoupled transfers to producers of basic crops may also help explain why Mexico's domestic supply of maize (and other basic crops) has not collapsed. Winters and Davis (2009) reviewed the empirical literature supporting the hypothesis. In their review, these authors included the effects of the conditional income transfers of *Oportunidades* on agricultural production of its beneficiaries. The empirical results indicate that both programmes have positively influenced the agricultural production of rural households. This, in addition to rural small farms' productivity and efficiency, has helped to maintain the role of small rural farming in contributing to food production and in the livelihoods of Mexico's rural population. Finally, by increasing the income of rural households, *Oportunidades* has provided access to food for the poorest population of Mexico.

6.6 Final Remarks

The increase or maintenance in some major grains' production in Mexico during the period of agricultural reforms and trade liberalisation may be taken as a success story by those who worry about endogenous food security in emerging as well as less-developed countries. However, these tendencies have been mainly based on the endurance of maize production of small and subsistence farmers and the target income transfers to big commercial farmers in the north of Mexico, as well as by subsidising transnational grain marketing enterprises and domestic processors with monopoly power to get them to buy domestically produced grains instead of importing them.

By isolating some large commercial Mexican farmers from competition, this type of policy conflicts with the efficiency goals of trade liberalisation, and hence is inefficient and expensive. At the other extreme, small-scale agricultural households have not benefited from government supports, with the exception of *Procampo's* transfers. For maize, small farmers producing this crop for the markets were negatively affected by declining maize prices following the reforms. Meanwhile, production in subsistence households remained or even increased.

Agricultural programmes in contemporary Mexico are not only expensive and inefficient, but they have been regressive, high, and have increased during the present century. For example, the United Nations' Food and Agricultural Organization (FAO) estimates that for Mexico, the relationship between agricultural subsidies/ total subsidies and Gross Domestic Agricultural Product/ total GDP is much higher with respect to the other 19 Latin American countries considered in the estimation; for example, in 2001 the ratio for Mexico was 1.4, whereas for Brazil it was less than 0.8, for Chile 0.5, for Peru 0.4, and for Colombia less than 0.05 (Scott 2010).

The regressive character of Mexico's agricultural policies has additional consequences: to reduce the effects of rural poverty alleviation policies and to create interest groups amongst big farmers with political power to press the government for the continuation of the subsidies channelled to them.

Table 6.8 Policy changes from 2001. (Source: Own)

Policy change	Main characteristics	Years of implementation
Law for sustainable rural development (LDRS)	Adds to agricultural government supports all rural activities and use of natural resources in a decentralised manner	From 2002
Special concurrent program (PEC, acronym in Spanish)	Instrumentation in public budget terms of the LDRS with the participation of all ministries involved in supports to the rural sector	From 2003
Special program for food security (PESA, acronym in Spanish)	Supports low income farmers to increase food production (follows FAO-type programs established in 1994 for countries with food deficits)	From 2005
Food Supports/'Vivir Mejor'	Special Program to protect the poor from food price surge	From 2008
The programmes in of the ministry of agriculture are rearranged	SAGARPA's more than 50 Programmes are regrouped into eight. PROCAMPO remains as a single programme, marketing supports become part of the 'Programme to Attend Structural Problems' and alliance for the countryside disappears as such and its components became part of two of the eight new programmes	2008–2010
The programmes in of the ministry of agriculture are rearranged	SAGARPA's eight programmes are regrouped again into five. PROCAMPO remains as a single programme, marketing supports become part of the 'Programme to Prevent and Manage Risks'[a]	From 2011

[a] The target population/attended farmers and the instruments of PROCAMPO and marketing supports suffer no major changes

The experience of Mexico shows that one condition for the expected effects of market-oriented policies to realise is the existence and/or functioning of markets, and this has not been the case for some relevant markets for the rural sector and rural households' economy. In addition, instead of using public resources for the provision of public goods to enhance technical change and markets (e.g. in research and development and investing in infrastructure), most government expenditure to the rural sector has been for the provision of private goods (e.g. income transfers for rural households and big farmers). To the above, one has to add that the transfer of public enterprises to the private sector without the application of laws for competition could have promoted monopoly power in some areas of the Mexican food chain, reducing the positive effects of liberalisation on final consumers (Economic Commission for Latin America 2006).

Public concerns in emerging countries about poverty reduction, equity, livelihoods and securing a food supply based partially on domestic production have to focus on their rural households. For this, Mexico has its LDRS (Table 6.8).

Unfortunately, this Law has not meant a change in the structure of public expenditure to the rural sector. However, there is a recent successful concrete experience based on the application of the special federal programme of food security (PESA) mentioned earlier. The experience is for rural areas of Guerrero, one of the poorest states of Mexico. The programme adds to the beneficiaries of *Oportunidades* supports for productive purposes and access to financial services. A recent rigorous evaluation of the effects of the programme shows that the programme has reduced poverty and increased the nutrition levels and food production of its beneficiaries (Yunez-Naude et al. 2009).

We are convinced that increasing food prices in the contemporary global economy offers an opportunity in Mexico to reform the agricultural reforms, by eliminating distorting subsidies to powerful basic crops farmers, by putting into practice competition laws, by adding to poverty-alleviating measures in rural productive programmes, and by putting into practice the LDRS (details in Taylor et al. 2007).

Based on the experience of Mexico, we propose that some of the challenges faced by governments in emerging countries to attend to poverty, inequality, and food security are the following: to know which rural households have the productive potential to make the transition to an increasingly globalised economy while designing effective policies to solve the problems of small-scale production and commercialisation (assisting the creation of co-operatives and/or associations, contract farming, etc.); to enhance rural financial and land markets; and to invest in public goods.

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References

De Janvry A, Sadoulet E, Gordillo G (1995) NAFTA and Mexico's maize producers. World Dev 23(8):1349–1362

Dyer G, Dyer D (2003) Policy, politics and projections in Mexican agriculture, ninth agricultural and food policy information Workshop. Farm Foundation, Oak Brook. http://www.farmfoundation.org/farmpolicy/dyer.pdf

Dyer G, Taylor JE, Boucher S (2006) Subsistence response to market shocks. Am J Agr Econ 88(2):279–291

Economic Commission for Latin America (ECLA) (2006) México: crecimiento agropecuario, TLCAN, capital humano y gestión del riesgo. Mimeo, New York

Robles H (2010) Una visión de largo plazo: comparativo resultados del VII y VIII censo agrícola ganadero 1991–2007. In: Fox J, Haight L (eds) Subsidios para la desigualdad: las políticas públicas del maíz en México a partir del libre comercio. Woodrow Wilson International Center for Scholars, Washington, pp 185–193

Sadoulet E, de Janvry A, Davis B (2001) Cash transfer programs with income multipliers: PROCAMPO in México. World Dev 29(6):1043–1056

Scott J (2010) Subsidios agrícolas en México ¿quién gana y cuanto? In: Fox J, Haight L (eds), Subsidios para la desigualdad: las políticas públicas del maíz en México a partir del libre comercio. Woodrow Wilson International Center for Scholars, Washington, pp 73–127

Sumner DA, Balagtas JV (2007) Economic analysis of the ingreso objetivo program in Mexico. Final Report for the project ‘Políticas y Gasto Público Federal en el Sector Rural en México’, Inter-American Development Bank, 13 August, pp 1–55
Taylor JE, Yúnez-Naude A, González A (2007) Estudios sobre políticas públicas para el sector rural en México’, Summary of Results, Final Report of the Project ‘Políticas y Gasto Público Federal en el Sector Rural en México’, Inter-American Development Bank, September
Taylor JE, Kagin J, Castelhano M, Yunez-Naude A (2011) Drivers of structural change and smallholder efficiency in Mexican agriculture’, food and agricultural organization. Mimeo, Rome
Winters P, Davis B (2009) Designing a programme to support small holder agriculture in Mexico: lessons from PROCAMPO and Oportunidades. Dev Policy Rev 27(5):617–642
World Bank (2005) Mexico: a study of rural poverty. The World Bank, Washington
Yunez-Naude A (2003) The dismantling of CONASUPO, a Mexican state trader in agriculture. World Econ 26(1K):97–122
Yunez-Naude A (2010) Las políticas públicas al sector rural: el carácter de las reformas para el cambio estructural. http://publicaciones.colmex.mx/
Yunez-Naude A (2011) The effects of agricultural domestic and trade liberalization on food security: lessons from Mexico, food and agricultural organization. Mimeo, Beijing
Yunez A, Barceinas F (2003) El TLCAN y la agricultura Mexicana. In: Sobarzo H, Cásares E (eds) Diez Años del TLCAN en México. Una Perspectiva Analítica (Lecturas vol 95). El Trimestre Económico, Mexico
Yunez-Naude A, Serrano V (2009) Liberalization of staple crops: lessons from the Mexican experience in Maize. Paper presented at the XXVII International Conference of Agricultural Economics, Beijing, August
Yunez-Naude AJ, Mora Rivera F, Rivera J, Jaramillo L, Fierros I (2009) Evaluación externa del programa especial para la seguridad alimentaria (PESA)-Guerrero Sin Hambre. http://www.colmex.mx/centros/cee/documentos/cee_2009.htm. Accessed Oct 2011
Yunez-Naude A, Mendez Navarro J, Arellano González J (2010) Cambios en el bienestar de 1990 a 2005: un estudio espacial para México. Estud Económicos 25(2):363–406

Website

http://www.banxico.org.mx/SieInternet/consultarDirectorioInternetAction.do?accion=consultarCuadro&idCuadro=CP173&sector=8&locale=es. Accessed Oct 2011
http://www.coneval.gob.mx. Accessed Oct 2011
http://www.nass.usda.gov/QuickStats/PullData_US.jsp. Accessed Oct 2011
http://www.das-ac.mx. Accessed Oct 2011
http://www.rlc.fao.org/prior/desrural/gasto. Accessed Oct 2011
http://www.siap.sagarpa.gob.mx/AnxInfo/. Accessed Oct 2011

Part II
Energy

Chapter 7
Brazilian Perspectives on Development of Clean Energy

Jose Roberto Moreira

7.1 Introduction

Concern with clean energy production and use is becoming increasingly significant in Brazil. The country's primary energy supply profile qualifies as one of the cleanest in the world since renewable energy sources (or, renewables) represent more than 40 % of the total primary energy sources. Renewable energy sources, mainly hydroelectricity, ethanol, firewood, biodiesel, and charcoal, are in use.

Energy efficiency has been understood as another important alternative for reducing energy cost in the country since as early as 1985, when the official electricity conservation programme—PROCEL—was implemented in the country. Another sign of the country's concern with clean energy sources is the significant participation of Brazil in the Clean Development Mechanism (CDM) in the initial years.

For the future, the energy system foresees large expansion in ethanol, biodiesel, bioelectricity generation, small hydropower, and wind electricity, as well energy efficiency improvement. In addition, Brazil has sufficient natural resources (rivers, land, wind, and solar energy) to be a major user and even an exporter of these clean energy sources. In Brazil, the government, the population, and the entrepreneurs are aware that clean energy is an important issue to consider since the world demand for such kinds of energy will continuously increase.

Brazil's energy profile is composed of a significant share of renewable sources. This has been the case for a long time, triggered by the significant support of financing decisions made by multilateral organisations in the early 1960s, and due to the availability of potential hydro resources relatively close to the densely populated area of the southeast region of the country (CANAMBRA 1959; Gomes 2002). Biomass, as another modern renewable energy source, was introduced in the 1920s as a liquid fuel feedstock when some cars were adapted for the use of ethanol. Nevertheless, the real push started in 1975, through the establishment of

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PROALCOOL[1] (the National Alcohol Program) driven by the huge increase in oil prices between 1973 and 1975 and the very limited availability of national sources of oil at that time.

The urgent necessity to limit the outflow of hard currency caused by large volumes of oil importation was an excellent motivation to build appropriate legislation opening the liquid fuel market to ethanol, as well as establishing very favourable financing conditions to new sugar mills interested in its production (Moreira and Goldemberg 1999).

Only after the Rio de Janeiro Summit in 1992[2] were renewable energy sources and energy efficiency presented by the government and large entrepreneur groups as energy alternatives that could help the country's economy. Considering the long tradition of the country in dealing with some of these sources, the climate change appeal gained momentum, especially taking into account that it could be an extra source of revenue for the country.

Interest in fostering the construction of small hydros, solar collectors, biomass-based thermoelectric plants and installing photovoltaic (PV) cells, which were already considered in the early 1980s, triggered research and academic work. Nevertheless, significant investment in most of these areas started only after 1995 when significant changes in energy legislation created the figure of the independent power producers (IPP)[3]. Before that date, only concessionaires had the right to produce and sell electricity to final consumers and these big companies were essentially interested in large units that were unfeasible for renewable energy sources, except hydroelectricity.

With the possibility of selling electricity, many medium-size companies demonstrated interest and once again the government created an attractive programme, the PROINFA,[4] which provides significant financial support to new investors. Regarding wind energy, only in this new century has wind energy started to find ways to become competitive with the subsidised tariffs set by the government and is now taking off (Feitosa 2005).

Essentially, the only renewable source that has been promoted based exclusively in social and environmental sustainability is biodiesel. This programme, launched officially in 2005[5] by means of government action, through the creation of captive consumer markets and the provision of financial support to producers, gained relative success in a short time. Starting with a compulsory blend of 2 % in all diesel sold in the country, 5 % blending of biodiesel became compulsory in 2010.

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[1] The PROALCOOL programme was created on November 14, 1975 through Federal Decree n° 76.593.

[2] United Nations Conference on Environment and Development (UNCED), Rio de Janeiro, 3–14 June 1992.

[3] The IPP was established in Brazil through Federal Law No. 9074 issued in 1995.

[4] PROINFA was established through Federal Law No. 10.438, issued on April 26, 2002 and reviewed by Law nº 10,762, from November 11, 2003.

[5] The Biodiesel Program was launched in 2005, Federal Law 11097/2005.

The CDM was also a useful driver for motivating private interest in renewables, in particular, bioelectricity generation in the sugar mills. From the very beginning, Brazil was one of the largest players in the CDM market. By June 2009, from a total of 1665 projects registered, Brazil had the third largest share at 9.5 %, after China and India. Regarding the expected average annual certified emission reduction (CER) participation, Brazil was also the third, but with a share of 6.7 %. This last figure can be explained by unfair competition from countries like China and India, which have a much higher electricity grid emissions factor than Brazil, since the revenue from carbon credits, as defined by the UNFCCC, is directly correlated to the 'dirty intensity' of the electricity supply system.

For the future, in official planning, a large increase in the share of new and renewable energy sources in the energy profile is being considered (EPE 2008). Hydroelectricity from medium and large dams will increase in absolute value but not in relative participation. There is a plan to increase the relative share of fossil fuel-based thermoelectricity.

On the other hand, at the national level, legislation (Law 12.014/09) claiming to reduce between 36.1 and 38.9 % of greenhouse gas (GHG) emissions by the year 2020 was issued on December 28, 2009 (InfoJus 2010). In the past 15 years, Brazil has emitted 2.2 billion t of GHG. From 1990 to 2005, emissions rose by 62 %. Deforestation accounts for 57.5 % of total emissions, followed by agriculture (22.1 %) and energy (16.4 %). The Brazilian government knows it will have to impose emission limits on the productive sector. The challenge is to do so without affecting the country's annual GDP growth rate of around 6 %.

7.2 The Brazilian Energy System

It is worth examining the historical participation of the primary energy sources to notice the relevance of renewable energy sources in the past decade.

Figure 7.1 shows the evolution of the major primary sources. It is possible to note that oil and oil derivatives are the leading sources and their use has increased more than four times in the period between 1970 and 2008. As expected from the economic progress of the country, wood fuel and charcoal have declined even in absolute value, mainly due to the reduction in traditional biomass used for cooking and heating. Charcoal that is mostly used by the iron and steel sector has also lost market share mainly due to the difficult economic competition with high-quality coal, which is imported (BEN 2009). Hydroelectricity shows an increase of more than eight times in the same period. The relatively small amount of hydroelectricity in Fig. 7.1 is due to the strange assumption that 1 kWh_e is taken as 3.6 MJ, when accounting for hydro sources. It is also worth noting that ethanol, used as liquid fuel for transportation, and sugarcane bagasse, used as a source of heat and electricity either in sugar mills or for export to the grid, have substantially increased their contribution in the past few years and today are together the second most important source of primary energy, surpassing hydroelectricity. Finally, natural gas, which

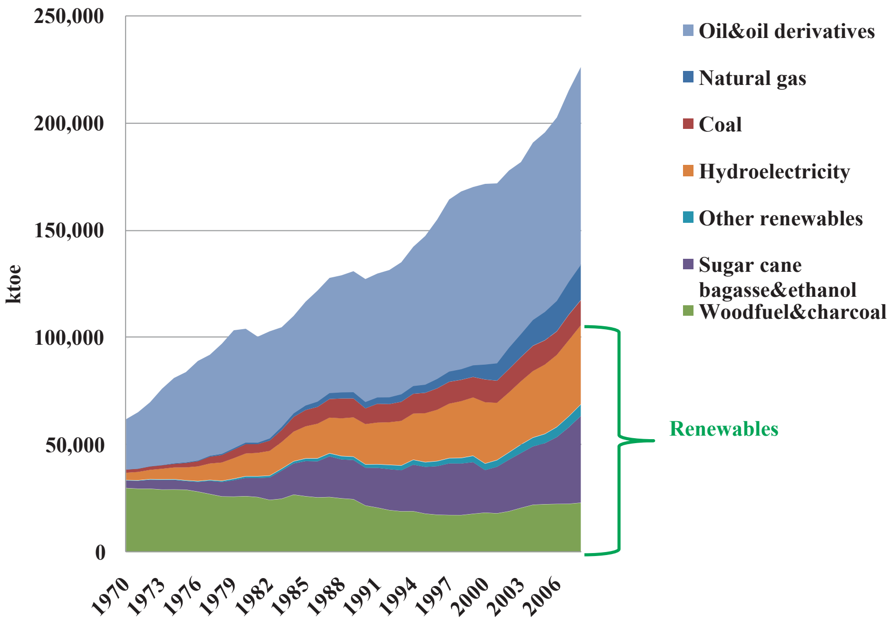


Fig. 7.1 Cumulative primary energy consumed—Brazil 1970–2008. (Source: BEN 2009)

for a long time occupied a miniscule share of the energy market, has been gaining relevance since the end of the last century. Regarding the remarkable fact that sugarcane bagasse and ethanol are ahead of hydroelectricity nowadays, it is worth commenting that this occurred once before between 1981 and 1985 (BEN 2009), driven by the significant boom in neat ethanol car sales in that period. After that, due to the shock caused to consumers by a shortage in ethanol supply (Moreira and Goldemberg 1999), this fuel lost its prestige and its presence in the market was only guaranteed by the legislation that requires a minimum amount of ethanol (20–25 % depending on the year) blended in all gasoline sold in the country. This trend was reversed by 2003 with the launch of the flexfuel car (a car that can use gasoline or ethanol in almost any proportion[6]), and was further driven by the high price of oil in 2007 and 2008.

Figure 7.2 shows that currently, a little more than 110 Mtoe (Million tonnes of oil equivalent) of primary energy is renewable, while the remaining 120 Mtoe is from fossils. It is also possible to examine the evolution of the renewable energy share over time and, unfortunately, it is losing space to fossil energy. Even considering the significant increase in the use of new and renewable sources (sugarcane bagasse,

[6] Since all gasoline sold has 20–25 % ethanol blend, flexfuel cars can be run using 20 to 100 % ethanol. The guarantee that some ethanol is always present in the fuel allowed manufacturers to design Otto-type engines with a high compression ratio (up to 12:1), which increases the engine efficiency. This means that these engines cannot use plain gasoline, unless it has a very high level of octane.

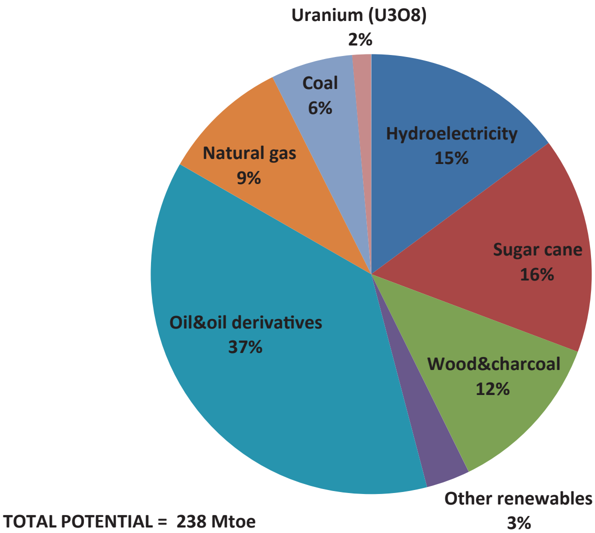


Fig. 7.2 Primary energy supply—Brazil 2007. (Source: BEN 2009)

ethanol, biodiesel, and small hydro), it is not enough to offset the reduction on large hydro plant construction.

On the demand side, Fig. 7.3 shows a decline in the share of energy used by the industrial sector, an increase in the residential sector and an almost stable share in the commercial sector. The relative growth of energy use in the agricultural sector is explained by the significant increase in agricultural production in the period 1970–2008.

Figure 7.4 shows two useful energy indicators for the country. One is the amount of energy used per inhabitant, and the other is the amount of energy used to generate one dollar of revenue in the country's economy. The figure uses the real gross national product (GNP) and concludes that the country's energy efficiency has been quite stable since 1980, which is a poor result when compared with other large developing countries, such as China and India (IEA 2009a).

7.3 The Ethanol Programme

Fuel ethanol has been replacing gasoline since 1975. From 1975 to 1980 it was only blended in gasoline. Starting in 1980 and motivated by the rapid increase in ethanol availability due to the success of the PROALCOOL programme driven by private entrepreneurs but with very attractive financing mechanisms from the federal government, the neat ethanol car started to be commercialised. These cars are powered by hydrous ethanol (93 % ethanol and 7 % water) as opposed to the ones that use gasohol, which is gasoline blended with neat ethanol (99.7 % ethanol) (Moreira and Goldemberg 2003).

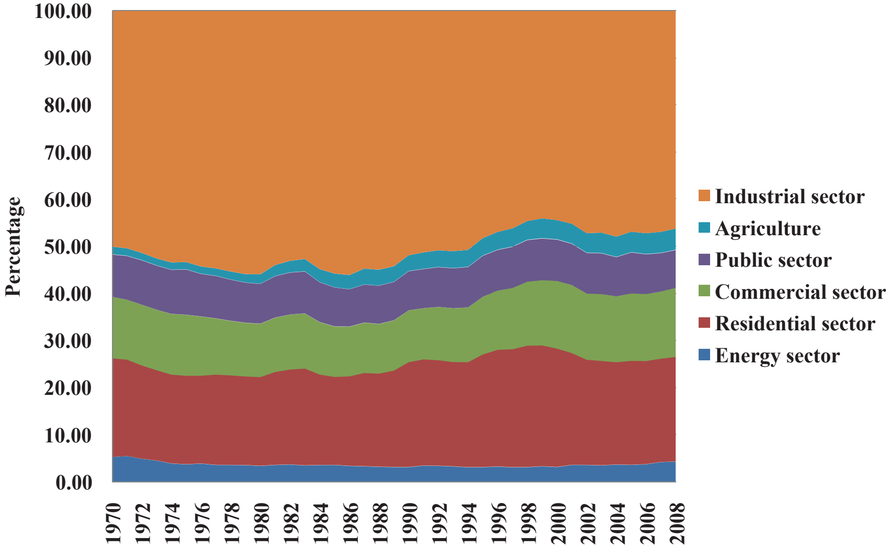


Fig. 7.3 Share of end-use sector participation in energy consumption Brazil 1970–2008. (Source: BEN 2009)

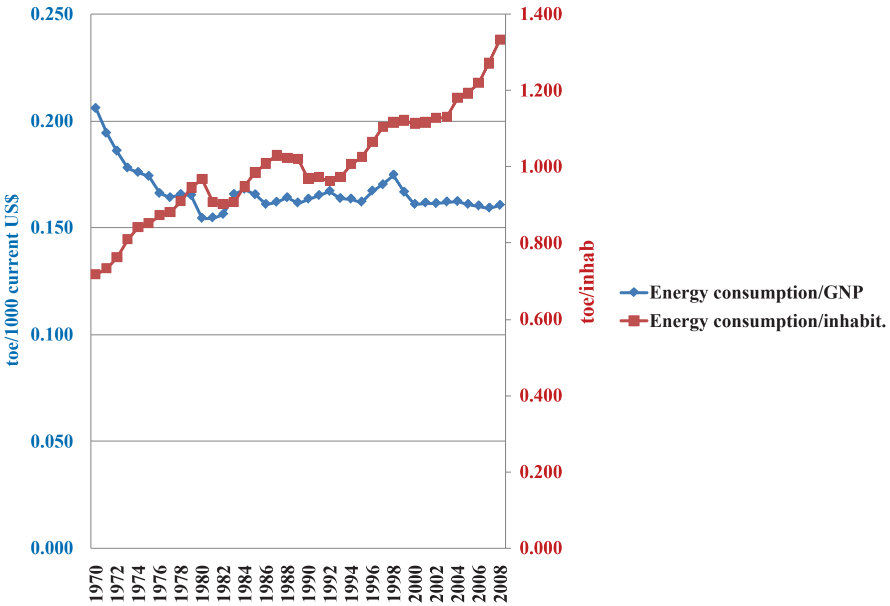


Fig. 7.4 Energy intensity—Brazil 1970–2008. (Source: BEN 2009)

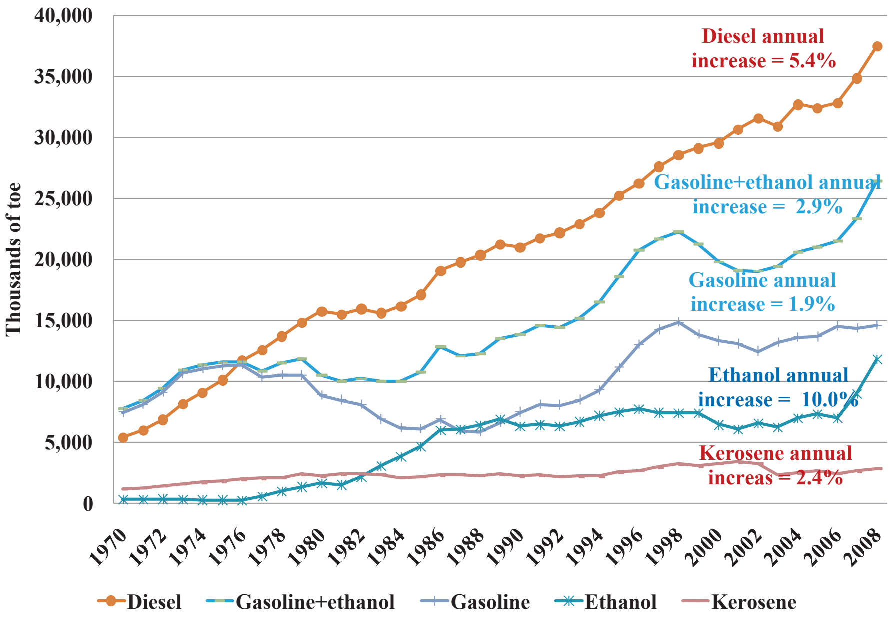


Fig. 7.5 Annual consumption of liquid fuels—Brazil 1970–2008. (Source: BEN 2009)

Ethanol production grew very rapidly in the first 10 years of the programme (1976–1986) (shown in Fig. 7.5), followed by a decline between 1999 and 2003 and a resurgence of growth from 2003 to 2008. This peculiar behaviour can be explained by the following major drivers (Proalcool 2010):

1976–1986 For the first 4 years, ethanol was only used as a blend in gasoline. In 1980 with the introduction of neat ethanol cars in the market, national energy legislation required that all service stations have at least one dedicated ethanol pump. With the low price of ethanol, the availability of supply, compulsory consumption through the blend in gasoline, and voluntary consumption by neat ethanol cars the demand rose very quickly. It is worth noting that neat ethanol cars represented 95 % of all new cars manufactured in 1985. A strong institutional infrastructure was created, price mechanisms were designed to keep ethanol prices below those of gasoline, and tax differentiation between both fuels drove up ethanol production. With favourable prices, demand also increased due to the production and sales of neat ethanol cars.

1986–1995 This was the phase of stagnation. From 1985 oil prices declined significantly to the level of US$ 12–20/bbl. In Brazil, this effect was noticed only in 1988 when there was a shortage of public money to subsidise programmes for alternative energies, driving down the volume of investments in further ethanol expansion. The low price of the fossil fuel also reduced availability of private investment in the ethanol sector, limiting production expansion since 1986. On the demand side, sales of neat ethanol cars continued. Nevertheless, the strong demand was not fulfilled by the installed capacity and a significant shortage of ethanol for voluntary consumers showed up. The problem was partially mitigated through imports of ethanol and methanol, and the replacement of the compulsory 20 % of ethanol blended in gasoline. As a result, ethanol producers decided to dedicate a significant share of sugarcane to sugar production, while the ethanol fuel market was supplemented by imported ethanol.

During these two phases it was necessary to subsidise ethanol since its price was controlled by the government and set as a fraction of the gasoline price. The total accumulated amount of subsidy was high, reaching more than US$ 30 billion by 1998 (Moreira 2008). Fortunately, this accumulated amount has started to decline in the past 10 years, after the government price control was removed (see next paragraph).

1995–2000 This was the phase of redefinition. The government removed price controls on fuels, letting ethanol rely on market competition to survive. During this time neat ethanol car sales dropped to 1 % of the total annual production. It is interesting to note that in this period sugarcane production continued to grow, essentially due to the expansion of sugar for export (Fig. 7.6).

2001–Today This is the present phase where significant expansion of sugarcane production occurred and fuel ethanol production surpassed gasoline consumption in 2009. New planting areas occurred in regions of the state of São Paulo and in neighbouring states like Minas Gerais, Mato Grosso do Sul, and Goias, which were modest sugarcane producers. Most of the motivation to increase ethanol

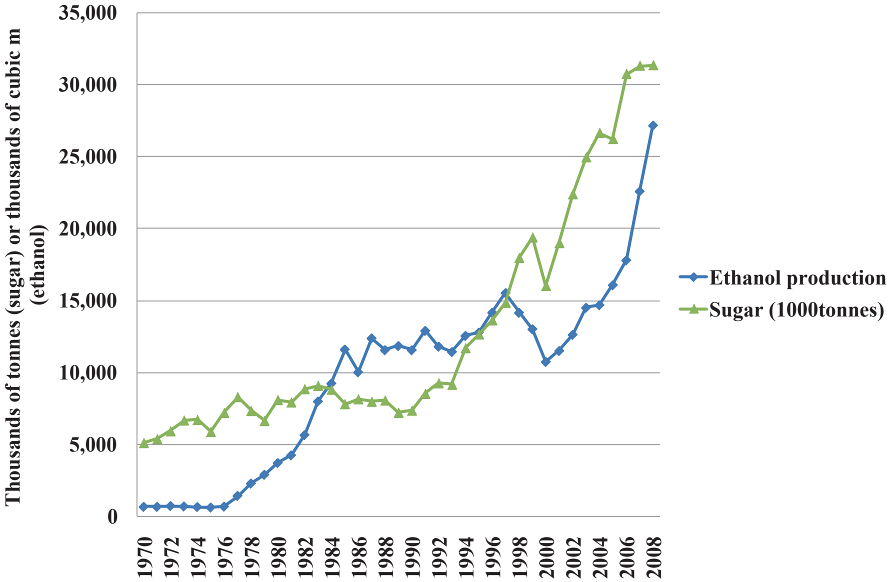


Fig. 7.6 Ethanol and sugar production—Brazil 1970–2008. (Source: BEN 2009)

production was the introduction of flexfuel cars (Poppe 2004). Simultaneously, the government understood the significant electricity potential associated with the use of an ethanol by-product—bagasse—and set policies in favour of its promotion. The promotion is being carried out not only through PROINFA, but also through public bidding especially designed for biomass-based electricity plants using the installed electric grid.

7.3.1 Major Outcomes from the Success of the Ethanol Programme

During the first and second oil shocks, (1973–1974 and 1977–1979) due to the strong dependence of the Brazilian energy sector on imported oil, a significant amount of hard currency was spent on importation. Figure 7.7 shows the impact of ethanol on the Brazilian trade balance. In some years, more than 50 % of the total hard currency obtained from international exports was spent on importing oil. With the production of ethanol, gasoline consumption declined due to the substitution effect.

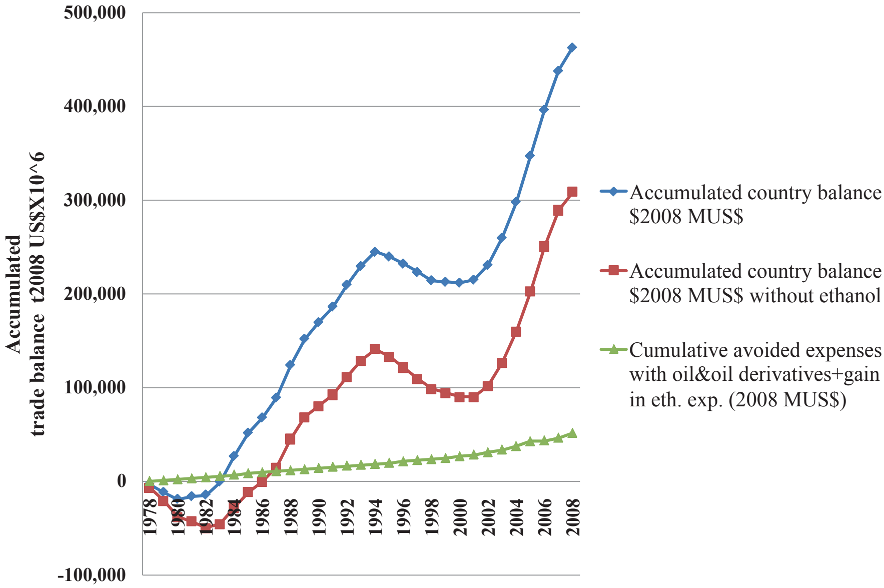


Fig. 7.7 Impact of ethanol in the Brazilian trade due internal use and exportation. (Source: Moreira 2010)

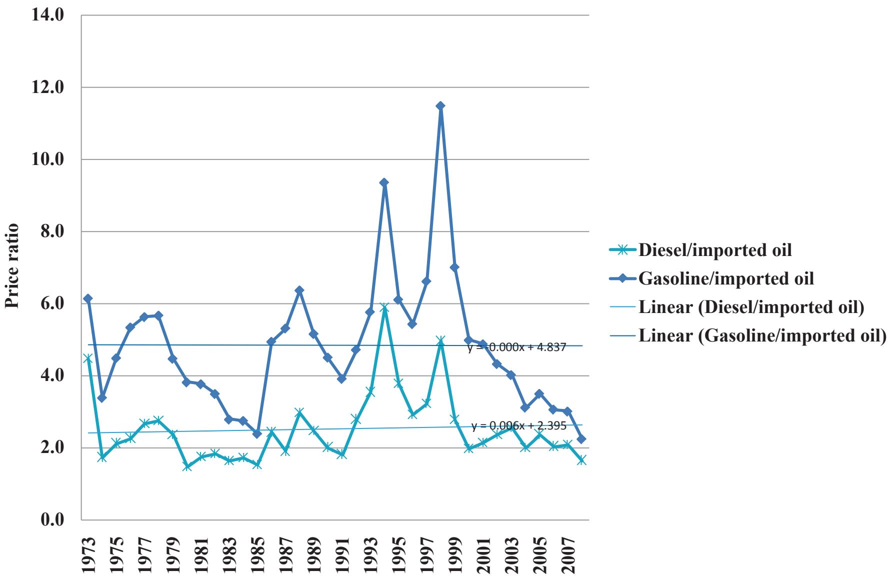


Fig. 7.8 Price ratio gasoline/imported oil and diesel/imported oil—Brazil 1973–2008. (Source: Based on data from BEN 2009)

7.3.2 Currency Savings by Passengers' Car Drivers

The presence of an alternative to gasoline increases competition and consequently reduces prices. Figure 7.8 shows the price of gasoline and diesel relative to imported oil. As can be seen, diesel has a lower price than gasoline. This is a long-term trend set by the government to control the prices of goods. It is possible to note also that the gasoline to imported oil ratio shows an almost horizontal trend, that is, the ratio is essentially constant over the 35-year period. In contrast, diesel prices increased with respect to imported oil. From Fig. 7.8 we note that gasoline prices decreased by 0.5 %, while that of diesel increased by 10 %.

Figure 7.9 allow us to see even better the effect of competition in the gasoline market. The oil company, in order to preserve its revenue and minimise market share losses, increased gain margins on diesel while reducing those on gasoline[7]. The conclusion is that alternative sources of energy can bring another advantage—a reduction in the cost of energy in case alternatives are available to replace the major fuels used in the transportation sector.

[7] Gasoline and diesel prices were controlled by the government up to the year 2000. Nevertheless, the government decisions were taken after consulting and hearing the government-owned oil company—PETROBRAS. Even in more recent years when PETROBRAS became free to set fuel prices, it has acted with care, trying to avoid difficulties regarding government policies. On the other hand, ethanol prices are set by the private sector. It is possible to see in the past 10 years that negotiations between the government and PETROBRAS concluded that to retain the economic health of the oil company it was more efficient to increase diesel prices faster than gasoline prices.

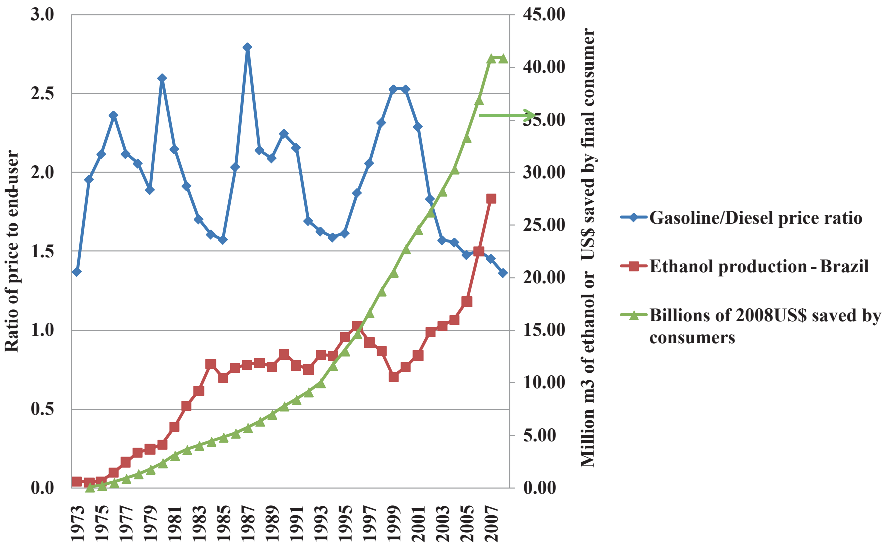


Fig. 7.9 Relative price to final consumer of gasoline/diesel, amount of ethanol production and amount of 2008 US$ saved by gasoline consumers—Brazil 1973–2008. (Source: Based on data from BEN 2009)

7.3.3 Liquid Biofuel and Reduction in GHG Emissions

The production and use of biofuels have been under criticism in the past 2 years due to some new sustainability indicators. One of them is the contribution of biofuels to GHG emissions due to direct land use change (LUC) and indirect land use change (ILUC). Another source of concern is related to the significant release of N_2O into the atmosphere due to the use of N-fertilisers when planting biofuel feedstock. Some authors have argued that not all biofuels are necessarily green (Crutzen et al. 2008; Fargione et al. 2008; Searchinger et al. 2008). However, all these evaluations conclude that sugarcane ethanol has the best capacity to mitigate climate change if properly managed (EPA 2010; Gibbs et al. 2008).

Ethanol from sugarcane produced in Brazil is able to reduce CO_{2eq} emission by 61 % considering LUC and ILUC effects (US EPA 2010). Pacca and Moreira (2009) tried to quantify the overall impact of the PROALCOOL programme from its launch in 1975 up to 2007. Figure 7.10 shows that in the initial years of the programme, the overall effect was negative, increasing GHG emissions, mainly due to carbon from above and belowground biomass that was lost to the atmosphere when converting earlier vegetation in sugarcane crops. It took 17 years for CO_{2eq} emissions from gasoline, due to its displacement by ethanol, to offset all the initial GHG emissions. Nevertheless, after 32 years it is possible to see that 125 tCO_{2eq}/ha has been avoided. The relatively long offset time was a consequence of the very poor initial efficiency of ethanol production.

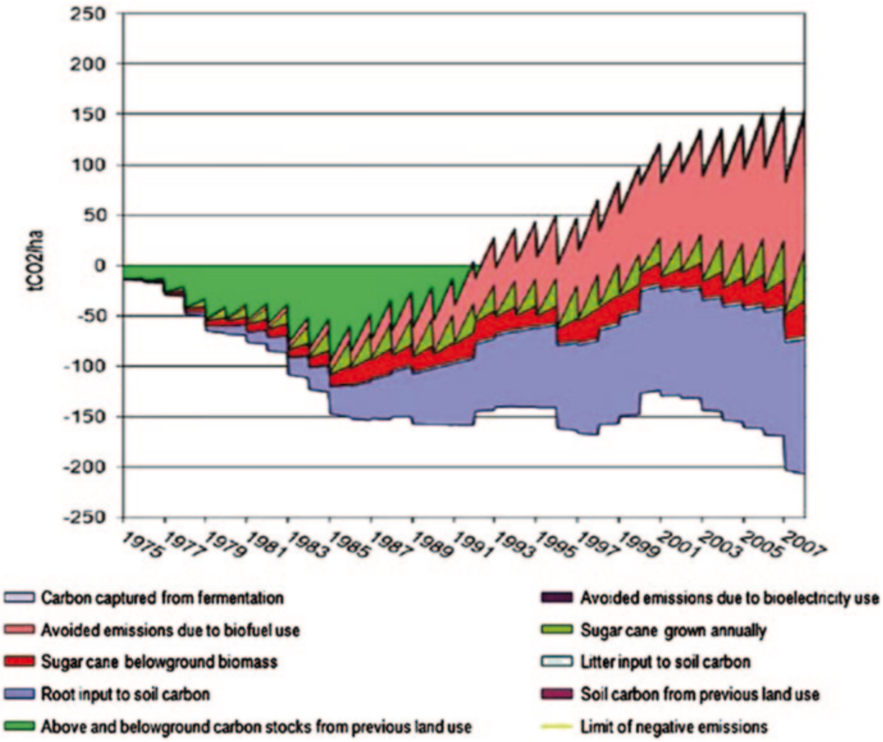


Fig. 7.10 Accumulated amount of GHG emissions avoided by the use of fuel ethanol as a replacement for gasoline in Brazil: 1975–2008. (Source: Pacca and Moreira 2009)

Figure 7.11, shows how much GHG mitigation could be obtained from the PROALCOOL programme, since the provided surplus electricity generation using present available technology (steam turbines) and carbon capture and storage (CCS) on CO_2 from fermentation were being performed since 1975. An accumulated abatement of CO_{2eq} of 400 t/ha would be achieved in 2007. Note that for Fig. 7.11, the historical low ethanol efficiency has been maintained.

Pacca and Moreira show that for the next 32 years, based on the available technologies, with the present and increasing yield of ethanol and an annual expansion of 4.3 % in the planted area for sugarcane, the practice would always be environmentally sound, accumulating CO_{2eq} abatement of 820 t/ha (until the year 2039).

7.4 Biodiesel

The use of biodiesel is relatively recent in Brazil. The programme was officially launched in 2005 and since then production has been increasing at a monthly rate of 13.5 % (Fig. 7.12). This huge increase, much bigger than the one observed for ethanol

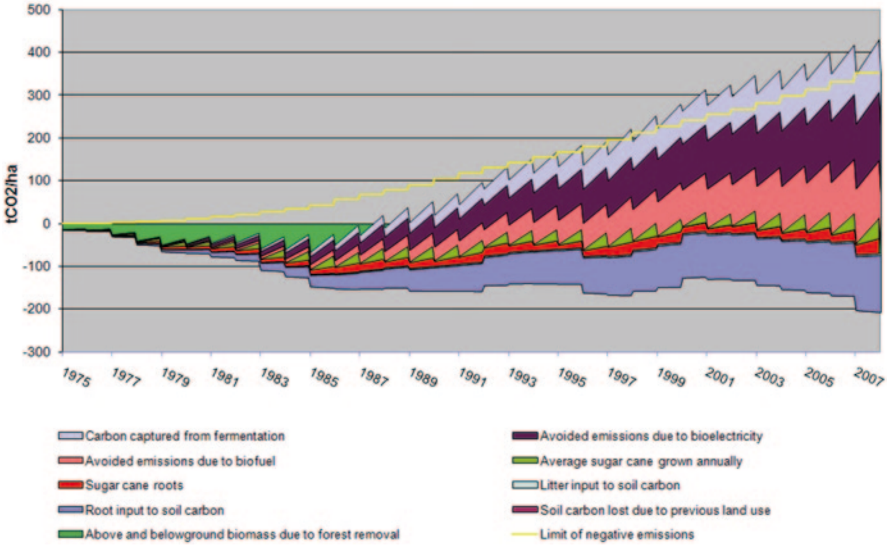


Fig. 7.11 Accumulated amount of GHG emissions avoided by the use of fuel ethanol as a replacement for gasoline in Brazil if electricity surplus generation and CCS had been in effect from the beginning of the programme (1975–2008). (Source: Pacca and Moreira 2009)

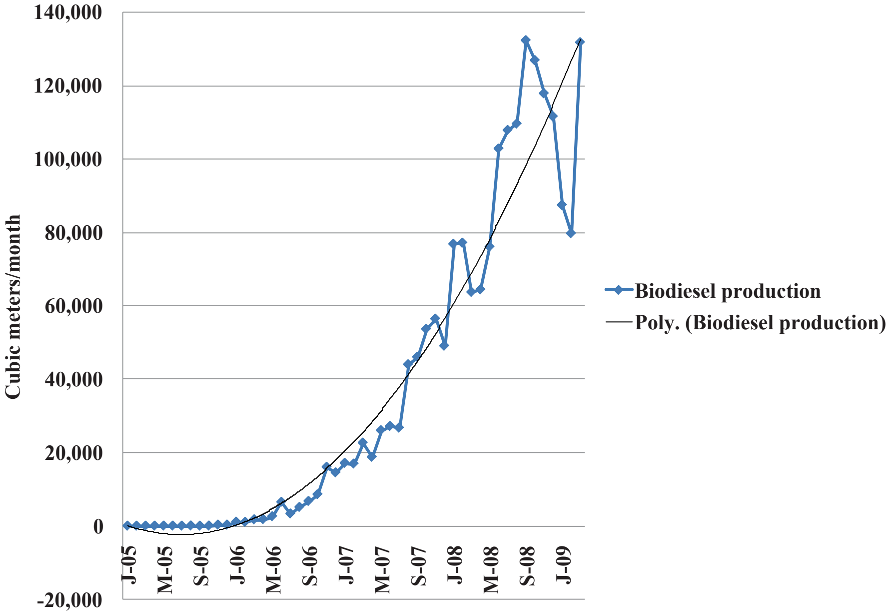


Fig. 7.12 Monthly biodiesel production—Brazil 2005–2009. (Source: MAPA 2009)

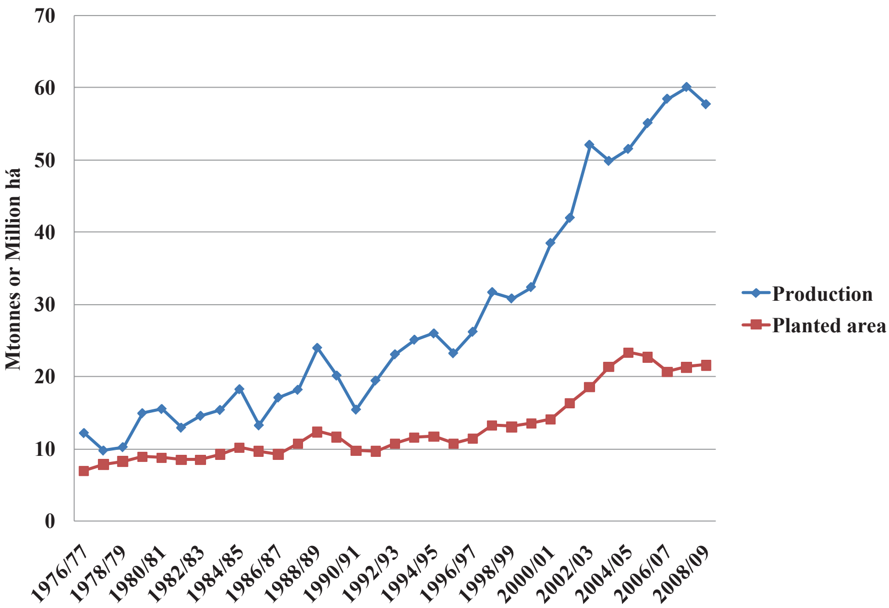


Fig. 7.13 Soybeans production and planted area—Brazil 1976–2009. (Source: MAPA 2009)

at the beginning of PROALCOOL, is explained by the immediate availability of vegetable oil crops and the shift of its products from the food to the fuel market.

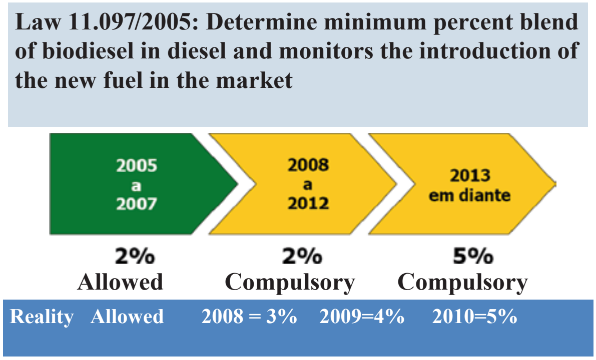
Most of the feedstock for biodiesel comes from soya, which has been extensively planted in the country. Figure 7.13 shows the increase in planted area for soybeans in the past 31 years. It is also possible to note the significant increase in yield, because while the planted area increased by a factor of three, production increased by a factor of six in this period.

The government's initiative was a very important driver for the implementation of this new renewable fuel market. Legislation issued in 2005 established a compulsory and cap voluntary index for the amount of biodiesel blended in diesel. Figure 7.14 shows the established values, which reached 5 % compulsory level by 2010. Also shown is the real achievement of the biodiesel market.

One major difference between the ethanol and biodiesel programmes was the strong social content of the latter. One of the targets of the biodiesel programme was to endorse familiar agriculture participation. For this purpose, Petrobrás invested in the production of biodiesel from castor oil, which can be planted in the northeast region of the country where a significant share of the farmers are very poor. In parallel with that, the federal government set lower taxes on biodiesel produced partially from vegetable oil crops grown by familiar agriculture.

The overall mechanism used by the government to fulfil the legislation was to acquire biodiesel from the market through public biddings. Figure 7.15 shows that a total of 2.6 Mm^3 of biodiesel was acquired by Petrobrás from November 2005 to February 2009, that is on average, 67 Ml/month. Also, it is interesting to note that

Fig. 7.14 Biodiesel legislation. (Source: Prepared by author)



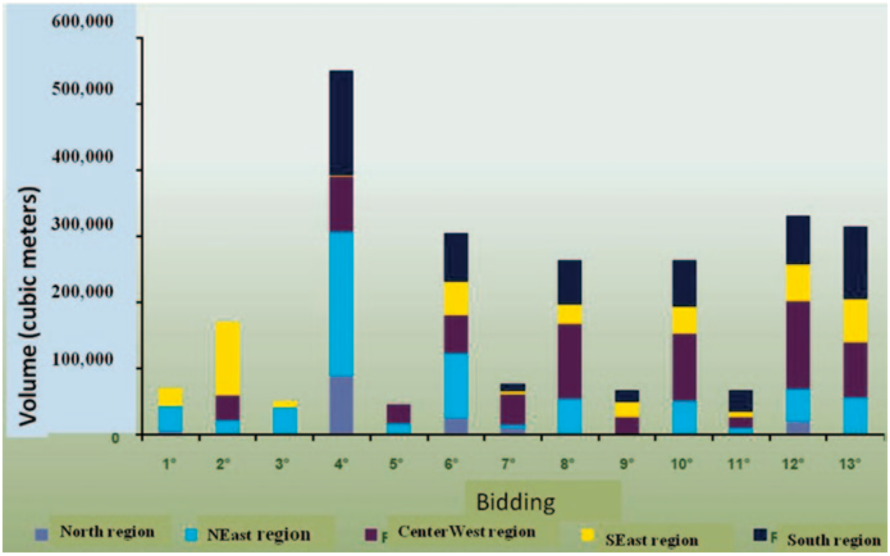


Fig. 7.15 Volume of biodesel acquired in each of the public biddings in the period 2005–2009 = Brazil. (Source: MAPA 2009)

the major contribution came from center-west and the southeast and south regions where soya is largely produced. The north and northeast regions, where biodiesel from palm oil and castor oil have some contribution, had smaller participation. This means that the fraction of biodiesel feedstock produced by the rural poor is a small component of the total production (probably less than 20 %). Figure 7.16 shows the average price paid by Petrobrás which ranges from 1.75 to 2.70 R$/l. Diesel fuel is sold by Petrobrás at 1.10 R$/l, which demonstrates that biodiesel, once tax, transportation and handling costs are included, should be sold at at least double the price of diesel.

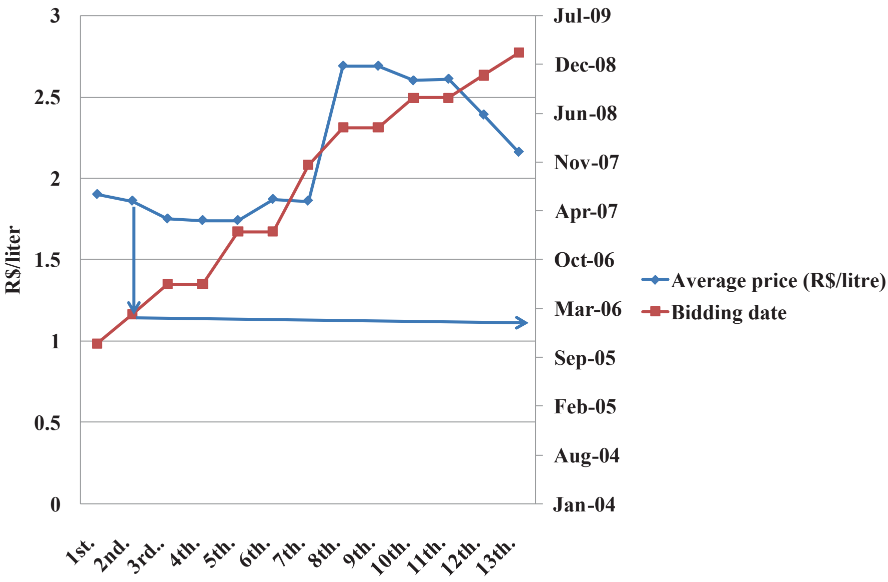


Fig. 7.16 Biodiesel average price (R$/l) as a function of date of bidding—Brazil 2005–2009. (Source: Based on data in MAPA 2009)

Table 7.1 Biodiesel from soya energy balance. (Source: NM0253 presented to UNFCCC-EB by MGM International in 2008)

Source document		Vegetable oil produced/fossil fuel consumed (MJ/MJ)
1	Neto et al. (2004)	3.2–3.4
2	Moreira (2003)	3.2
3	ENVOLVERDE (2008)	3.0
4	Nelson (2006)	3.2
5	Costa et al. (2006)	3.2–3.4
6	Sheehan (1998)	3.2
Average		3.17–3.23
Standard deviation		±0.15 to ±0.08

Regarding climate change mitigation, there is not enough consensus about its real impact on vegetable oil feedstock. Energy and CO_2 balances for the production of biodiesel usually show a benign environmental impact, when direct and indirect land use change (LUC and ILUC) emissions are excluded (Table 7.1).

This table shows the relation of energy content (MJ) of vegetable oil (VO) and the amount of fossil energy (MJ) used in VO production. The value considered is 3.17 less one standard deviation, which is 3.02.

Nevertheless, when LUC and ILUC impacts are added the situation is not very clear. USEPA has evaluated the complete GHG emission for biodiesel from soya

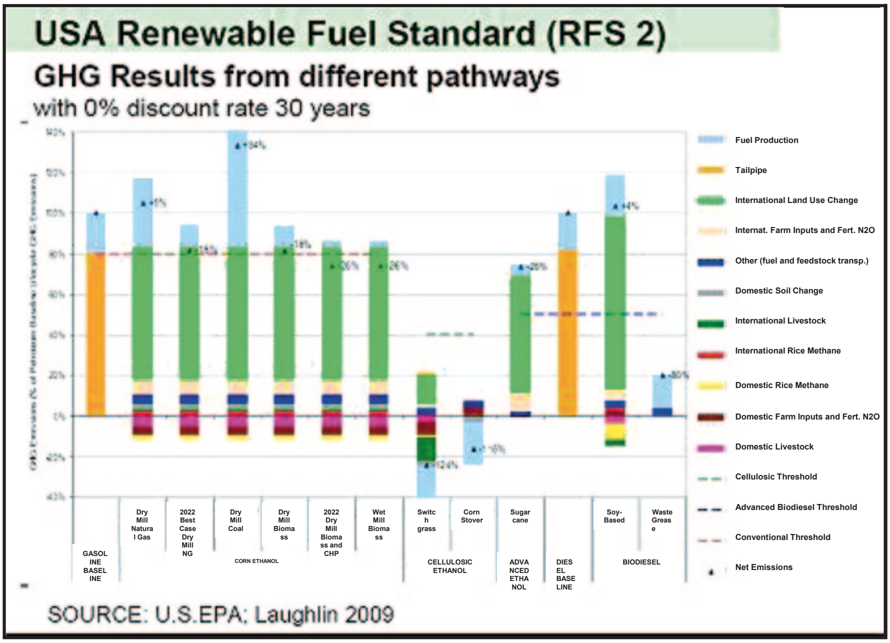


Fig. 7.17 USA renewal fuel standard (RFS 2). (Source: U.S.EPA; Laughlin 2009)

and arrived at an initial conclusion that, at least for the US, total GHG emissions exceed fossil diesel emissions by 4 % (Fig. 7.17). This issue is still controversial. Nevertheless, it is important to note that many technological improvements can still be introduced in the first generation of biofuels, which can change ILUC contribution in the future.

The biodiesel programme is moving forward in Brazil. Since January 2010, a blending of 5 % has become compulsory, while the voluntary cap is 20 %. The total installed capacity in 2009 was 3.9 Mm^3 (Table 7.2) while demand was estimated as 1.3 Mm^3 for a 3 % blend (B3). It is possible to see that the total installed capacity is enough to fulfil the demand for the 5 % blend in 2010 (B5).

Table 7.2 Installed capacity of biodiesel plants, and biodiesel demand by region Brazil 2009 (m^3/yr). (Source: MAPA 2009)

Region	Installed capacity 2009	Average size of plants	Demand 2009 B3	Self-sufficiency (%)	Demand 2010 B5
North	40,320	10,080	100,758	(−60.0)	168,434
Northeast	698,904	87,363	212,675	181.6	355,522
Southeast	769,839	48,087	595,214	29.26	994,999
Southeast	727,801	103,972	260,673	179.2	435,758
Center west	1,642,283	54,742	173,598	846	290,198
Brazil	3,878,697	59,672	1,342,919	188.82	2,244,911

Table 7.3 Federal taxes on biodiesel and diesel used for fuel and applicability conditions. (Source: Federal Decrees No 5297/04 and 5457/05; Federal Decree Ministry of Agrarian Development No. 1 from 7/5/2005)

Federal taxes	Biodiesel				Diesel
	Family agriculture-North, Northeast and arid zone; Palm or Castor oil	Family agriculture	North, Northeast and arid zones; Palm and Castor oil	Other cases general rule	
IPI	Zero	Zero	Zero	Zero	Zero
CIDE	Not applicable	Not applicable	Not applicable	Not applicable	0.035
PIS;COFINS	100% discount	68% discount	31% discount	Equal diesel	0.074
Total	US$/liter	US$/liter	US$/liter	US$/liter	US$/liter
	0	0.035	0.075	0.11	0.11

Note: US$ 1 = R$ 2.00

Conditions for Biodiesel producers to qualify for Federal Taxes
Acquire minimum amount of feedstock from familiar agriculture: 50% in Northeast; 30% in South and Southeast; 10% in North and CenterWest
Sign contract with family agriculture suppliers stating price, duration of agreement, conditions guiding feedstock delivery and provision of technical assistence
Projects must be approved by the Ministry of Agrarian Development

The taxes, which added a value of US$ 120/m^3 in 2004, were reduced as shown in Table 7.3 (biodiesel). Nevertheless, due to the recognition that it is impossible to fulfil demand only by relying on familiar agriculture, the present legislation states that such reduction applies to all biodiesel, provided the shares of vegetable oil from familiar agriculture are fulfilled according to the values shown in the lower part of Table 7.3.

7.5 Charcoal

Charcoal is another potential renewable fuel prepared from wood and largely used in Brazil. Figure 7.18 shows the historical consumption of charcoal. It is possible to see that most of it is for industrial use. Iron and steel and iron alloy manufacturers are the major users (Fig. 7.19).

Charcoal, as produced in Brazil, unfortunately cannot be considered fully renewable and sustainable. As shown in Fig. 7.20 only a share of the charcoal is produced from planted forests. The use of wood from native vegetation is legally allowed either due to agricultural frontier expansion or through partial deforestation of new occupied areas. The use of wood though illegal removal from native forests and from the cerrado (a kind of land with vegetation similar to savannahs) is not allowed, but the regulation enforcement is not perfect. Due to this, some of the feedstock used for charcoal is obtained from native vegetation. An amount of

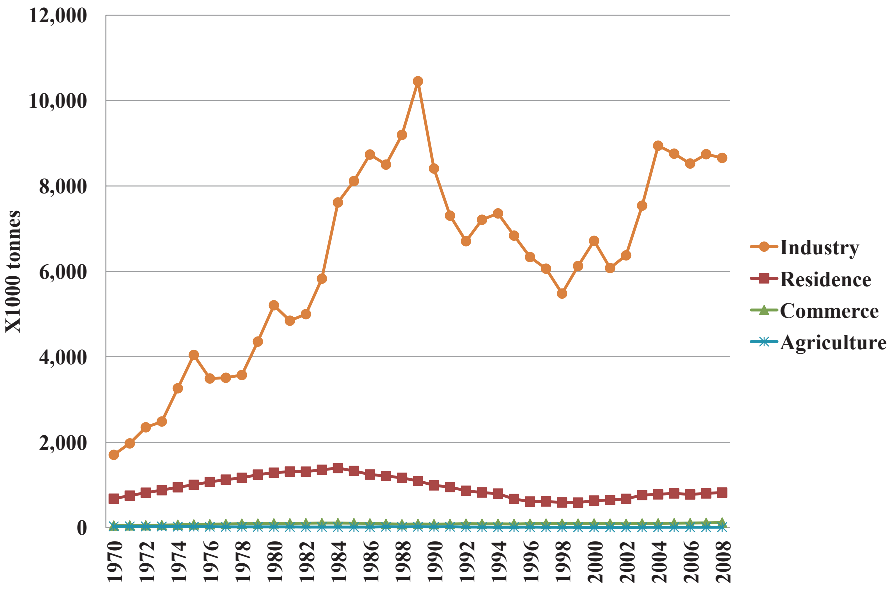


Fig. 7.18 Charcoal consumption by end-sectors—Brazil 1970–2008. (Source: BEN 2009)

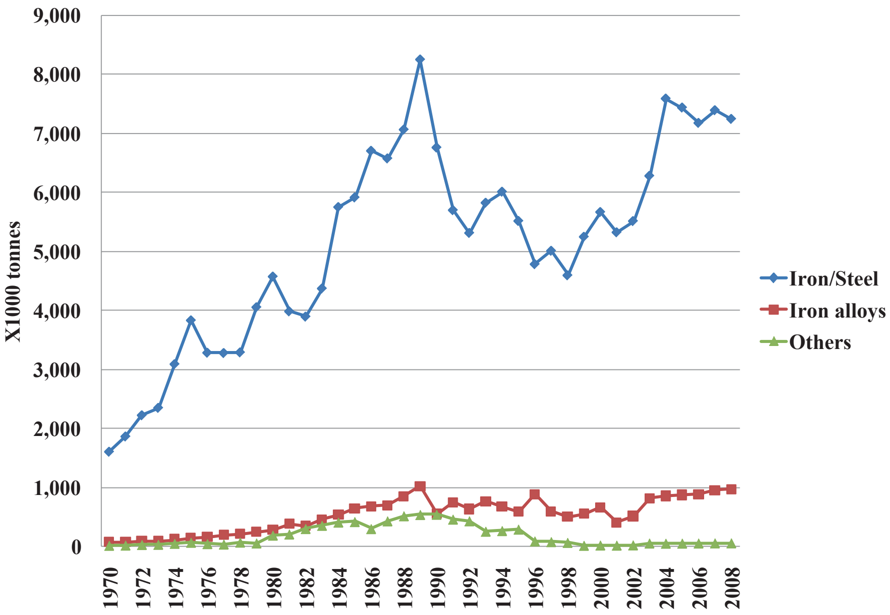


Fig. 7.19 Charcoal use in industries 1970–2008—Brazil. (Source: BEN 2009)

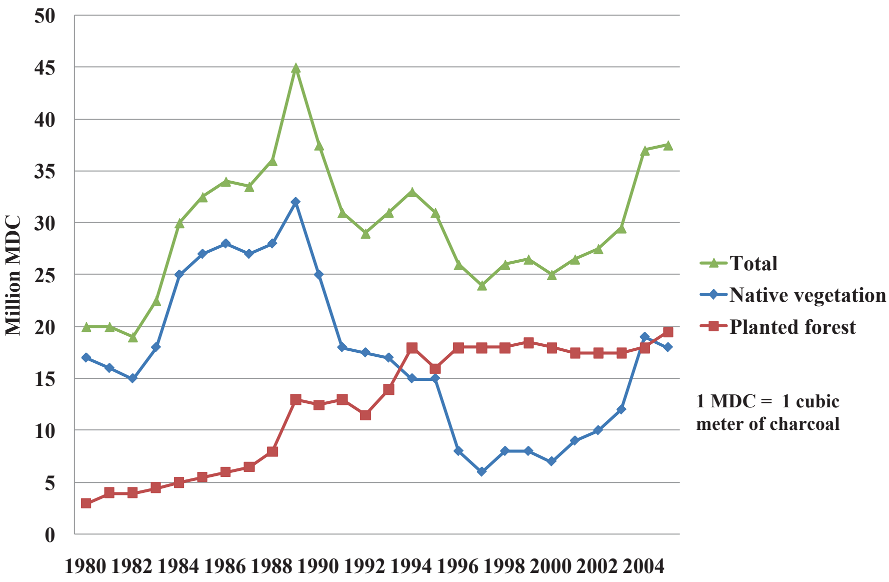


Fig. 7.20 Charcoal production from different biomass feedstock—1980–2005—Brazil. (Source: Uhlig et al. 2008)

10 million MDC (1 MDC is the amount of coal contained in 1 m^3 and 10 million MDC is equal to 2.5 Mt of charcoal) requires the use of 8.3 million t of wood (6 Mt of dry wood). Such an amount of wood, if collected from native forests (wood density of 250 t/ha) may require deforestation over an area of 33,000 ha. Thus, an area as large as 160,000 ha has to be cleared annually. Precise data on this share is not available, but assuming that agricultural area expands by 0.1 % per year, and half of the new areas are tropical forests and half cerrados, around 7.5 Mt of wood from tropical forest and 1.5 Mt of wood from the cerrado would be available as a source of charcoal. This amount is half the maximum demand for feedstock from planted forests (Fig. 7.20). The conclusion is that new agricultural areas must be expanding, probably at annual rates of at least 0.2 % a year (Ferreira Filho and Felipe 2007).

Consequently, the future growth of the charcoal industry depends on the increasing use of planted forests, which are growing very modestly, as shown in Fig. 7.21.

7.6 Hydroelectricity

Figure 7.22a shows the total electricity generated by different sources of energy, while Fig. 7.22b shows hydroelectricity generated in the country and the net amount of electricity imported. It is possible to see that hydroelectricity generation has increased at a rate of 6.04 % per year, which is below the total increase in electricity

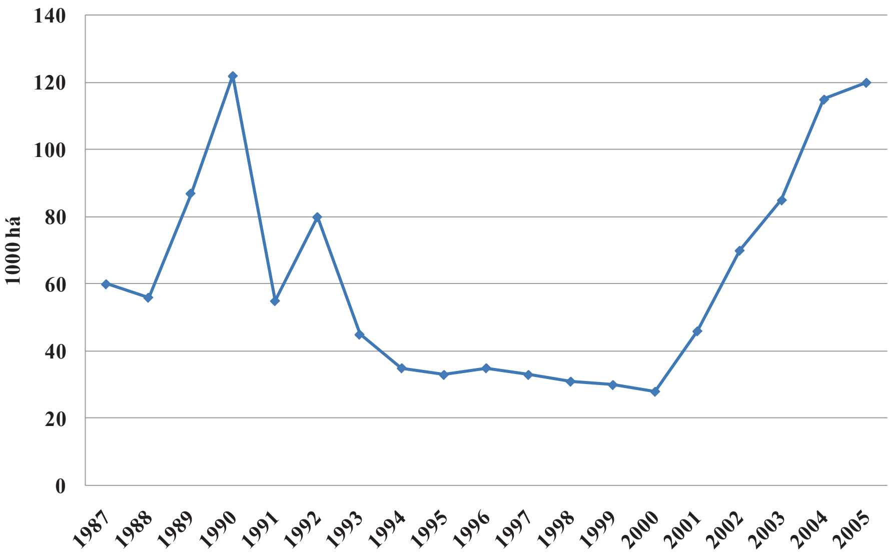


Fig. 7.21 Annual planted forest area for charcoal production—Brazil 1984–2004. (Source: Uhlig et al. 2008)

generation in the country (6.38% per year), while imports have increased after 1985. Consequently, the share of hydroelectricity in the national supply of electricity has declined in favour of fossil fuel-based generation, even considering the increasing participation of biomass-based electricity (wood fuel, sugarcane bagasse and black liquor), shown in Fig. 7.23.

Significant environmental and social barriers have been limiting the expansion of hydroelectricity in the past 10 years (Sternberg 2008). The potential is still quite significant and 41,100 MW of new installed capacity is already under construction and 11,780MW are forecast to be in operation up to 2017 (EPE 2008). This is significant since the installed hydro capacity was 81,669 MW in 2009, when total installed power was 107,188 MW (see the relative share of electricity generated in Fig. 7.24). Nevertheless, thermo-capacity is also expected to increase from 17,307 MW in 2009 to 30,000 MW by 2017 (see the relative share of electricity generated in Fig. 7.24). Total biomass-based electricity is assumed to increase from 1637 MW in 2009 to 4170 MW by 2017.

Figure 7.24 shows the expected growth in electricity capacity addition from 2008 to 2017. It is possible to calculate the hydro share, based on installed capacity, from Fig. 7.24. The conclusion is that hydro share will be reduced from 79.31 to 70.98%, while fuel oil-based units will increase their share from 1.34 to 5.75% and coal from 1.39 to 2.05%. Some new and renewables are expected to increase from 3.87 to 5.00% (small hydro), 0.96 to 2.70% (biomass) and 0.27 to 0.92% (wind energy). Nuclear-based capacity will remain practically stable (2%). We cannot make a direct correlation between the installed capacity and electricity generation; nevertheless, the significant reduction in hydro share will increase the CO_2 intensity of the electric grid.

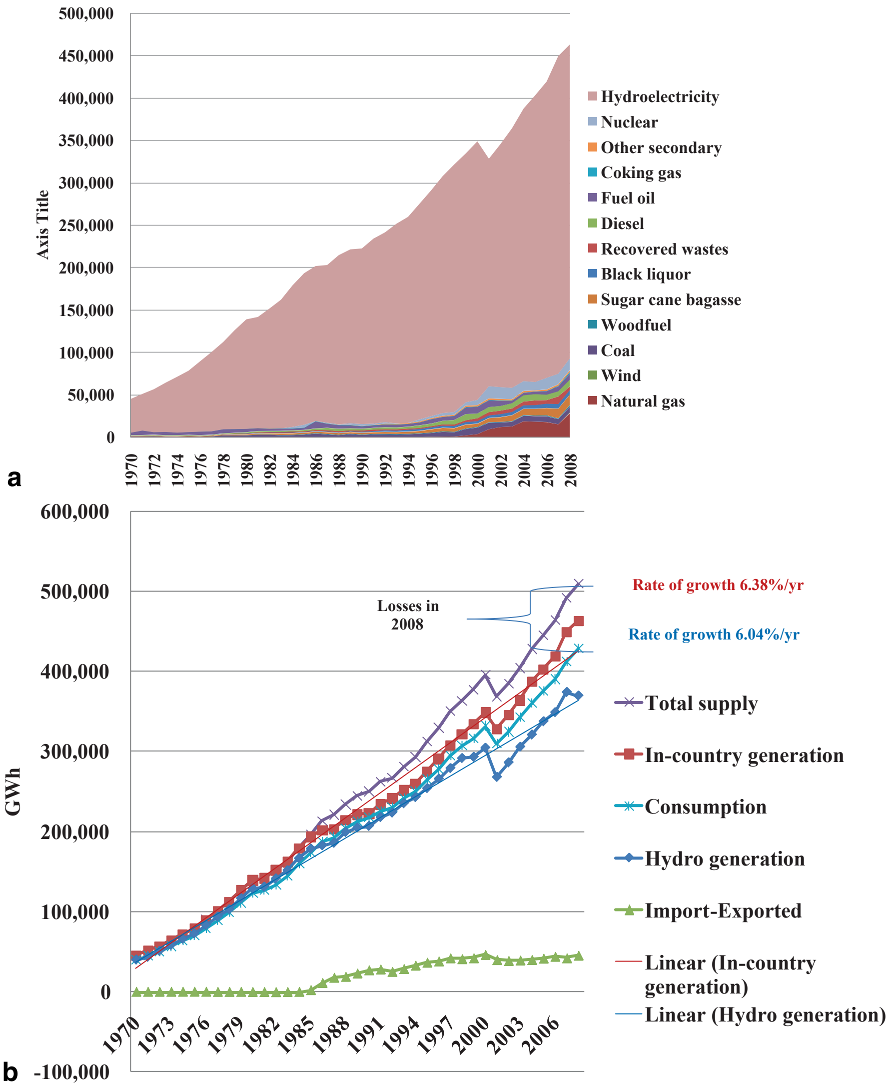


Fig. 7.22 **a** Electricity generation portfolio by energy sources—Brazil 1970–2008 **b** Hydroelectricity generation—Brazil 1970–2008. (Source: BEN 2009)

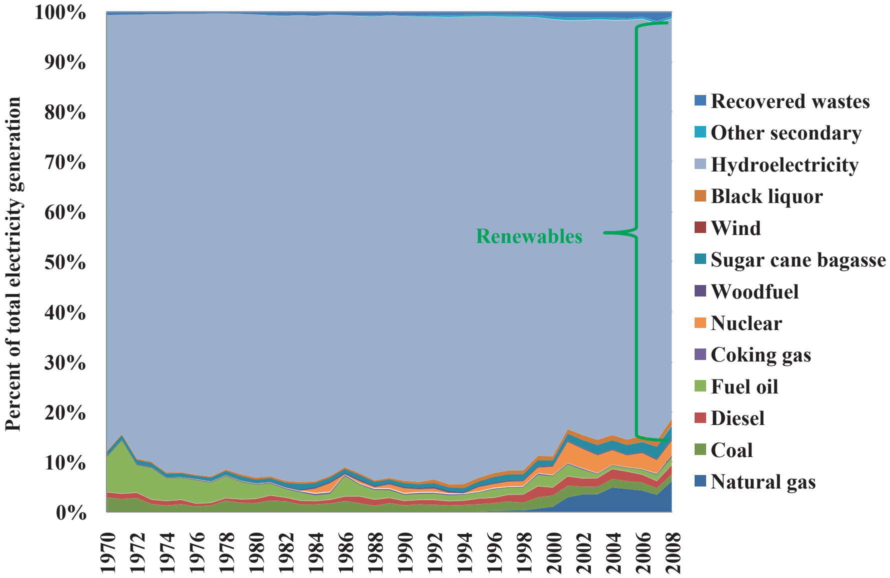


Fig. 7.23 Relative participation of energy sources in electricity. (Source: BEN 2009)

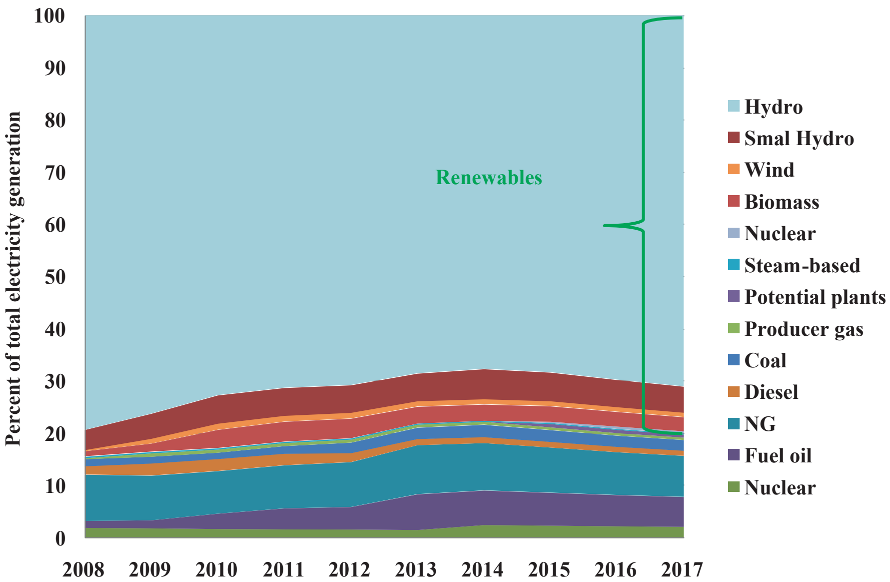


Fig. 7.24 Relative participation of energy sources in electricity generation—Brazil 2008–2017. (Source: EPE 2008)

7.7 Small Hydropower Plants (SHPs)

SHPs are defined as hydroelectric power plants with an installed capacity between 1 and 30 MW, with a total water reservoir equal to or less than 3 km^2 (Resolution 394/1998 item 2). As shown in Table 7.4, the total installed capacity was 2235 MW by 2007.

The main advantages of SHPs are: (1) Construction and operation do not require bidding for concessions to explore natural resources (waterfalls); (2) Freedom to commercialise electricity with consumers with demand equal to or above 500 kW; (3) Qualification for a discount of 50 % in welling tariffs; in some circumstances it is 100 %; (4) No tax collection for the use of natural resources; and (5) Free access to the integrated network system, provided that the technical specifications are met.

The major risk is that SHPs are not controlled by the National System Operator (NSO) and consequently are exposed to rainfall instability, which may require electricity acquisition in the spot market; nevertheless, this risk can be minimised.

Electricity tariff is freely negotiated between SHPs and consumers. The government set reference values for electricity generated by alternative sources at the start of the PROINFA programme (Table 7.5), and the idea is that the real market will converge to these prices as they grow. It is interesting to note from Table 7.5 that a significant subsidy was allocated for PVs and wind-based electricity, while SHPs

Table 7.4 SHP, biomass and wind installed capacity—Brazil-2007. (Source: ONS e CMSE 2007)

Electric source	Installed power (MW)
Small hydro plants (SHPs)	2235
Biomass	499
Wind	219
Total	*2953*

Table 7.5 Electricity tariffs in 2004 set by PROINFA as a function of primary energy—Brazil. (Source: Prepared by the author based on Bercht et al. 2002; Carlos de Carvalho 2004)

Source	R$/MWh	US$/MWh
Competitive level	113.10	38.45
Steam coal	117.02	39.79
SHPs	123.94	42.14
Biomass-sugar cane	93.77	31.88
Biomass-rice husks	103.20	35.09
Biomass-firewood	101.35	34.46
Biomass-landfill gas	169.08	57.49
Wind: Use factor <32.4 %	204.35	69.48
Wind: 32.4 % < Use factor <41.9 %	From 180.18 to 204.35	From 61.26 to 69.48
Wind: Use factor >41.9 %	180.18	61.26
PVs	412.87	140.37

Table 7.6 PROINFA status by August 2009. (Source: MME 2009)

Energy source		Commercial operation under PROINFA		Construction completed/waitin	Under construction		Not under construction: Turn-key contract		Not under construction: Traditional contract		Not under construction: Total		Contract cancelled/Under judgement		Total contracted
SHP	Number	46	73.0%	0.0	15	23.8%	0	0.0%	1	1.6%	1	1.6%	1	1.6%	63
	MW	925.5	77.7%	0.0	249	20.9%	0.00	0.0%	6.70	0.6%	6.70	60.0%	10	0.8%	1191
BIOMASS	Number	19	70.4%	1.0	1	3.7%	0	0.0%	0	0.0%	0	0.0%	6	22.2%	27
	MW	504.3	73.6%	10.0	38	5.3%	0.00	0.0%	0.00	0.0%	0.00	0.0%	134.9	19.7%	687
WIND	Number	22	42.6%	0.0	14	25.9%	14	25.9%	3	5.6%	17	31.5%	0	0.0%	54
	MW	385.4	27.1%	0.0	445.8	31.3%	381.34	26.9%	210.40	14.8%	591.74	41.6%	0	0.0%	1423
TOTAL CONTRA	Number	88	61.1%	1.0	30	20.8%	14	9.7%	4	2.8%	18	12.5%	7	4.9%	144
	MW	1815.3	55.0%	10.0	739.8	22.1%	381.34	11.6%	210.40	6.6%	591.74	18.1%	144.9	4.4%	3302
Sub total SHP	Number	61				96.8%							2	3.2%	63
	MW	1175				98.6%							17	1.4%	1192
Sub total BIOMASS	Number	21				77.8%							6	22.2%	27
	MW	550				80.3%							135	19.7%	685
Sub total WIND	Number	37				68.5%							17	31.5%	54
	MW	831				58.4%							592	41.6%	1423
Sub total ALL	Number	119				82.6%							25	17.4%	144
	MW	2556.06				77.5%							743	22.5%	3299

and biomass-based generation got modest or even no subsidy as compared to natural gas or oil derivative electricity units.

The proposed tariffs set an upper limit for electricity commercialisation inside PROINFA, causing a significant lack of interest in the programme. The selection of the low tariffs was a real mistake, since the programme has attractive components (see Carlos de Carvalho 2004).

As can be seen from Table 7.6, the major share of expected potential electricity installed should be wind electricity (53 plants and 1423 MW) followed by SHP (63 plants and 1191 MW). By the middle of 2009, SHP was leading with 77.7 % of its promised capacity already operational and 20.9 % under construction, followed by biomass with 73.6 % in operation and 5.3 % under construction. Wind electricity was far behind.

7.8 Wind Energy

For several years the potential of wind energy in Brazil has been recognised (CBEE 1998). Figure 7.25 shows wind potential in Brazil. Nevertheless, the installed capacity at the end of 2009 was only 359 MW (EPE 2009). Motivated by a very favourable report issued by EPE in 2009 (EPE 2009) a special bidding for wind energy providers was carried out in December 2009. More than 10,000 MW was offered through 441 projects which qualified for the bidding. At the price of R$ 148/MWh, 1807 MW of new capacity was contracted (http://www.epe.gov.br/imprensa/PressReleases/20091214.1pdf). This potential will be distributed in 71 plants and contracted by the electric system for a period of 20 years. They were all required to be in operation by July 2012.

The major driver for the success in the wind contracts was the new regulation issued by the Electricity Board Authority. The regulation has several innovative aspects which were introduced to facilitate the participation of renewable energy sources in the electricity market.

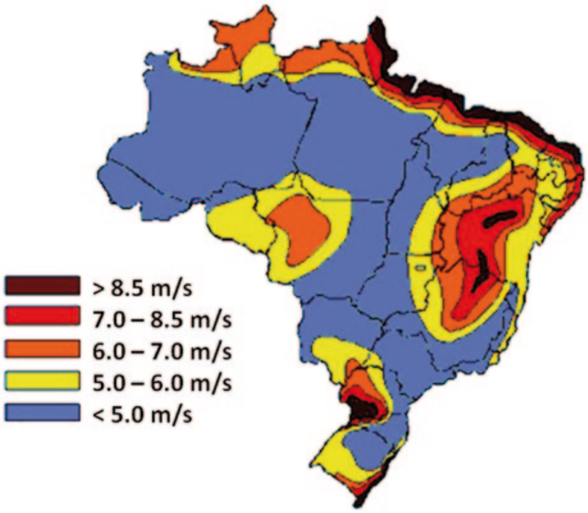


Fig. 7.25 Wind speed—Brazil. (Source: Feitosa 2005)

Availability-based contracts are useful for thermal generation from biomass. For such sources, variable production costs are negligible and there is little uncertainty in the delivery of the amount contracted. However, they could be exposed to high financial risk during the non-harvest period since they would have to buy electricity at the spot market, which is quite unstable regarding the price. Considering that a contract based on availability requires the delivery of a certain amount of electricity accumulated during an agreed time period (EPE 2009), it is easier for the supplier to overproduce during more favourable feedstock conditions and under-produce when feedstocks are short.

For wind energy a contract based on availability would require an economic evaluation based on wind speed and frequency, which are not fully available. On the other hand, wind energy has similar characteristics with small hydroelectric plants, where electricity production is always possible but is linked to the volume of water available. Thus, another contract model was created to provide a better guarantee to the producer, similar to the existing one for small hydro. A model of annual accounting was created, with some margin for supply variability mitigating the natural uncertainty.

On top of that, renewable electricity plant construction is being driven by several transmission contracts that can help the supplier. Access to the electricity grid is guaranteed for any supplier and access can be obtained through three procedures: (1) access to the basic grid, (2) access to the distribution grid, and (3) access to the basic grid through transmission installation of exclusive interest of such electricity producers called shared connection.

With these creative policies, renewable energy electricity providers, including the ones using wind, are entering the market, and based on the results of the 2009 bidding there is good evidence that the forecast set by EPE and shown in Table 7.7 is underestimated.

Table 7.7 Evolution of electric installed capacity by primary energy source—Brazil 2008–2017 (MW)

Source	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Hydro	79.31	76.19	72.66	71.23	70.71	68.47	67.62	68.27	69.70	70.98
Smal Hydro	3.87	4.81	5.44	5.35	5.30	5.31	5.78	5.51	5.22	5.00
Nuclear	1.97	1.87	1.74	1.67	1.65	1.55	2.51	2.39	2.27	2.17
Fuel oil	1.34	1.56	2.96	4.04	4.33	6.88	6.64	6.33	6.00	5.75
NG	8.81	8.50	8.10	8.19	8.53	9.33	9.01	8.59	8.14	7.80
Diesel	1.62	2.35	2.34	2.24	1.75	1.22	1.18	1.12	1.06	1.02
Coal	1.39	1.32	1.23	1.47	2.03	2.18	2.37	2.26	2.14	2.05
Biomass	0.96	1.53	3.47	3.80	3.75	3.23	3.12	2.97	2.82	2.70
Producer gas	0.19	0.64	0.60	0.57	0.56	0.53	0.51	0.49	0.46	0.44
Potential plants	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.61	0.58
Steam-based	0.27	0.25	0.24	0.23	0.22	0.21	0.20	0.19	0.18	0.18
Wind	0.27	0.97	1.24	1.19	1.17	1.10	1.06	1.01	0.96	0.92
Nuclear	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.43	0.41
Total	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*

Further, the price offered in this last bidding was quite low compared to the price of other new and renewable energy sources (biomass and small hydro), opening a bright future for wind power in Brazil.

7.9 Energy Efficiency

Energy efficiency is considered one of the largest clean energy sources. Examining the ratio GNP/toe consumed for Brazil (Fig. 7.4), the result is disappointing and one of the immediate conclusions is that apparently little effort has been dedicated to energy efficiency improvements.

Unlike most developing countries, Brazil has had, for a long time, government programmes to promote energy efficiency that are administered separately for electricity and fuels through two state-owned companies, Eletrobrás and Petrobrás.

- PROCEL, for electricity, was established in late 1985. The programme is managed by Eletrobrás, the federal holding company in the power sector.
- CONPET, for oil and gas, was established in 1991. The programme is managed by Petrobrás, the national oil and gas company.

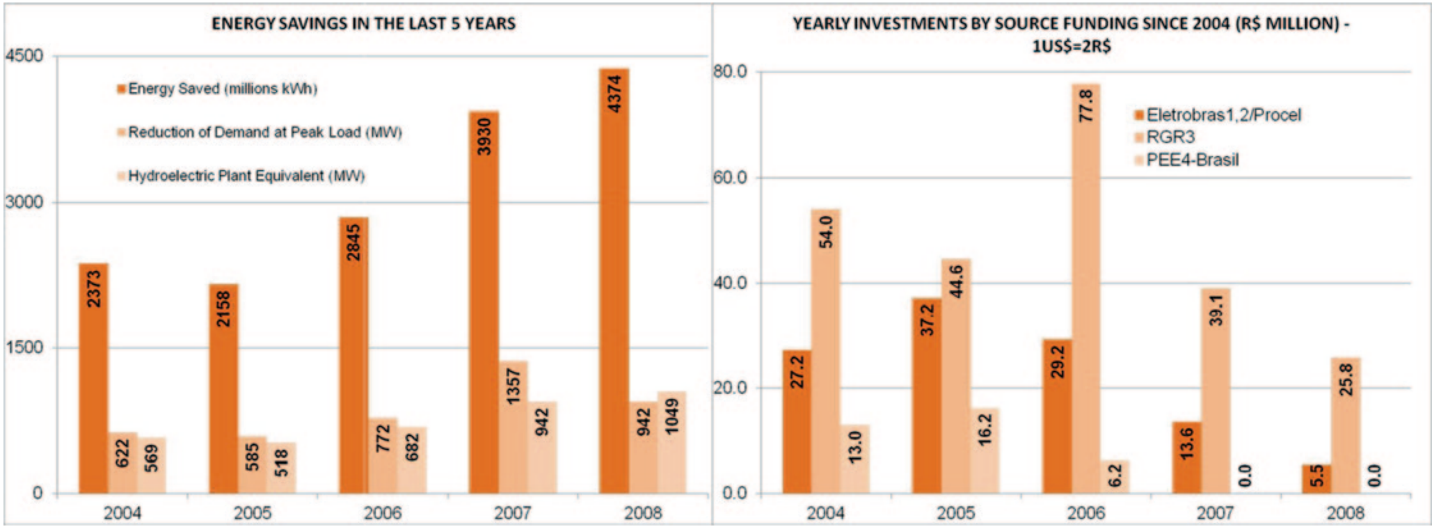
The electricity efficiency (EE) programme is substantially larger than that for fuels—which is mostly focused on initiatives in the transport sector. Apart from PROCEL, two other programmes for electricity efficiency have been established since the late 1990s:

- The public benefit EE wire-charge on utility revenues[8] for energy efficiency, which is managed by the utilities, with oversight by ANEEL, the regulator for the power sector.
- The RELUZ programme for subsidised financing of improved efficiency of public lighting, using the resources of Eletrobrás.

Government programmes have achieved significant EE gains in some areas, for example, with appliance labelling programmes and in public lighting. Figure 7.26 shows quantitative results due to PROCEL activities from 2004 to 2008. The results are impressive mainly when compared to the volume of the investments.

Taking into consideration the accrued results of PROCEL initiatives in the period of 1986–2008, the overall energy savings obtained totalled 32.9 million MWh, representing:

[8] The EE wire charge represents 1 % of the bruit revenued from energy utilities. When established, the full budget was used for energy efficiency improvements. At present, only 0.5 % is for this purpose. The remaining money is shared by EPE operations and for financing R&D in the energy sector. The money is paid by all energy consumers once the 1 % is added on top of the price charged by the utilities.



1) Includes only the Eletrobras budgetary resources invested in each year
2) Eletrobras costing defined as: cost of human resources, physical infraestructure (buildings and equipments) and inputs such as transportation, and electricity plus water consumption
3) RGR is a Fund for electricity feeded by charge at the consumer electricity bill
4) PEE- Brasil is an Energy Efficiency Program

Fig. 7.26 Quantitative results due to PROCEL activities in the period 2004–2008. (Source: 2008 PROCEL results 2008)

- Sufficient energy to supply 18.9 million households for 1 year; or
- Enough electricity to supply approximately 27,000 new, small and medium-sized industries employing 2.7 million workers for 1 year; or
- Energy produced in 1 year by a hydroelectric power plant with a capacity of approximately 7890 MW.

However, little attention has been given to the market segment, that is, energy efficiency projects in existing industries and buildings. The consolidation of this 'EE services sector' requires overcoming historic barriers to implementing economically viable projects (Poole et al. 2006).

One relevant programme has been the EE wire-charge, which has created an important source of income for some energy service companies (ESCOs). However, the operations are structured in such a way that they have so far done nothing to develop commercial financing of projects and little to consolidate a commercially sustainable EE services sector.

7.9.1 Shortage of Commercial Bank Credit for EE Projects

In Brazil, third party financing is mostly via debt. Capital markets are relatively small, though there has been some evolution of equity markets (both public and private).

The interest rates on credit for 'active operations' (i.e. excluding directed operations for rural and housing finance and BNDES operations) are very high by international standards (see below). Spreads are much higher for small and mid-size companies than larger companies.

The Brazilian development bank, BNDES (Banco Nacional de Desenvolvimento Econômico e Social), is the main vehicle of the federal government for financing development and is also the main source of financing for long-term credit in the Brazilian financial market. The BNDES makes loans either directly or indirectly through accredited commercial banks. Most loans for EE projects would fit in the latter category.

The interest rate on indirect loans is composed of the TJLP (long-term interest rate), the administrative spread of the BNDES, and the spread of the intermediary bank (which varies within a range, depending on the borrower). The interest rate in 2008 was 13 % or less, after some years when it was near 15 %. This is substantially lower than the interest rates for 'active' or 'free' operations of commercial banks. The BNDES has had a credit line specifically for EE projects for some years. However, it has almost never been used, due in large part to the guarantees required.

In general, guarantee requirements have been the single greatest barrier to ESCOs in accessing bank credit. A response to this problem, which has long been advocated, is the creation of a guarantee facility (Fundo de Aval) specifically for the credit risk of EE projects. A programme—called PROESCO—seeks to eliminate the requirement for collateral, though personal guarantees are still needed (see Poole et al. 2006).

7.9.2 Development of the Energy Efficiency Services Sector in Brazil

Energy service companies, or ESCOs, can make important contributions to transforming the market for EE products and services on a sustainable basis.

In Brazil, some firms started providing specialised energy rationalisation and efficiency services in the early 1980s, but a specific ESCO sector only emerged in the mid-1990s. This period saw the beginning of the definition of EE services as a sector and the public discussion of energy performance contracts (EPC). An EPC may be broadly defined as a contract between the ESCO and its client, involving an energy efficiency investment in the client's facilities, the performance of which is somehow guaranteed by the ESCO, with financial consequences for the ESCO if the promised results are not achieved.

There have been periods of growth in the market for EE services, followed by periods of stagnation or even retraction. Over time the market has shown growth. It is estimated that the annual revenue of the sector for efficiency projects grew from roughly US$ 16 million in 1996 to about US$ 25–30 million on the eve of the energy crisis of 2001–2002 and reached a level of US$ 30–35 million in 2004. It must be emphasised that the estimates are quite rough. The growth is probably underestimated, since not all EE services companies are included—especially in the area of co-generation (Poole et al. 2006).

It is important to note the impact on energy efficiency as a consequence of the electricity shortage of 2001. As already discussed, electricity supply is mainly provided by hydro sources. As such, historically the electric system has added significant water storage reserves to face low rainfall periods. In the 1980s and 1990s, the stored energy was enough to cover three consecutive years of low rainfall, which was the worst case that had been reported since 1900. Even so, the system reliability was limited and operated for many years with a risk of shortage below 3 %. By the end of the 1990s there was unusual economic progress, not matched by investments in new storage capacity. With the occurrence of only two consecutive years with a rainfall index below average, the country suffered a very serious electricity shortage. Electricity had to be cut by 20 % in several end-use sectors (Poole et al. 2006).

As a consequence of this cap on consumption, many energy-efficient technologies penetrated households in Brazil, but probably the one with the largest impact was the use of compact fluorescent lamps. The major lesson is that behavioural changes triggered by the energy situation were permanently adopted by the population. Unfortunately, the lesson learnt by the residential sector did not have the same effect in other sectors of the economy, namely, commercial (Fig. 7.27) and industrial.

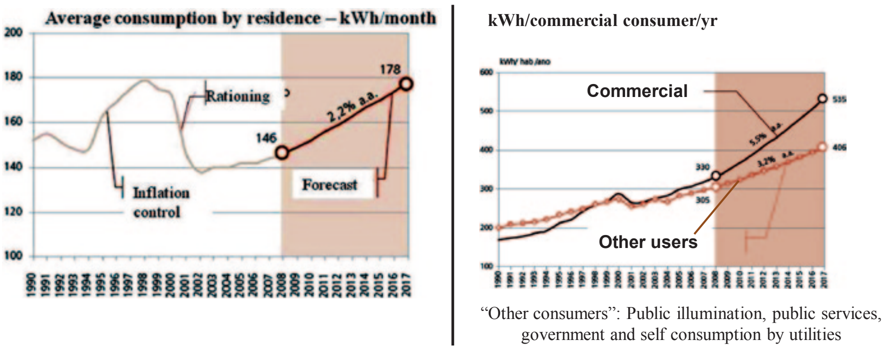


Fig. 7.27 Commercial electricity consumption—Brazil 1990–2017. (Source: EPE 2008)

7.10 Energy Future in Brazil

It is very interesting to compare the official energy development energy programme and the environmental political position of the country. The official energy plan, (EPE 2008), which is essentially a guidance programme since the energy sector is currently driven by public and private investments, (see, for example, Table 7.8 describing the evolution of the electricity market) concludes that more than US$ 430 billion (1.8 R$ = 1 US$) will be invested in the period of 2008–2017 to provide reliable energy supply to the population (see Table 7.9). Furthermore, the programme states that more than 90 % will be invested in traditional energy sources. And even stranger is the fact that oil exploration and production will be responsible for 69.9 % of this investment, much above the investments to supply electricity (23.6 %). Thus, official plans are prepared with the strong participation of well-established energy companies in the area of oil, gas and electricity while renewables are unfairly represented.

Table 7.8 Regulatory models used in Brazil in the past 30 years. (Source: http://www.ccee.org.br)

Old model (up to 1995)	Free market model (1995–2003)	New model (2004)
Integrated utilities	Fragmented utilities (gener., transm., distr., commercialisation)	Utilities divided by activities (gener., transm., distr., commercial., import.& exportation)
Mainly state-owned utilities	Utilities privatization is major goal	Competition between public and private utilities
Monopolies-no competition	Competition for generation and or commercialization	Competition in generation and commercialization
Captive consumers	Captive and free consumers	Captive and free consumers
Tariffs regulated to all consumers	Generation and commercialization tariffs are freely negotiated	Free market with free tariffs for generation and commercialisation; Regulated market (biddings and contracts closed by lowest tariff)

gener. = generation; transm.= transmission; dist. = distribution

Thus, from the official planning document it is possible to see that most of the money is addressed to conventional energy sources, while on the other side, the plan presents an optimistic view of the penetration of new and renewable sources of energy. As an example, Fig. 7.28 has three scenarios for ethanol from sugarcane up

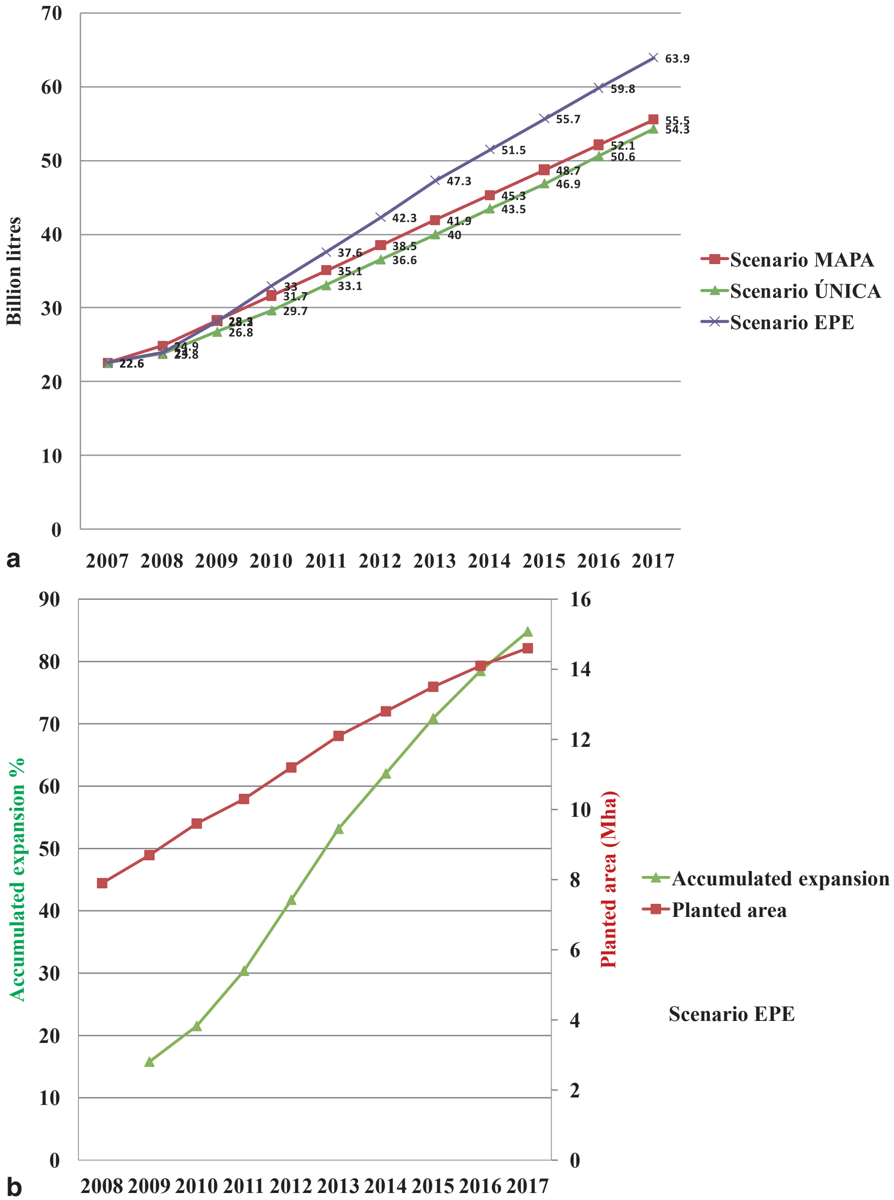


Fig. 7.28 **a** Ethanol production for different scenarios—2008–2017 **b** Sugarcane planted area—Brazil 2008–2017. (Source: EPE 2008)

Table 7.9 Total investments in the energy supply sector (2008–2017)—Brazil. (Source: EPE 2008)

Energy sector	Investment (2008 R$)	Relative share (%)
Electricity supply	*181*	23.60
Generation	142	18.50
Transmission	39	5.10
Oil	*536*	*69.90*
Exploration	333	43.40
Oil derivatives supply	182	23.80
Refineries (new and expansion)	21	2.70
Infrastructure for transport	*50*	*6.50*
Natural gas	40	5.20
Supply	9	1.20
Infrastructure for transport	*1*	0.20
LNG conversion facilities	*767*	100.00
Biofuels	*8.01*	–
Ethanol mills	6.2	1.00
Infrastructure for transport/storage	1.2	0.20
Biodiesel supply	0.61	100.00
Total	*775.01*	–

to 2017. It is clear that doubling ethanol production will require much more investment, while the forecast of the official energy plan is around 6 billion (Table 7.9).

Investments will also be needed in bioelectricity since at present, almost all new sugar mills include a high-pressure boiler to obtain revenue from the sales of electricity (Fig. 7.29).

Regarding biodiesel, the consumption forecast for the period of 2008–2017 is shown in Fig. 7.30, and is fully determined by the compulsory consumption since the supply potential is much higher and does not set any constraints on availability (Fig. 7.31), while the cost is higher than for conventional diesel fuel. The forecasted demand is limited due to serious economic constraints, which is the reason to assume that no voluntary consumption will occur. Table 7.10 shows the expected prices for biodiesel feedstock. On top of these prices, it is necessary to account for conversion costs to biodiesel. If these costs are assumed to increase the feedstock price by 20 %, which is a conservative approach (IEA 2007), the price of biodiesel will be above US$ 2.50/l for sunflower, rapeseed, and soya before 2015, while for palm oil and national castor oil it will be US$ 2.20/l by 2017. Since the price of diesel is considered almost stable during this period, and even somewhat lower than in 2008, its cost for most of the years will be around US$ 1.00/l to the final consumer. Under this scenario only used oil and waste oil can be economically competitive, but their availabilities are quite modest (Fig. 7.31).

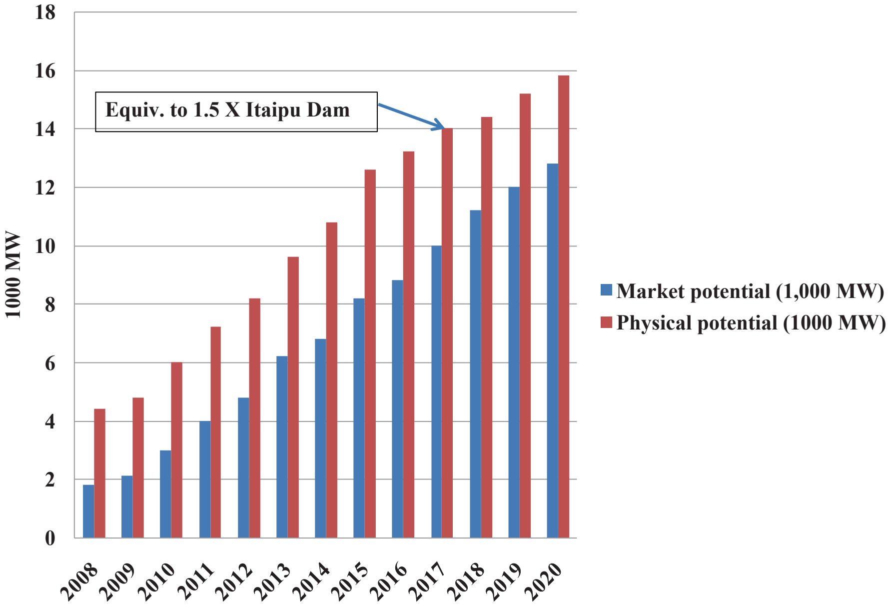


Fig. 7.29 Potential bioelectricity from sugar cane—Brazil 2008–2020. (Source ÚNICA—Etanol e Bioeletricidade 2009)

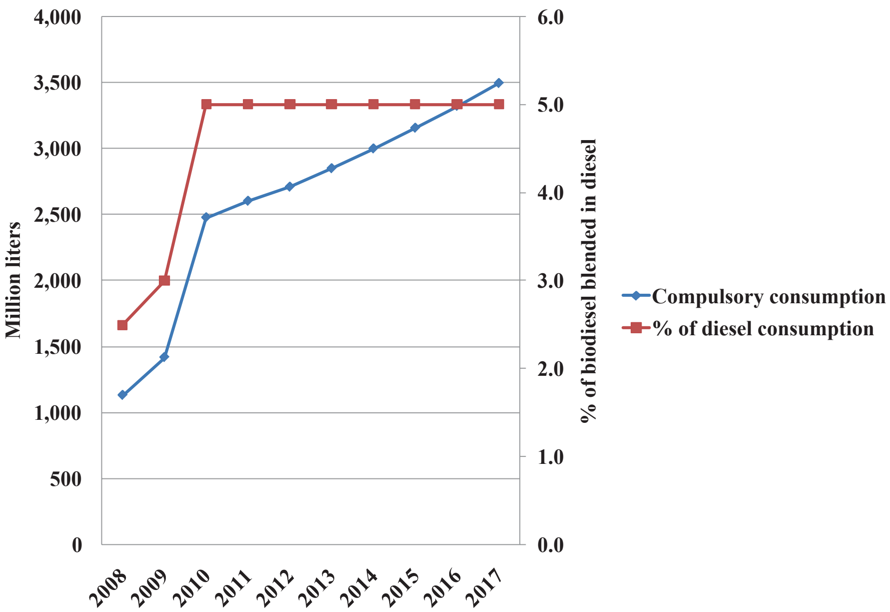


Fig. 7.30 Forecasted biodiesel consumption—Brazil 2008–2017. (Source: EPE 2008)

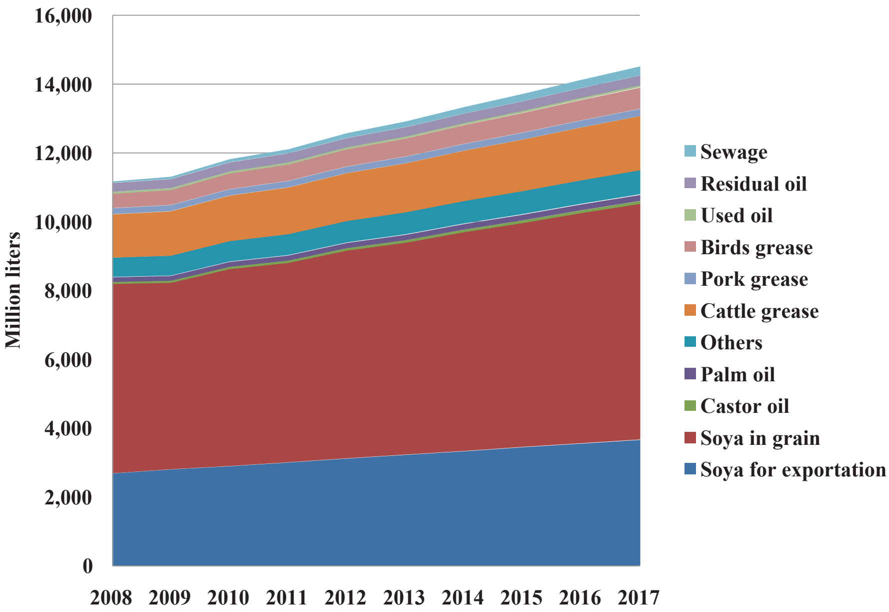


Fig. 7.31 Vegetable oil availability—Brazil 2008–2017. (Source: EPE 2008)

Brazil is a large exporter of soya as grain as well as for feed, and thus the displacement of this crop for fuel may impact the international market with an increase in food and feed prices. Assuming that biodiesel consumption by 2017 will be set by the compulsory index (5 % blend), 3,500 million l of biodiesel will be needed, while the potential supply will be 14,500 million l. Thus, fuel requirements may reduce the availability for food and feed by 24 % if production remains stable. Such reductions will induce further soya plantation or other vegetable oil feedstock. This issue is known as indirect land use change (ILUC) and is a source of extra GHG emission. The USEPA has already chosen an approach for its calculation and concluded that biodiesel based on soya will emit more GHGs than diesel (4 % more) (Fig. 7.17).

This issue, associated with the high prices of biodiesel from several feedstocks, is motivating a discussion with policymakers about the replacement of diesel by ethanol. There are several efforts in this direction (Cenbio 2009). Some are very simple, requiring the use of Otto engines to replace diesel ones. Others are more sophisticated like the use of 2-injection systems and preserving the diesel cycle, which is powered by diesel and ethanol in variable proportions. Another interesting option is the use of additivated ethanol in diesel engines (Cenbio 2009). Ethanol can have its cetane number increased by additives and then become a suitable fuel for the diesel cycle. Considering an ethanol price at US\$ 550/m^3 and the additive at SKR 24 per kg, it is possible to show that additivated ethanol has almost the same price as diesel.

Table 7.10 Biodiesel feedstock price (US$/t). (Source: EPE 2008)

Year	Soya (average)	Rapeseed	Sunflower	Palm oil	Peanuts	Castor oil (international)	Animal Grease	Castor oil (national)	Used oil	Waste oil
2008	1097.31	1482.97	1542.53	1045.57	1887.61	2004.71	771.28	907.96	658.39	219.46
2009	1127.20	1280.73	1423.65	1003.69	1829.45	2059.32	792.29	932.69	676.32	225.44
2010	1208.09	1413.62	1464.49	1026.39	1857.77	2207.10	849.14	999.62	724.86	241.62
2011	1284.00	1459.46	1507.69	1056.97	1878.07	2345.78	902.5	1062.43	770.4	256.8
2012	1315.59	1436.40	1520.91	1080.87	1884.55	2403.49	924.7	1088.57	789.36	263.12
2013	1337.47	1467.18	1548.42	1110.49	1888.87	2443.47	940.08	1106.68	802.48	267.49
2014	1366.32	1504.59	1581.78	1146.06	1901.55	2496.16	960.35	1130.54	819.79	273.26
2015	1395.84	1543.47	1618.85	1185.26	1916.37	2550.10	981.1	1154.97	837.5	279.17
2016	1425.78	1586.55	1658.27	1229.25	1927.17	2604.80	1002.15	1179.75	855.47	285.16
2017	1466.30	1642.45	1701.34	1275.48	1946.56	2678.83	1030.63	1213.28	879.78	293.26

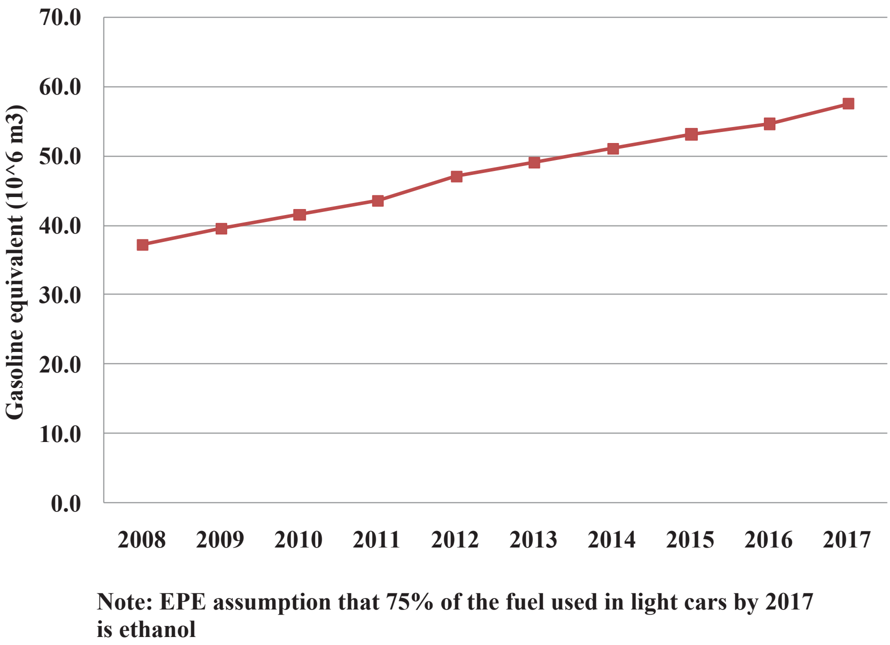


Fig. 7.32 Total fuel demand for Otto-cycle light vehicles—2008–2017. (Source: EPE 2008)

Examining Fig. 7.32, which shows in-country potential ethanol demand, and comparing it with Fig. 7.28a, which shows production, the large interest of the ethanol sector in Brazil is very clear regarding its use as a diesel alternative.

With respect to hydroelectricity, forecast capacity installation in the period between 2009 and 2017 is expected to reach 41,127 MW, through the construction and operation of 70 new plants (EPE 2008).

Considering that the existing installed hydroelectric capacity in 2008 was near 81,000 MW, Fig. 7.33 shows the accumulated operational capacity of hydroelectricity up to 2017, which should reach near 110,000 MW. The average load factor for hydro plants in Brazil is around 55 %, which means an expected generation of 605 million MWh per year. In reality, the average demand for all the integrated electric systems should reach 86,000 MWh/h[9] with a peak demand of 95,500 MWh/h[10] by 2017 (EPE 2008). This means that hydro plants alone, with an installed capacity of 110,000 MW, should be able to supply all the electricity demand in years that have rainfall precipitation equal to and above the historical average index.

[9] MWh/h is a unit of power and is equivalent to MW. The reason why it is presented in the former unit is because usually average demand is obtained from the measurement of consumed energy (MWh) divided by the total number of hours the consumption was recorded.

[10] For peak demand, sometimes this unit of demand is used instead of MW. The way to obtain the peak value is through recording consumption during the period when the peak was observed. In some cases the peak demand may occur for just a few minutes (or a fraction of hours).

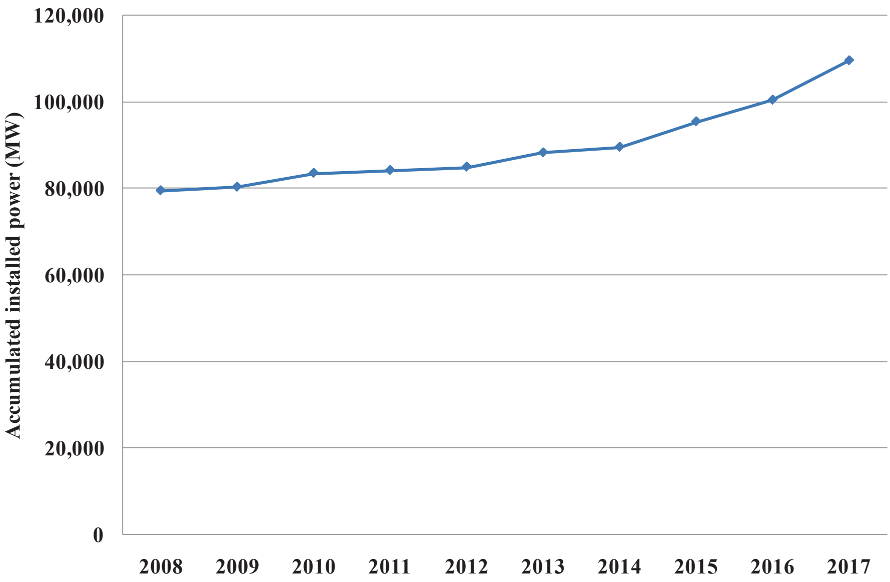


Fig. 7.33 Accumulated hydroelectric installed capacity—Brazil 2008–2017. (Source: EPE 2008)

Regarding the future of SHP and wind, both are very promising. As already discussed in Sect. 7, the installed capacity of SHP according to official plans is expected to increase to 7700 MW by 2017 (Fig. 7.24) from 2200 MW installed in 2007 (see Table 7.4). For wind, Fig. 7.34 shows that its share in non-hydro sources of electricity will increase from 1.6 to 3.8 % at least. From the discussion, as presented in Sect. 7.11, the reality may be greater than anticipated in official scenarios.

It is possible to see from Fig. 7.34 that, at least based on the official planning body, the growth of renewable sources of electricity generation is modest, while fossil fuel will present the leading role. Fuel oil and coal will have a larger share

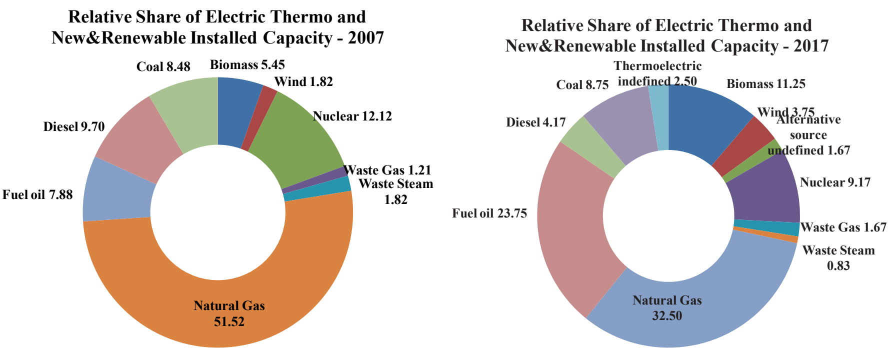


Fig. 7.34 Expected evolution of non-hydro sources for electricity generation—Brazil 2008 and 2017. (Source: EPE 2008)

in 2017 than in 2008, while biomass and wind will double their share. Such results have been criticised by some energy experts.

7.11 Conclusion

The Brazilian energy system can be considered environmentally friendly due to the significant share of renewable energy sources. For the next decades there are some concerns that renewables may lose market share if we trust official plans and the maintenance of unfair barriers created by environmental bodies on further medium and large hydroelectricity additions. Nevertheless, on one side the highly anticipated progress in the use of bioenergy, SHP and wind energy sources and, on the other side, future commitments of the country in controlling its GHG emissions may demonstrate that in the near future new and renewable energy sources should be able to guarantee that fossil fuel-based energy sources will not show the relative growth identified in the official planning programme (EPE 2008) extensively discussed in this chapter.

Also, it is clear that many renewable energy sources that started to be used for economic and financial reasons a long time ago are being seen nowadays not only as energy sources but as environmentally friendly due to their GHG emission mitigation capacity. The country's population is aware of the full consequences of climate changes and about the capacity of the country in being an important supplier of renewable energy for the internal and external market. This last point is another important driver for the interest in such energy options since economic gains can be obtained.

Polices for further deployment of renewables are in place and all that is required are minor adjustments to them to overcome the few remaining barriers. Not only is the government involved in this effort but large and medium-size private investors are also working together, showing that governance is already in place in Brazil to promote new energy sources.

The major barrier, at this moment, is related to the large oil resources identified on the southeast coast of the country. Exploration of such oil will consume a significant share of the energy sector investment (Table 7.9) and will be a competitor for money allocation to other energy sources. Some experts understand that investments in renewables may be a more reliable alternative, considering the necessary future behaviour of major energy-demanding countries to address potential new commitments to mitigate climate change. As the country experiences economic progress, the cost of money decreases and investments with a long payback time are better considered. Thus, if oil wells have an expected lifetime of less than two decades, this point nowadays should be taken into account as it negatively impacts the oil industry.

References

BEN, National Energy Balance (2009) Published by the Ministry of Mines and Energy. https://www.ben.epe.gov.br/

Bercht AJ, Bremer O, da Silva PR (2002) Informe sobre as PCH's prepared for the Banco Regional de Desenvolvimento do Extremo Sul Porto Alegre.

CANAMBRA Report (1959) Cited in Gomes 2002, prepared by Canambra Consulting Engineers Ltd

Carlos de Carvalho HB (2004) PROINFA—Programa de Incentivo às Fontes Alternativas de Energia Elétrica, presented at UNICA, São Paulo, 16 Apr 2004

CBEE-Centro Brasileiro de Energia Eólica (1998) Wind energy atlas from the Northeast region—Brazil, Federal University of Pernanbuco, Pernambuco and ANEEL—National Agency of Electric Energy, Ministry of Mines and Energy, Brasilia, Brazil. http://www.aneel.gov.br/aplicacoes/Atlas/energia_eolica/6_3.htm

Cenbio (2009) Report on experiences of ethanol buses and fuel stations in São Paulo—Final Report Brazilian reference center on biomass, Institute of Electrotechnology and Energy, University of Sao Paulo, Brazil, prepared for the Best Project, TREN/05/FP6EN/S07.53807/019854, Dec 2009.

Costa RE et al (2006) The energy balance in the production of palm oil biodiesel—two case studies: Brazil and Colombia. Federal University of Itajubá/Excellence Group in Thermal and Distributed Generation NEST (IEM/UNIFEI)

Crutzen PJ, Mosier AR, Smith KA, Winiwarter V (2008) N_2O release from agro-biofuel replacing fossil fuels. Atmos Chem Phys 8:389–395

Empresa de Planejamento Energético (2009) Proposta para a Expansão da Geração Eólica no Brasil (in Portuguese) (Technical note PRE 01/2009-r0). Ministry of Mines and Energy, Brasilia, Brazil

ENVOLVERDE (2008, June) Eco & Ação: ecologia e responsabilidade. http://www.ecoeacao.com.br/index.php?option=com_content&task=view&id=7982&Itemid=44

EPA (2010) Renewable fuel standard program (RFS2) Regulatory impact analysis. Assessment and Standards Division Office of Transportation and Air Quality, U.S. Environmental Protection Agency, EPA-420-R-10-006, Feb 2010

EPE-Empresa de Planejamento Energético (2008) Plano Decenal de Expansão de Energia 2008–2017. Prepared by EPE for the Ministry of Mines and Energy, Secretariat of Planning and Energy Development, Brasilia, DF

Fargione J, Hill J, Tilman D, Hawthorne P (2008) Land clearing and the biofuel carbon debt. Science 319:1235–1237

Feitosa EA (2005) Energia Eolica no Brasi: Situação Atual e Perspectivas. Conference sustainable energy generation and use in Brazil: the next 20 years, Recife, 2005

Ferreira Filho JBS, Felipe FI (2007) Crescimento da produção agrícola e o consumo de tratores de rodas no Brasil entre 1996–2005 (in Portuguese). Presented at XLV Congress of Brazilian Economy, Administration and Rural Sociology Society, July 2007

Gibbs HK, Johnston M, Foley JA, Holloway T, Monfreda C, Ramankutty N, Zaks D (2008) Carbon payback times for crop-based biofuel expansion in the tropics: the effects of changing yield and technology. Environ Res Lett 3:10.034001. doi:10.1088/1748-9326/3/3/034001

Gomes ACS et al (2002) BNDES 50 anos, Cap. XIV: O Setor Elétrico, Margraf, 2003

IEA (2007) IEA energy technology essentials. Biofuel Production, ETE02, IEA, Paris, France, Jan 2007

IEA (2009a) Key world energy statistics, 2009 and previous years. IEA, Paris, France

InfoJus (2010) http://www.infojus.com.br/noticias/lula-sanciona-politica-nacional-de-mudancas-climaticas/. Accessed 20 March 2010

MAPA, Ministerio da Agricultura, Pecuaria e Abastecimento (2009) Anuário Estatístico da Agroenergia, Brasilia, DF

MOREIRA, J.R., 2010. Brazilian Perspectives on Development of Clean Energy, Multi-Country Research Dialogue on Emerging Economies in the New World Order: Promises, Pitfalls and Priorities, New Delhi, India, April 12–13, 2010

MME (2009) Programa de Incentivo Às Fontes Alternativas de Energia Elétrica. General coordination of alternative energy sources. Department of Energy Development, Secretariat of Planning and Energy Development, Ministry of Mines and Energy.

Moreira JR (2003) Biodiesel in Brazil—potential and CDM projects. Bioenergy World Americas

Moreira JR (2008) Evaluation of the ethanol cost to Brazilian society. Internal report, Cenbio, University of Sao Paulo

Moreira JR, Goldemberg J (1999) The alcohol program. Energ Policy 27:229–245

Nelson RG (2006) Energy analyses/balances of biodiesel: soybeans and beef tallow. Presentation to Select Joint Committee on Energy, Topeka, Kansas

Neto JA et al (2004, Nov) Balanço energético de ésteres metílicos e etílicos de óleo de mamona. I Congresso Brasileiro de Mamona: Energia e Sustentabilidade

ONS- National System Operator and CMSE- Monitoring Committee of the Electric System (2007) Planejamento Anual da Operação Energética (PEN) (in Portuguese). Federal Government, Brasilia, Brazil. http://www.ons.org.br/download/sala_imprensa/pen_ciclo-2007.pdf. Accessed Dec 2007

Pacca S, Moreira JR (2009) Historical carbon budget of the Brazilian ethanol program. Energ Policy 37:4863–4873

Poole A, Meyer AS, de Lima e Silva O, Starosta J, Amaral MC, Bandeira de Mello E, Murasawa L (2006) Developing financial intermediation mechanisms for energy efficiency projects in Brazil, China and India—Brazil Country Report—Executive Summary. ESMAP, UNDP, Riso

Poppe M (2004) Biofuels for Latin America and the Caribbean: lessons from Brazil. CGEE-Center for Strategic Management and Studies. http://www.eclac.org/dmaah/noticias/paginas/5/23775/poppe.pdf

Proalcool—Programa Brasileiro de Alcool (2010) http://www.biodieselbr.com/proalcool/pro-alcool.htm

PROCEL Results (2008) Procel, Eletrobras

Programa de Incentivo Às Fontes Alternativas de Energia Elétrica (2009) Coordenação-Geral de Fontes Alternativas Departamento de Desenvolvimento Energético, Secretaria de Planejamento e Desenvolvimento Energético, Ministry of Mines and Energy

Sheehan J (1998) An overview of biodiesel and petroleum diesel life cycles. U.S. Department of Agriculture and U.S. Department of Energy

Smeets WE, Bouwman LF, Stehfest E, van Vuuren D, Posthuma A (2009) Contribution of N_2O to the greenhouse gas balance of first-generation biofuels. Glob Change Biol 15:1–23

Sternberg R (2008) Hydropower: dimensions of social and environmental coexistence. Renew Sust Energ Rev 12(6):1588–1621

Uligh A, Goldemberg J, Teixeira Coelho S (2008) O Uso de Carvãovegetal na Indústria Siderúrgica Brasileira E O Impacto Sobre as Mudanças Climáticas. Rev Bras Energ 14(2):67–85

Chapter 8
Energy Development and Efficiency in China

Gao Shixian

8.1 Review of China's Economy and Energy

8.1.1 Status Quo and Features of China's Economy

China is the most populous country in the world. By the end of 2010, China's total population (not including the populations of Hong Kong and Macau special administrative regions, and Taiwan Province, see below) had reached 1.34 billion, making up about 20 % of the world total. Of China's total population, 50.1 % is rural, yet there is a world of difference in the quantity and quality of energy consumed by China's urban and rural residents. China's per capita rural household energy and electricity consumption is much lower than it is in urban households; for example, it was 206 kgce and 318 kWh in 2010, only 80 and 83 % of the total China average.

Since the reform and opening up in 1978, the Chinese economy has been developing rapidly. In 2010, China's GDP reached 40.12 trillion yuan, ranking second in the world in terms of the official exchange rate, but China's per capita GDP still ranks below the 100th in the world. In 2001, China's per capita GDP exceeded US$ 1000 and the country was starting to enter the stage of rapid industrialisation. Rapid economic development, especially the high-speed growth of the high-energy intensity sectors, has fuelled the rapid growth of energy consumption (Tables 8.1 and 8.2).

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Table 8.1 Output of China's high-energy intensity products. (Source: China Statistical Yearbook 2010)

	Cement (Mt)	Plate glass (M weight cases)	Pig iron (Mt)	Crude steel (Mt)	Rolled steel (Mt)
1980	80	25	38	37	27
1990	210	81	62	66	52
2000	597	184	131	129	131
2005	1069	402	344	353	378
2010	1882	663	597	637	803

Table 8.2 China's GDP indices (Year 1978 = 100). (Source: China Statistical Yearbook 2010)

	GDP	Agricul-tural	Secondary industry[a]			Tertiary industry	Per capita GDP
			Sub-total	Industry	Construc-tion sector		
1978	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1980	116.0	104.6	122.9	122.4	129.2	114.3	113.0
1990	281.7	190.7	304.1	304.9	298.8	362.1	237.3
2000	759.9	277.0	1081.8	1118.3	799.1	956.1	575.5
2005	1210.4	336.0	1807.9	1874.7	1305.0	1574.7	887.7
2010	2058.9	418.9	3202.9	3261.2	2623.4	2762.4	1471.6

Calculated at present prices
[a] The secondary industry includes the manufacturing and construction sectors

8.1.2 Status Quo and Features of China's Energy Production and Consumption

8.1.2.1 Energy Production

China's energy production has grown rapidly. The total energy production increased from 628 million t of coal equivalent (tce[1]) in 1978 to 2.97 billion tce (China Statistical Yearbook 2010) in 2010. China's energy production has ranked first since 2005. During 1978–2010, China's energy production grew at an average annual rate of 5 %; particularly since 2000, the growth of energy production has further accelerated, with the average annual growth rate during 2000–2010 reaching 8.4 %.

Coal is China's dominant energy source. In 2010, the composition of China's energy production was made up of 76.5 % of coal, 9.8 % of oil, and 4.3 % of natural gas. From Table 8.3, we see that the proportion of natural gas and hydropower, nuclear power, and wind power in the total energy output increased, while the proportion of crude oil dropped. From Table 8.4, we find that the energy output grew rapidly in the past 30 years.

[1] 1 kgce = 5000 kcal.

Table 8.3 China's energy output and composition. (Source: China Statistical Yearbook 2010)

Year	Total energy output (Mtce)	Proportion in total energy output (%)			
		Raw coal	Crude oil	Natural gas	Hydro[a], nuclear, and wind power
1978	627.7	70.3	23.7	2.9	3.1
1980	637.4	69.4	23.8	3.0	3.8
1990	1039.2	74.2	19.0	2.0	4.8
2000	1350.5	73.2	17.2	2.7	6.9
2005	2162.2	77.6	12.0	3.0	7.4
2010	2969.2	76.5	9.8	4.3	9.4

[a] Hydro-power includes large, middle and small hydro-power, same as the below

Table 8.4 Output of China's major energy products (in absolute units). (Source: China Statistical Yearbook 2010)

Year	Raw coal	Crude oil	Natural gas	Power generation	Hydro[a] power (TWh)
	(Mt)	(Mt)	(GCM)	(TWh)	
1978	618.00	104.05	13.73	256.60	44.60
1980	620.15	105.95	14.27	300.60	58.20
1990	1079.88	138.31	15.30	621.20	126.70
2000	1384.18	163.00	27.20	1355.60	222.41
2005	2349.51	181.35	49.32	2500.26	397.02
2010	3235.00	203.01	94.85	4207.16	722.17

[a] Hydro-power includes large, middle and small hydro-power

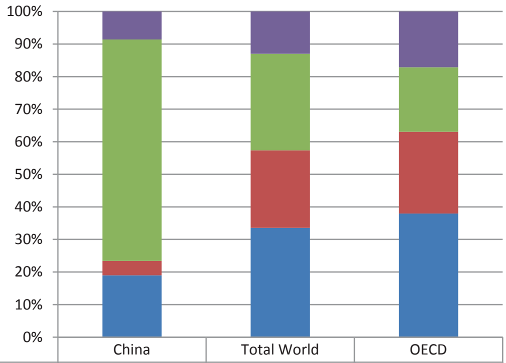
8.1.2.2 Energy Consumption

In 2010, China's total energy consumption reached 3.25 billion tce, being the largest energy consumer in the world and making up about 20% of the world total (Table 8.5).

Table 8.5 China's total energy consumption and composition. (Source: China Statistical Yearbook 2010)

Year	Total energy consumption (Mtce)	Proportion in total energy consumption (%)			
		Coal	Oil	Natural gas	Hydro, nuclear, and wind power
1978	571.4	70.7	22.7	3.2	3.4
1980	602.8	72.2	20.7	3.1	4.0
1990	987.0	76.2	16.6	2.1	5.1
2000	1455.3	69.2	22.2	2.2	6.4
2005	2360.0	70.8	19.8	2.6	6.8
2010	3249.4	68.0	19.0	4.4	8.6

Fig. 8.1 China's energy consumption structure and comparisons in 2010



	China	Total World	OECD
Primary electricity	8.6%	13.0%	17.1%
Coal	68.0%	29.6%	19.8%
Natural Gas	4.4%	23.8%	25.1%
Oil	19.0%	33.6%	38.0%

Over 32 years from 1978 to 2010, the Chinese economy maintained a fairly high growth rate. With the development of the Chinese economy and the improvement in living standards, China's energy consumption has increased rapidly, with the average annual rate of increase reaching 5.6 %.

China became a net oil importer from 1993 because energy consumption was higher than production, and became a crude oil importer from 1996. The dependency rate of overseas energy is about 10 % at present.

Under the influence of energy resources and the level of economic development, an energy consumption structure focused on coal has come into being in China (Fig. 8.1).

Secondary industry is China's largest energy-consuming sector; it accounts for about 70 % of total primary energy consumption.

The secondary industry is a high-energy sector; for example, value-added of the secondary industry accounted for 46.8 % in total GDP, but energy consumption from this sector was 81.1 % in the total primary energy consumption (deducting the household sector) in 2010.

With the rapid growth of the high-energy intensity sectors in the process of industrialisation, the composition of energy consumption in the secondary industry grew, but then it plateaued (Table 8.6).

The level of per capita energy consumption, especially of quality energy consumption, reflects the level of economic development of a country. In 2008, China's per capita energy consumption amounted to 1.51 toe, accounting for 90 % of the world average (1.68 toe[2]), while that of the USA and Japan amounted to 7.55 and 3.97 toe, respectively. China's per capita quality energy consumption was even lower; the per capita consumption of natural gas and oil registered 13.0 and 16.0 %, respectively, of the world average (Table 8.7).

[2] 1 kgce = 10,000 kcal.

Table 8.6 China's energy consumption composition by sector. (Source: China Energy Statistical Yearbook 2011)

	1980	1990	2000	2005	2010
Primary industry (%)	7.8	4.9	2.7	2.6	2.0
Secondary industry (%)	66.3	69.7	72.8	72.9	72.5
Tertiary industry (%)	7.7	9.4	13.8	13.8	14.9
Household (%)	18.3	16.0	10.7	10.7	10.6

Table 8.7 International per capita energy consumption in 2008. (Source: Calculated based on selected BP statistical data)

	Oil	Natural gas	Coal	Nuclear power	Hydro-power	Total
USA	2.90	1.97	1.86	0.63	0.19	7.55
France	1.49	0.64	0.19	1.61	0.23	4.16
Germany	1.44	0.90	0.98	0.41	0.05	3.78
Italy	1.35	1.17	0.28	–	0.15	2.95
UK	1.28	1.38	0.58	0.19	0.02	3.45
Australia	1.99	0.99	2.41	–	0.16	5.55
Japan	1.74	0.66	1.01	0.45	0.12	3.97
Korea	2.13	0.74	1.36	0.70	0.02	4.94
OECD	1.83	1.13	0.98	0.43	0.24	4.62
China	0.28	0.05	1.06	0.01	0.10	1.51
India	0.12	0.03	0.20	0.00	0.02	0.38
World	0.59	0.41	0.49	0.09	0.11	1.68
China/World	0.48	0.13	2.15	0.13	0.93	0.90
China/OECD	0.16	0.05	1.08	0.03	0.41	0.33

Unit: toe
BP British Petroleum

8.1.3 Problems Facing China's Energy Development

With the rapid development of the Chinese economy and the acceleration of industrialisation and urbanisation, there has been a constant increase in the demand for energy. As a result, constructing a stable, economical, clean, and safe energy supply system is confronted with serious challenges, which are prominently manifested in the following aspects:

- Resource constraints are conspicuous, energy efficiency is low, and the safety of the energy supply is being threatened. China's quality energy resources are relatively insufficient, hindering the enhancement of China's ability in energy supply. The energy resources are distributed unevenly—coal resources are distributed mainly in north, northwest, and south China and hydro resources are distributed mainly in southwest China, but south and east China are the major energy consuming areas, making it difficult to maintain a continuous and stable energy supply. The extensive rate of economic growth, the irrational energy structure, the low-level energy technology and equipment and the relatively backward management levels have all resulted in the fact that the energy consumption per unit GDP and the energy consumption from major energy-consuming products are higher than the average level of the major energy-consuming countries, thus aggravating the contradictions between energy supply and demand. It is difficult to meet the constantly growing consumption demand only by increasing domestic energy supplies, the dependency rate of overseas energy, in particular crude oil and natural gas, will be increasingly higher.

- Energy consumption is focused on coal, which has intensified the environmental pressure. Coal is one of the main energy resources of China, and it is difficult to change the coal-centred energy structure for some time. The relatively backward modes of coal production and coal consumption have intensified the pressure on environmental protection. Coal consumption is one of the main causes of air pollution, as well as one of the sources of greenhouse gases. With the rapid increase in the number of motor vehicles, the air over some cities has become a mixture of black smoke and exhaust gases emitted by motor vehicles. If this situation continues, more pressure will be brought to bear on the environment.
- The market system is imperfect and the ability to respond to emergencies should be enhanced. China's energy market system should be improved, for the energy price mechanism is unable to completely reflect the scarcity of resources, the supply-demand situation and the environmental cost. The prospecting and development of energy resources need to be further standardised and the energy supervising system be improved. There are many safety gaps in coal mine production, the grid structure is unreasonable, the oil reserves are inadequate, and the warning and emergency systems for effectively responding to unexpected serious events and suspending the energy supply should be further improved and strengthened.
- The management of energy efficiency and 'clean energy' are distributed among different ministries/departments. The pricing system is handled by the Department of Price of the NDRC,[3] while energy efficiency comes under the Department of Resource Conservation and Environment Protection of the NDRC. The NDRC, Ministry of Finance, Ministry of Technology, Ministry of Environment Protection, and National Energy Administration are involved in 'clean energy' development.

8.1.4 China's Energy Policies

Proceeding from the main problems facing energy development, the main objectives of China's energy development policy are: ensuring safety in energy supply,

[3] NDRC is the abbreviation for the National Development and Reform Commission, PR China.

optimising the energy structure, improving energy efficiency, reducing environmental pollution caused by energy development and utilisation, striving to construct a stable, economical, clean, and safe energy supply system and using sustainable energy development to support sustainable economic and social development.

There are three targets of China's energy development: to decrease the energy intensity in terms of GDP by 16 %; to decrease the intensity of carbon in terms of GDP by 17 % during 2011–2015; and non-hydrocarbon energy should form 11.4 % of the total energy consumption by 2015.

8.1.4.1 Ensuring Safety in Energy Supply

China has improved its ability in energy supply by reducing its dependence on foreign energy supplies, capping total energy consumption, improving energy efficiency, and increasing domestic supply. By steadily improving China's ability in energy supply, the country should continue to enhance its ability to supply coal, oil, natural gas and electric power, as well as renewable energy, on its own and to develop oil substitutes to constantly meet the growing needs for energy and to reduce China's dependence on overseas energy supplies.

China guarantees energy transportation channels and ensures the safety and openness of oil–gas transportation channels. The four channels through which energy is imported into China are: the northeast channel which imports crude oil, natural gas and coal from the Russian Federation; the northwest channel which imports crude oil and natural gas from central Asia and the Russian Federation; the southwest channel which imports crude oil and natural gas from west Asia through Myanmar; and sea routes for south China and the eastern coastal provinces to import crude oil, liquefied natural gas (LNG) and coal from the Middle East, Africa, Australia, Southeast Asia, etc.

China has diversified its energy resources. It takes vigorous action on international energy cooperation and seeks more sources and channels to import oil and gas. The country should, in particular, reduce its dependence on supplies from the Middle East and actively develop various energy resources, so as to reduce its dependence on oil.

China has started to set up strategic oil reserves to reduce the risk of oil supply suspension. China started strategic oil reserves in 2003; four projects of volume 14 Mt in the first phase were put into operation in 2008 and seven projects in the second phase are under construction since 2009. Based on estimates, the total scale of strategic oil reserves in China will reach the IEA requirement of 90 days by 2020, and the total volume will be in the second position after the USA.

China should save its energy resources and restrain energy demand from growing excessively. The Chinese central government issued 'China's Comprehensive Working Program of saving energy and reducing emission during the 12th Five-Year Plan (2011–2015)' in August 2011. It pointed out that the energy intensity of GDP should decrease by 16 % by saving a total of 670 Mtce during 2011–2015, and broke down the national target to the provincial governments. The measures that China promotes to improve energy efficiency are: adjusting the economic structure, implementing key programmes to save energy, reducing emission and circular economy, perfecting policies that encourage saving energy and reducing emission, increasing the central budget for investment, setting up a central government special fund, pricing and subsidising energy-saving products, accelerating the implementation capacity of key projects in energy saving, speeding up research and development of technologies for saving energy, etc.

8.1.4.2 Optimising the Energy Structure

China has paid attention to strengthening the development of natural gas, hydroelectric power, nuclear power, and renewable energy resources to optimise its primary energy structure and, by utilising coal in a clean way, optimising the terminal energy consumption structure.

China gives priority to the development of hydropower, accelerated the development of such renewable resources as nuclear power, and increased the proportion of quality energy sources. The Chinese government has targeted the proportion of non-hydrocarbon energy to reach 11.4 (Outline of National Economic and Social Development Twelfth Five-Year Plan 2011) and 15 % by 2015 and 2020, respectively.

China gives full play to the role of domestic and overseas energy resources and markets. It continues to carry out the ‘going abroad’ strategy and actively encourages oil companies to accelerate their pace and increase their proportion in sharing overseas oil and gas resources. China has implemented the ‘going abroad’ strategy since 1999. In the first phase, national oil companies followed the strategy of ‘going abroad’, and companies of coal, electricity, and equipment manufacture followed. They go to almost five continents. In 2010, China had 75 Mt share in oil.

China gives impetus to the industrialisation of clean coal technologies (CCTs) to realise the clean utilisation of coal. It has developed and popularised CCTs and popularised ultra-critical and even higher units for future development. Meanwhile, China should develop Circulating Fluidized Bed Combustion (CFBC) as a supplement and arrange demonstration projects for integrated gasification combined cCycle (IGCC) and pressurized fluidized bed combustion (PFBC) in a planned way; popularise haze desulphurisation technology and develop low-nitrogen combustion technology; intensify the transformation and management of industry boilers; and devote major efforts to developing advanced industry boiler technologies. China should actively explore new ways for clean utilisation of coal, including the co-production technology of the coal–chemical industry, coal liquefaction and gasification technologies, and underground coal gasification technology, and take the road to sustainable development in the clean utilisation of coal.

China should rationally utilise quality energy[4] resources based on their economic advantages. It should gradually include the external cost, such as the ecological,

[4] Quality energy is a relative concept that includes renewable energy, natural gas, and sometimes oil.

environmental and health losses caused by coal mining, transportation and utilisation, into the coal prices and increase coal prices accordingly. China should improve the competitiveness of the quality energy resources.

8.1.4.3 Saving Energy Resources and Improving Energy Efficiency

China should accelerate structural readjustment and eliminate backward structures. It should adjust the industrial and product structures in a reasonable way, develop tertiary industries and new hi-tech industries that consume less energy resources, and transform traditional industries with high technologies and advanced yet practical technologies. It should eliminate workmanship, technologies, and equipment that have high-energy consumption, low efficiency, and heavy pollution. It should prevent high-energy intensity sectors from investing blindly and expanding at a low level. China should devote major efforts to regulating and optimising the energy consumption structure and to developing clean coal technologies.

8.1.4.4 Protecting the Environment

Economical and clean requirements will both be set on China's energy development. China should do everything possible to bring down the negative effects of energy development and utilisation on the environment and strive to bring about harmonious energy and environmental development.

China encourages the development of such advanced energy technologies as coal washing, inversion by processing, advanced combustion, and haze purification. Desulphurisation equipment should be installed simultaneously with the construction of coal-burning power plants or with the extension of such power plants and desulphurisation in the existing coal-burning power plants should be accelerated.

During the 12th Five-Year Plan period (2011–2015), the total emission of the main pollutants will be brought down, by 8 % for chemical oxygen demand (COD), 8 % for sulphur dioxide (SO_2), 10 % for ammonia, and 10 % for nitrogen oxides (NOx); the intensity of carbon dioxide (CO_2) in terms of GDP will decrease by 17 %.

8.1.4.5 Enhancing International Cooperation in the Energy Sector

To solve China's energy problems, it should be self-reliant while enhancing cooperation with various countries. China should utilise foreign resources in an appropriate way and take foreign resources to supplement its energy supplies.

China has joined many multilateral energy cooperation mechanisms and is a full member of the International Energy Forum (IEF)World Energy Council (WEC), Asia-Pacific Economic Cooperation (APEC), Association of Southeast Asian Nations (ASEAN)+3, and the Asia Pacific Partnership (APP). China, as an observer of the Energy Charter, has maintained close ties with such international energy organisations as the International Energy Agency. Meanwhile, China has established bilateral energy dialogues with the USA, Japan, Britain, India, the European Union, and Organization of the Petroleum Exporting Countries (OPEC).

In future, China will continue to adhere to the principle of promoting equality and mutual benefit, enlarging cooperation, seeking common gains, adopting a sincere attitude towards others, and strengthening communication. Proceeding from the protection of global energy security, China will make full use of the complementarities of resources, economies and technologies from various sides, take vigorous action to conduct international cooperation in the energy field, improve cooperation mechanisms in a positive way, deepen cooperation areas, and safeguard the security and stability of international energy resources.

8.2 Development of 'Clean Energy' (Non-hydrocarbon)

8.2.1 The Development Situation of Clean Energy

China's government has attached importance to developing and utilising clean energy. The technologies of wind power, solar energy and biomass have been developed in steady stages since the 1980s, as well as hydropower since the 1950s; they have stepped into the front position in the world.

The total clean energy consumption was 282.59 Mtce, which accounted for 9.9 % of total energy consumption in 2008 (Table 8.8).

Table 8.8 Clean energy production in China in 2008

	Capacity	Unit	Production	Unit	Mtce
1. Power generation	195,940	MW	654.22	GWh	244.29
Hydro	171,520	MW	563.3	GWh	210.74
Nuclear	9100	MW	68.4	GWh	25.59
Wind	12,170	MW	14.8	GWh	5.33
PV	150	MW	0.22	GWh	0.08
Biomass	3000	MW	7.5	GWh	2.55
2. Biogas			14	GWh	10.00
Household use	30	Million units			
Large projects	1600	Unit			
3. Heating					28.30
Solar water heaters	125	Million m^2			25.00
Solar cookers	0.45	Million units			0.10
Geothermal	40	Million m^3	80	TJ	3.20
4. Biofuels	1.65	Mt			1.55
Total					282.59

Fig. 8.2 Growth of capacity and generation of hydropower in China

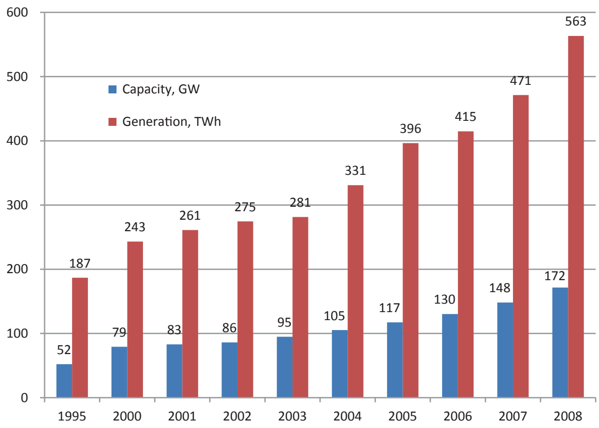
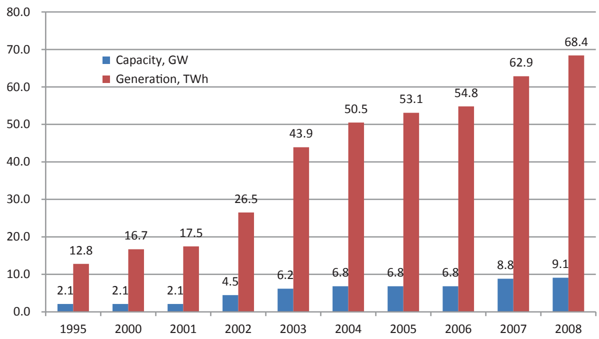


Fig. 8.3 Growth of capacity and generation of nuclear power in China



8.2.1.1 Hydropower

China's installed hydropower capacity reached 171.52 GW, which accounted for 21.6 % of the total national power capacity by the end of 2008 and ranked first in the world; the annual average growth rate was 9.6 % (Fig. 8.2).

8.2.1.2 Nuclear Power

China developed nuclear power late, with the first unit operation in 1992. The proportion is low with 1.1 % of the total electric power capacity in 2008, but the growth rate of installed capacity was very rapid at 10.3 % annually (Fig. 8.3).

8.2.1.3 Wind Power

In the twenty-first century, China's wind power has grown rapidly on a large scale. Capacity grew from 344 MW in 2000 to 12,170 MW in 2008, at 56.1 % annually.

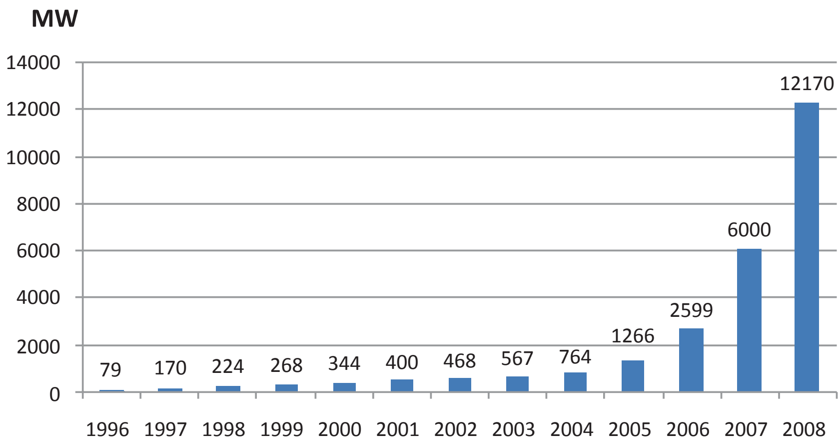


Fig. 8.4 Growth of capacity of wind power installed in China

The growth rate of the capacity and energy of wind power has been very high since 2006 when the Renewable Energy Law was issued (Fig. 8.4).

8.2.1.4 Solar Energy

Solar energy includes solar power generation (PV), solar water heaters, and solar cookers. General speaking, China's PV industry has developed rapidly, and solar water heaters play a major role in both urban and rural areas.

The productive capacity of PV modules was lower than 10 MW; it reached 2 GW and ranked first in the world.

Due to the high cost, the installed PV capacity is still low at 150 MW; it is used to access electricity that is at a distance from the grid. A 10 MW PV project in Dunhuang city of Gansu province was constructed in 2009.

Solar water heaters have been used widely in China. About 125 million m^2 were used and the productive capacity was 25 million m^2 in 2008; the productive capacity and use of solar water heaters are in the first position in the world.

8.2.1.5 Biomass

Biomass is various in type and use. The technology of biogas is mature, in particular household biogas. A total of about 30 million wells produced 13 billion m^3 biogas for residential use for a rural population of about 80 million by the end of 2008.

The development of other biomass is in the beginning industrial phase. The installed capacity of biomass was 3 GW by the end of 2008 and biofuels production was 1.55 Mtce in 2008.

8.2.2 Constraints in Developing Clean Energy

China faces several constraints in developing clean energy.

- *The high cost of low-carbon energy development and utilisation*. The cost of 'clean energy' is much higher than that of traditional energy, such as power-fired coal.
- *Long distances for energy delivery*. Since most of the hydropower resources are located in southwest China, but the consuming areas are mainly in the south and east coastal areas, hydropower has to be transported from west to east over a long distance.
- *Insufficient pre-feasibility studies and evaluation of surveys and research*. Resources are the base for the development of clean energy, such as wind power and solar energy, as well as biomass for liquid fuel. China with its large population and limited land resources should deal with grain acreage and the development of biofuels.
- *Scattered policies and new standards to encourage development*. With the rapid development of clean energy, many new situations are arising which the former policies and standards do not match, such as the stability standards of the power grid that connects large-scale wind power, and the use of dimethyl ether (DME) for vehicles.
- *Immature technology and market system*. The technology and market system are in the early and middle phases for industrial development in the 'clean energy' sector.

8.2.3 Roles and Targets of Clean Energy

Clean energy plays different roles in developed and developing countries. Developed countries take clean energy as one measure to cope with climate change, whereas developing countries take it as an important measure to meet energy demand in rural areas, to supply energy, and to guarantee energy security. China has taken clean energy as an important measure to optimise the energy structure, to guarantee energy security, to mitigate environmental pollution, and for sustainable development.

8.2.4 Goals of Clean Energy Development

China targets 15 % of clean energy in the total energy demand by 2020. Based on the general goal, the installed capacity of hydropower, wind-power, nuclear power, and biomass power will reach about 340, 120, 70–80, and 40 GW, respectively.

8.2.5 Policies and Measures to Promote Clean Energy Development

The Chinese government has adopted certain policies and measures to promote the development of clean energy.

8.2.5.1 Attention to Construction and the Infrastructure Plan

China's renewable energy resources, such as hydropower, wind power, and solar energy are located in the remote western areas where the economic levels and power loads are low, so the renewable energy has to be transmitted over a long distance. Another factor is that clean electricity affects grid security.

Nuclear power in the future will develop quickly and new added capacity will reach about 6–7 GW annually. So, nuclear power projects should be planned carefully.

8.2.5.2 Developing and Upgrading the Equipment Sector of Clean Energy

The equipment sector of clean energy in China has made significant progress in the past decades, but accessories, equipment production, process capacity, material capability, etc. are relatively backward compared with global levels, so there is a lot of room to upgrade, particularly in cutting-edge areas.

Domestic-made equipment in clean energy will receive a boost, and the cost will drop rapidly under the effects of scale economy. Developing and upgrading equipment for clean energy will activate the national economy. Some developed countries set equipment manufacture of clean energy as one of the recovery tools for their national economy at the beginning of the global financial crisis.

8.2.5.3 Push Demonstration and Popularise Key Techniques in Clean Energy

To develop clean energy on a large scale, technological reliability, economic feasibility, and industrial match should be reached. More attentions should be paid to the cost of wind power, solar water heaters, and biogas in rural areas and the technological reliability of third-generation nuclear power, PVs, second-generation biofuels, wind power from the sea, etc.

8.2.5.4 Foster Capacity of Research and Innovation in the Clean Energy Sector

Technological research and innovation are key factors in the competition for clean energy. The central government should invest in building capacity in R&D in the clean energy sector.

8.2.5.5 Perfect Further Regulations

The development of clean energy in the beginning phase should be supported by favourable policies. These policies include tariffs, subsidies, government funds, favourable load, and standards, and the regulations should be consistent with the responsibilities under ministries, etc.

8.2.5.6 Enhance International Cooperation

International cooperation should be enhanced to develop clean energy, such as technology transfer and the clean development mechanism (CDM). China's development of clean energy depended mainly on domestic technology, funds, and human power, but international cooperation should be enhanced also. China will develop clean energy under international cooperation mechanisms, such as the CDM, to eliminate trade barriers and to obtain additional financial assistance.

8.3 Saving Energy and Improving Energy Efficiency

8.3.1 Development of Energy Saving and Efficiency Improvement

8.3.1.1 Energy Intensity in Terms of GDP

Annual energy growth of 7.34 % supported 11.2 % growth annually; the elasticity of energy consumption in terms of GDP was 0.65 in China during 2006–2008. The energy conservation rate in 2006, 2007 and 2008 was 1.79, 4.04 and 4.59 %, respectively. Energy intensity in terms of GDP dropped 10.1 % totally, and accumulative total energy conservation amounted to 300 Mtce during 2006–2008.

8.3.1.2 Energy Intensity in Terms of Product

Energy intensity in terms of product has decreased in high-energy intensity sectors in China since 2005. Energy intensities of copper smelt and plate glass were higher than 20 %; the electricity intensity of coal production decreased 10 % (Table 8.9).

8.3.1.3 Measures to Promote Energy Conservation

The China State Council has come up with some political measures to promote energy conservation in order to achieve the target—decrease 20 % of energy intensity in terms of GDP during 2006–2010.

Table 8.9 Energy intensity in high-energy intensity products

	Unit	2005	2006	2007	Annual drop during 2005–2007 (%)
Coal production	kWh/t	26.7	24.4	24	−10.11
Thermal power generation	gce/kWh	343	342	333	−2.92
Steel (large and middle scale)	kgce/t	714	676	668	−6.44
Electrolysis of aluminium	kWh/t	14680	14671	14488	−1.31
Steel smelt	kgce/t	780	729	610	−21.79
Cement	kgce/t	167	161	158	−5.39
Plate glass	kgce/weight case	22	19	17	−22.73
Refinery	kgce/t	114	112	110	−3.51
Ethylene	kgce/t	1073	1013	984	−8.29
Ammonia	kgce/t	1650	1581	1553	−5.88
Caustic	kgce/t	1297	1248	1203	−7.25
Soda ash	kgce/t	396	370	363	−8.33
Calcium carbide	kWh/t	3450		3418	−0.93
Paper and paper board	kgce/t	1380	1290		

- *Place a premium on energy conservation*. The central government put 12 billion yuan into 1737 projects with an energy conservation capacity of 52 Mtce in 2008.
- *Subsidise products of high-efficiency lighting*. The Ministry of Finance and National Development and Reform Commission choose 13 plants with high-efficiency lighting through bidding in 2008. Central finance subsidises 50% for residential users and 30% for big buyers.
- *Carry out difference tariffs*. NDRC issued regulations on difference tariffs in eight high-energy intensity sectors. The electricity price in these sectors is 0.5 and 0.2 yuan higher than in the normal sector.
- *Promote purchases of energy conservation products.* NDRC issued regulations on promoting purchases of energy conservation products in 2004. The regulation requires governmental organisations to preferentially purchase products of energy conservation, and issues a list of these products.
- *Provide favourable taxation policies for energy conservation*. In order to encourage companies to save energy, NDRC issued regulations on favourable policies for energy conservation in 2007.

8.3.2 Targets and Key Fields for Saving Energy and Improving Energy Efficiency

China's energy efficiency is relatively low and the wastage of energy resources is serious. The Chinese government has come to realise the urgency of saving energy and improving energy efficiency and has set forth the objective of increasing energy utilisation efficiency by 20% during the 11th Five-Year Plan period.

8.3.2.1 Targets for Saving Energy and Improving Energy Efficiency

Based on the resources, environment and energy demand in the country, China's central government set a target for saving energy and improving energy efficiency, namely, about 20 % of energy intensity in terms of GDP decrease during 2006–2010. It achieved 14.38 % by 2009; it is a hard target for China.

8.3.2.2 Key Fields for Saving Energy and Improving Energy Efficiency

China focuses attention on high-energy intensity sectors, manufacture, transportation, and building use. Of them, the key industries include the power industry, iron and steel industry, nonferrous metal industry, oil and petrochemical industries, chemical industry, building materials industry, coal industry, and machine building industry. The transportation sector includes road transportation, newly increased motor vehicles, urban traffic, railway transportation, air transportation, water transportation, as well as agricultural and fishery machinery, etc. Building use includes buildings, household and office electrical appliances, and lighting equipment.

China has started ten programmes: transformation of the coal-burning industry boiler (kiln stove), regional thermoelectricity co-production, utilisation of after-heat and excess voltage, saving oil and making oil substitutes, saving electric machinery energy, optimisation of the energy system, building energy saving, promoting green lighting, saving government institution energy and constructing an energy-saving monitoring, and technical service system. China should place great importance on key energy-consuming sectors and set store by enterprise energy saving. It should emphasise doing well in such key energy-consuming sectors as metallurgy, coal, power, petrochemicals, and building materials and focus on the operations of 1000 high-energy-consuming enterprises.

8.3.3 Policies and Measures to Promote Energy Saving and Improve Energy Efficiency

- *Continue accusatorial system to achieve target of saving energy and improving energy efficiency*. To set up a series of reasonable, systemic systems in statistics, supervise, and assess, and take saving energy and improving energy efficiency as one of the indictors in estimating economic and social development in local governments, and in promoting local governors.
- *Implement more encouraging policies of saving energy and improving energy efficiency based on market-orientation*. Policies based on market-orientation will play a greater role in saving energy and improving energy efficiency in the future.
- *Speed up efficient measures in the Law of Energy Conservation*[5] *in the long term*. The Law of Energy Conservation should play a more important role in promoting

[5] The Law of Energy Conservation was issued on October 28, 2007.

saving energy and improving energy efficiency, but some articles have not been strictly implemented, so China will speed up fulfilling the measure in this Law in the future.

- *Pay more attention to adjusting structures to push saving energy and improving energy efficiency.* To adjust structure is one of the four measures in China; it plays a very important role now in China. China is in the progress of industrialisation and high-energy intensity sectors are developing much quicker than the total. It is very efficient to adjust the structure of industry, process, and product.
- *Strengthen the management of saving energy and improving energy efficiency*. At present, management distributes about 15 % of total saving energy in China. Management should be strengthened so that it continues to contribute to saving energy and improving efficiency in China.
- *Perfect measures of saving energy and improving energy efficiency*. China will perfect support measures to save energy and improve energy efficiency, such as in finance and taxation.
- *Pay greater attention to saving energy and improving energy efficiency in building use and transportation sectors.* Increased energy demand in building use and the transportation sector will be the norm in China, so China should pay more attention to these sectors.

References

China Statistical Yearbook (2010) National Bureau of Statistics of China, Beijing

Outline of National Economic and Social Development Twelfth Five-Year Plan, March 2011, Beijing

Report on China's energy development (2009) Economic Science Press, Beijing

The trend and countermeasures for the adjustment of energy consumption structure change in China, Shixian GAO etc. (2010) Plan Press, Beijing

White paper on China's Energy Policy (2012) The information office of the state council, Oct 2012, Beijing

Chapter 9
Indian Perspective on Clean Energy and Energy Efficiency

Aparna Sawhney and Meeta Keswani Mehra

9.1 Introduction

The high growth rate in present as well as future energy demand in an emerging economy like India, due to its large population and rapid economic development, has driven international concerns for adverse climatic impacts. The energy mix in India is carbon-intensive as coal continues to be its primary energy source (being a low-cost indigenous resource). Indeed, it is recognised that coal will continue to be a major source of energy in the country. The evaluation of the Alternative Policy Scenario of a clean growth trajectory for the global economy, with special focus on China and India, indicates that renewable energy needs to play an increasingly significant role especially in the power sector, and become the second-largest source of electricity after coal by 2030 (McKinsey 2009).

Energy efficiency is the other key focus of India's national climate change policy initiatives. India envisions lowering of GHG emission by 7 % of the 2020 Business-as-Usual level and carbon intensity by 20–25 % below 2005 by the year 2020 (Stern 2009). The low carbon development scenarios envisaged for India rely on a range of ambitious investments in energy efficiency-enhancing measures that include ambitious investments in improved power generation technologies as well as measures towards lowering of electricity intensity of household appliances through efficiency rating and labelling schemes as well as improved efficiency in residential and non-residential buildings through appropriate building codes (Planning Commission 2006; World Bank 2009).

The switchover of the current energy systems from conventional towards greater use of renewable forms in order to meet present and projected energy demand needs conducive regulatory and market policies. Economic incentives have thus been built in through fiscal benefits in investment as well as generation of cleaner power,

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along with measures to enhance energy efficiency. Sustainable energy investment during 2008 in India increased to US$ 3.7 billion, representing a 12 % increase over 2007 (UNEP 2009, p. 12).

This chapter presents an Indian perspective on low-carbon growth through increasing energy efficiency and renewable energy forms. The rest of the chapter is organised as follows: Section 9.2 provides a snapshot of the energy sector in India. Section 9.3 analyses in particular the electricity sector and the move towards renewable sources in grid as well as off-grid power, while Sect. 9.4 critically reviews the energy-efficiency coefficients across the different sectors of transport and major energy-intensive industries in India. Section 9.5 outlines some recent policy initiatives adopted in India to promote cleaner forms of energy in the electricity sector and energy efficiency measures. Section 9.6 concludes.

9.2 Energy Sector in India

9.2.1 The Macro Picture

While India is poised to grow at an annual rate of 8–9 % over the next two decades (Planning Commission 2006), the population is likely to reach a level of 1.45 billion by 2030 (IEA 2007), with the proportion of the urban population rising from the prevailing 30–49 % in 2030. The total primary energy supply (TPES) from commercial and non-commercial sources in India in 2007 was estimated at 595 mtoe (million tonnes of oil equivalent)[1] (Table 9.1). Although in 2007 the level of per

Table 9.1 Key energy-economy indicators, 2007. (Source: IEA (2007))

Country	Population (million)	GDP (PPP) (billion 2000 US$)	Energy prod. (Mtoe)	Net imports (Mtoe)	TPES (Mtoe)	Elec. consumption (TWh = 10^{12} watt hours)	CO_2 emissions (Mt)
Brazil	191.60	1561.26	215.58	24.81	235.56	412.69	347.09
China	1319.98	9911.78	1813.98	166.75	1955.77	3072.67	6027.85
India	*1123.32*	*4024.89*	*450.92*	*150.03*	*594.91*	*609.74*	*1324.05*
South Africa	47.59	516.63	159.59	−21.86	134.34	238.56	345.77
UK	60.78	1832.63	176.23	44.88	211.31	373.36	523.01
USA	302.09	11468	1665.18	713.97	2339.94	4113.07	5769.31
World	6609	61,428	11,940		12,029	18,187	28,962

[1] In comparison with these IEA estimates, the Expert Group on Integrated Energy Policy (EGoIEP) (Planning Commission 2006) puts TPES in 2006–2007 at 542–550 mtoe, of which 153 mtoe is drawn from non-commercial energy forms, and TEDDY (2009) put the total primary commercial energy supply at 360 mtoe in 2006–2007.

Table 9.2 Energy and CO_2intensity, 2007. (Source: IEA (2007))

Country	TPES/ pop. (toe per capita)	TPES/GDP (PPP) (toe per thousand 2000 US $)	Electricity consumption/ pop (kWh per capita)	CO_2/TPES (t per toe)	CO_2/pop (t per capita)	CO_2/GDP (PPP) (kg per 2000 US$)
Brazil	1.23	0.15	2154	1.47	1.81	0.22
China	1.48	0.20	2328	3.08	4.57	0.61
India	*0.53*	*0.15*	*543*	*2.23*	*1.18*	*0.33*
South Africa	2.82	0.26	5013	2.57	7.27	0.67
UK	3.48	0.12	6143	2.48	8.60	0.29
USA	7.75	0.20	13615	2.47	19.10	0.50
World	1.82	0.20	2752	2.41	4.38	0.47

capita consumption of primary energy in India was merely 0.53 toe (tonnes of oil equivalent) compared to 1.82 toe for the world as a whole, India's energy consumption is likely to grow to sustain higher economic growth rates, support developmental priorities, and enhance economic well-being (Table 9.2).

In terms of aggregate efficiency of energy use, as captured by the energy intensity of GDP, namely, the TPES/GDP ratio, India performs well in comparison to other countries. At 0.15 toe, India uses a lower level of primary energy for producing each thousand dollar of GDP,[2] as compared to the world average of 0.20 toe. The corresponding comparison for electricity consumption per capita presents a similar picture for India. Its electricity consumption was a mere 543 kW h per capita per annum in 2007 as compared to the world average of 2752 kW h (Table 9.2).

Given its growing consumption of oil and natural gas, and the limited availability from domestic sources, India's overall energy import dependence at 25 % and a much higher oil import-dependence at 74 % in 2007 continues to be high relative to that for other emerging market economies. This has significant implications for its energy security.

9.2.2 Energy Supply

The key sources of primary commercial energy in India comprise coal, lignite and petroleum. The total primary commercial energy supply (including imports) in 2006–2007 was estimated at 360 mtoe, of which over half derived from coal and lignite, with the remaining made up by hydrocarbons (crude and natural gas) and a small amount from power from hydro, nuclear and renewable energy (Table 9.3).

[2] Here, GDP is in 2000 prices and purchasing power parity (PPP) terms to enable international comparison.

Table 9.3 Primary and secondary commercial energy supply in 2006–2007 (Mtoe). (Source: TEDDY (2009))

									Shares of different fuels			
	Coal and Lignite	Hydro power	Nuclear power	Renewable energy sources	Natu-ral gas	Crude oil	Total petroleum products	Total energy	Coal and lignite	Total power	Crude oil plus petroleum products	Natural gas
Production	168	10	2	1	29	34	–	243	47%	3%	9%	8%
Imports	27	–	–	–	–	112	17	156	8%	0%	36%	0%
Exports	1	–	–	–	–	–	34	35	0%	0%	9%	0%
Stock change	−4	–	–	–	–	1	−1	−4	−1%	0%	0%	0%
Total	*191*	*10*	*2*	*1*	*29*	*147*	*−19*	*360*	*53%*	*3%*	*36%*	*8%*
								Import dependence				
								Total energy	*Coal and lignite*	*Total power*	*Crude oil plus petroleum products*	*Natural gas*
Production	–	–	–	–	–	–	–	68%	88%	100%	27%	100%
Net imports	–	–	–	–	–	–	–	*34%*	*14%*	*0%*	*74%*	*0%*
Stock change	–	–	–	–	–	–	–	−1%	−2%	0%	0%	0%
Total	–	–	–	–	–	–	–	100%	100%	100%	100%	100%

9.2.3 Energy Demand

The rising trends in GDP and per capita income, as well as changes in lifestyle, have led to a significant growth in commercial energy consumption in India. The period 1990–1991 to 2006–2007 witnessed a near doubling of final energy consumption from 125 mtoe to 230 mtoe across the sectors put together (Table 9.4).

Industry continues to be the largest energy consumer at a consumption level of 102.9 mtoe in 2006–2007, with a share at 45 % in 2006–2007. The transport sector's consumption level has increased to 40 mtoe in 2006–2007, although its share is smaller at 18 %. The share of non-energy use of commercial fuels also depicts a small decline. The shares of agriculture and residential and commercial sectors show an increase and are found to be 7 % and 10 % in 2006–2007 with a nearly 3.5–4-fold increase over the previous 15–16 year period (Table 9.4).

9.2.4 Future Energy Sector Trends

In making its choices for the future, it is a challenge for India to strike a balance among high growth and development, energy security and an urgent need to contain local pollution as well as greenhouse gases (GHGs).

The International Energy Agency (IEA 2007) provides projections up to the year 2030, for three specific scenarios, of which two distinct ones are discussed below. The *Reference Scenario* assumes no energy-policy intervention by the government on either the demand or the supply side and provides the baseline. The *Alternative Scenario* incorporates the goal of achieving long-term stabilisation of atmospheric GHG concentrations at 450 ppm of CO_2equivalent that could attain a rise in global temperature no higher than those believed to be acceptable by the world scientific community. Since the IEA scenarios rely on a lower growth rate of GDP than what might be considered more likely for India, we compare the two IEA scenario estimates with two of those derived by the Expert Group on Integrated Energy Policy

Table 9.4 Trends in final energy consumption by sector (Mtoe). (Source: TEDDY (2009))

	1990–1991	2006–2007	Proportion-ate increase	% growth per year	% share in 1990–1991	% share in 2006–2007
Agriculture	4.9	16.8	3.4	8 %	4 %	7 %
Industry	62.9	102.9	1.6	3 %	50 %	45 %
Transport	28	40.3	1.4	2 %	22 %	18 %
Residential and commercial	12.6	35	2.8	7 %	10 %	15 %
Other energy uses	3.9	16.5	4.2	9 %	3 %	7 %
Non-energy use	12.6	18.4	1.5	2 %	10 %	8 %
Total	*124.9*	*229.9*	*1.8*	*4 %*	*100 %*	*100 %*

Table 9.5 Energy demand projections for the Reference Scenario (IEA 2007). (Source: Compiled from IEA (2007))

				Share (%)		Growth (% p.a.)
	1990	2005	2030	2005	2030	2005–2030
Total primary energy demand	*320*	*537*	*1299*	*100*	*100*	*3.6*
Coal	106	208	620	39	48	4.5
Oil	63	129	328	24	25	3.8
Gas	10	29	93	5	7	4.8
Nuclear	2	5	33	1	3	8.3
Hydro	6	9	22	2	2	3.9
Biomass and waste	133	158	194	29	15	0.8
Other renewables	0	1	9	0	1	11.7

(EGoIEP) (Planning Commission 2006), namely Scenario 1 (based on dominance of coal) and Scenario 11 (based on energy efficiency, demand-side management, fuel switching and diffusion of renewable energy).

The trends in total primary energy demand (including biomass and wastes) under the *Reference Scenario* indicate a growth from 537 mtoe in 2005 to 1299 mtoe in 2030, implying a growth of 3.6% per annum. The split between commercial and non-commercial energy is estimated to be 379 mtoe (158 mtoe in 2005) and 1105 mtoe (194 mtoe in 2030). Further, during 2005–2030, energy intensity is lowered significantly. The shares of individual fuels shown in Table 9.5 imply a significant rise in the share of coal and a decline in the share of biomass. The annual emissions of CO_2 increase threefold from 1147 million t (mt) in 2005 to 3314 million t, with the annual rate of increase of energy sector emissions estimated to be 4.3% (Table 9.6).

In comparison with the IEA projections, the EGoIEP forecasts the energy requirement at a higher real rate of growth of GDP of 8–9%, as is also envisaged by the Indian government. One of the scenarios that stipulate dominance of coal in the energy supply mix (Scenario 1) puts the total primary commercial energy demand in 2031–2032 at 1702 mtoe under an 8% rate of GDP growth. In addition, with the total non-commercial energy requirement at 185 mtoe under each, the total primary commercial energy will be 1887 mtoe in 2031–2032 (Planning Commission

Table 9.6 CO_2 emissions for the Reference Scenario (IEA 2007). (Source: Compiled from IEA (2007))

	CO_2 emissions (Mt)			Shares (%)		Growth (% p.a.)
	1990	2005	2030	2005	2030	2005–2030
Total CO_2	*587*	*1147*	*3314*	*100*	*100*	*4.3*
Coal	404	774	2284	67	69	4.4
Oil	164	312	829	27	25	4
Gas	19	62	201	5	6	4.8

Table 9.7 Energy demand projections for the Alternative Policy Scenario (IEA 2007). (Source: Compiled from IEA (2007))

	Energy demand (mtoe)		Shares (%)	Growth (% p.a.)	Change vs. Reference Scenario (%)
	2005	2030	2030	2005–2030	2030
Total primary energy demand	*537*	*1082*	*100*	*2.8*	*−16.7*
Coal	208	411	38	2.8	−33.7
Oil	129	272	25	3	−17.1
Gas	29	89	8	4.6	−4.3
Nuclear	5	47	4	9.9	41.9
Hydro	9	32	3	5.3	42.3
Biomass and waste	158	211	19	1.2	8.5
Other renewables	1	21	2	15.8	145.5

2006), which is significantly higher than that estimated by the IEA. Consequently, CO_2emissions are estimated to rise around 5500 mt in 2031–2032 in this scenario.

The disquieting outcomes of the Reference Scenario are tackled by constructing an *Alternative Policy Scenario* that incorporates effective enforcement of specific policies ranging from energy efficiency improvements to new and better technologies for power generation. These measures yield an overall primary energy consumption reduction of 17 % compared to the Reference Scenario in the year 2030. The absolute level growth in primary energy demand from 537 mtoe in 2005 to 1082 mtoe in 2030 translates into an annual rate of growth of 2.8 % compared to 3.6 % in the Reference Case (Table 9.7). The share of coal in total primary energy demand is lowered marginally, while those of nuclear and hydro are raised. Commensurate with the above trends in energy consumption, the aggregate emissions of CO_2 rise more gradually from 1147 million t in 2005 to 3314 mt in 2030, registering an average annual increase of 3 % (Table 9.8).

Compared to the above estimates, the EGoIEP projects 8 % GDP growth based on total primary energy demand under Scenario 11 (that incorporates the full impact of energy efficiency improvement, fuel switching, demand-side management

Table 9.8 CO2 emissions for the Alternative Policy Scenario (IEA 2007). (Source: Compiled from IEA (2007))

	CO_2 emissions (mt)	Shares (%)	Growth (% p.a.)	Change vs. Reference Scenario (%)
	2030	2030	2005–2030	2030
Total CO_2	*2415*	*100*	*3.0*	*−27.1*
Coal	1544	64	2.8	−32.4
Oil	678	28	3.2	−18.2
Gas	193	8	4.7	−4.0

and greater reliance on renewable) to be 1536 mtoe in 2031–2032. Of this, the mix between commercial and non-commercial energy is estimated to be 1351 mtoe and 185 mtoe, respectively. These are again much higher than those derived by IEA under the Alternate Policy Scenario for 2030. In this case, at 3900 mt in 2031–2032, the CO_2 emissions are around 35 % lower than in Scenario 1 of EGoIEP, albeit higher than the IEA scenario discussed in this section.

9.2.5 Select Issues in India's Energy Sector

9.2.5.1 Augmenting Energy Supplies and Switchover to Clean Energy

The prevailing situation of constrained domestic energy resources of oil, gas, uranium and hydropower deem it necessary to seek ways and means to augment supplies of coal, hydrocarbons, nuclear and renewables such as solar and wind energy. At the prevailing rates of extraction, India's known oil and gas reserves will run out over the next 20–25 years. While efforts towards exploration have not resulted in any significant new oil finds in the recent past, reportedly a mere one-third of the potential oil-bearing geographical area has been explored so far, pointing towards the need to intensify exploration by utilising technologies for deep drilling. Acquiring stakes in overseas oil and gas resources (in Mozambique, Sudan, Brazil and other countries) has also been part of India's overall strategy towards oil security.

India is also facing a shortage of uranium reserves, causing nuclear reactors to operate at 50 % capacity. Efforts have been directed towards exploration of new uranium resources as well as entry into international cooperation for supply under the India–US Nuclear Cooperation Approval and Non-proliferation Enhancement Act 2008.

India's estimated potential capacity for hydropower is put at 84,000 MW at 60 % load factor. By 2011, only 38,748 MW capacity had been installed. Besides realising the underdeveloped potential domestically by overcoming the social and environmental constraints, India has and could enhance cooperation with the neighbouring countries of Nepal and Bhutan, whose combined economically viable hydro potential has been put at over 55,000 MW.

Notwithstanding its relative abundance, at current rates of extraction the proven reserves of coal will last for around 80 years, while all (proven, indicated and inferred resources) are likely to last for not more than 140 years. In view of the mere 45 % of potential coal-bearing areas under regional surveys, there exists substantial potential to augment India's recoverable stock of coal reserves by undertaking more comprehensive geographical and detailed drilling activities.

From the longer-term perspective of enhancing development of indigenous supply options and diversifying the fuel mix, renewables remain critical to India's energy economy. The EGoIEP (Planning Commission 2006) puts the annual exploitable potential for the individual renewable energy resources as follows: wood-based biomass (620 mtoe), biogas (15 mtoe), biodiesel (20 mtoe), ethanol (10 mtoe), solar photovoltaic (1200 mtoe), solar thermal (1200 mtoe) and wind power (onshore capacity of 65,000 MW at 20 % load factor).[3]

9.2.5.2 Energy Efficiency and Demand-Side Management

India's total energy intensity of GDP has been falling, and is currently half of what it was in the 1970s (Planning Commission 2006). Compared to the world average and countries like China and the USA, India's energy intensity of GDP is lower, but it is somewhat higher in comparison with several countries of Europe (at or below 0.15) and Japan (0.14) as highlighted in Table 9.2. This indicates that there is scope for improvement given the available energy-efficient technologies on a commercial basis.

According to EGoIEP, there is scope for as much as 20–25 % lowering of energy intensity on average compared to the prevailing levels by technologies that are commercially viable. The promotion of energy efficiency measures will require benchmarking of energy appliance standards for different sectors, incentives for energy-related R&D and technology commercialisation for firms, getting fuel prices right for consumers, energy labelling and so on.

9.2.5.3 Energy and GHG Emissions

India's CO_2 equivalent emissions from fossil fuel burning amounted to 1.1 billion t in 2004 (World Bank 2007), compared to 743 billion t in 1994 (NATCOM 2004) and 960 billion t in 2000 (Sharma et al. 2006). This amounts to an increase of around 150 % over 1994. In per capita terms, Indian emissions were estimated to be a mere 1.02 t, much lower than the world average of around 4.4 t (IEA 2009c).

The EGoIEP (Planning Commission 2006) estimates that at 8 % rate of growth of India's GDP, its CO_2 emissions in per capita terms in 2031/2032 will rise to a mere 2.6–3.6 t as compared to the global average of a little over 4.4 t. This implies that there are prospects for India to remain on a relatively low carbon growth trajectory in the future.

9.3 Clean Energy Options in Electricity

A review of electricity generation from renewable sources across the globe shows that the large share of clean electricity is hydro, especially in non-OECD countries. In OECD countries, among non-hydro power, wind-based electricity is the most significant, followed by biomass energy. In particular, large hydro has one of the most mature renewable technologies, which is able to compete in today's

[3] While these do incorporate the land availability constraint for growing plantations or installation of solar panels, these are not additive as they all draw on the same supply of land.

energy markets without policy support. Other renewable energy sources including decentralised generation by solar photovoltaic in remote areas/villages (where providing grid connection is very expensive), wind farms on exceptional sites, and solar water heating are also competitive. The IPCC (2007) noted that certain wind, solar (crystalline photovoltaic) and bioethanol technologies have become competitive and experienced declining costs due to enhanced learning. Much of the solar energy technology, on the other hand, is still evolving—except for crystalline photovoltaic solar water heating that has wide commercial use, concentrating solar dish (although technologically viable) has immature markets, thin film photovoltaic is in the demonstration phase and nanotechnology solar cell is still in the technology research stage.

A recent study indicates that India can potentially reduce emissions by 30–50 % by 2030 (equivalent to 2.8–3.6 billion carbon dioxide equivalent) with the use of commercially available and feasible clean technology (McKinsey 2009, p. 13).[4] The study estimated that the maximum potential for this emission reduction is offered by a clean power sector, where approximately 0.9 billion t of carbon dioxide equivalent or 35 % of the total potential reduction in emissions can be achieved. The emission abatement potential in the power sector during the 20-year period is driven by the use of different technologies to meet base and non-base (i.e. peak) demand. While base-load power demand can be met through clean coal-based generation, hydro, nuclear and biomass-based generation, the non-base peak demand can be ideally met by renewable sources of reservoir hydro and solar power (especially since solar generation coincides with day-time peak).[5] Since solar photovoltaic has witnessed a reduction in costs of about 22 % for every doubling of cumulative capacity in the past three decades, the cost of solar power equipment is expected to continue to decline, which would make this renewable form a cost-effective source of peak power. Renewable energy forms of solar and wind can be potentially increased in the next 20 years in India's clean power path: 56 GW of solar power (30 GW of concentrating solar power and 26 GW of photovoltaic solar power) and 42 GW of wind power capacity can replace fossil fuel-based power generation to meet peak demand by 2030 (McKinsey 2009).

In 2011, the total installed electricity capacity in India was 185 GW in utilities,[6] about 10.8 % of which is based on renewable energy sources and 21 % on (large) hydro (Table 9.9). Electricity is largely coal-based, constituting about 56 % of the

[4] The case for emission abatement was assessed with 200 opportunities that can reduce energy consumption and carbon emissions in the ten highest energy-consuming and-emitting sectors. The study analysed the potential emission reduction and abatement cost of carbon dioxide for the period 2010–2030. It is important to note, however, that a number of options identified for the emission abatement potential for India are based on technologies which are still emerging, like solar thermal with storage and LED lighting (whose actual application faces high up-front costs and untested efficacy).

[5] Gas-based combined cycle gas turbines, cycling coal-plants, open cycle gas- and oil-based generation are also proposed for meeting peak-demand.

[6] While we report here the installed capacity of electric utilities, the non-grid captive power installation is quite substantial of about 15 % of total power capacity in the country in 2008–2009 (based on data reported in Economic Survey of India 2008–2009).

Table 9.9 Installed capacity of electric utilities and fuel-mix (MW and % share) in India, 1999–2011. (Source: Ministry of Power, http://www.powermin.nic.in last accessed 10th Jan 2012)

Energy Source	1999–2000		2011[a]	
	MW	% Share	MW	% Share
Total thermal	70,186	71.7	1,22,963.9	65.8
Coal	–	–	104,021	*55.7*
Gas	–	–	17,743	*9.5*
Oil	–	–	1200	*0.6*
Hydro (Large)	23816	24.3	38,748	20.8
Nuclear	2680	2.7	4780	2.5
Renewable energy sources[b]	1155	1.2	20,162	10.8
Total	*97,837*	*100.0*	*1,86,654*	*100*

[a] As of November 2011

[b] Renewable energy sources include small hydro, biomass gasifier, biomass power, urban and industrial waste power

total installed capacity in 2011. Indeed much of the power capacity under construction in the country continues to be coal-based, indicating that coal will continue to be the major source of power in the growing economy.

The increase in renewable energy capacity in India, however, has been quite rapid in recent years, increasing more than threefold between 2005 and 2011, led by the growth of capacity in wind energy (Fig. 9.1). Lately, India has been in the top-ten highest growth countries in renewable energy capacity. The renewable-based capacity has been led by wind energy and biomass-cogeneration capacity (Table 9.10). In terms of capacity achievement vis-à-vis the potential, it is the highest in the wind sector. Although India has a natural advantage in solar energy availability, installed capacity remains rather small due to the high, albeit declining, cost of photovoltaic technology.

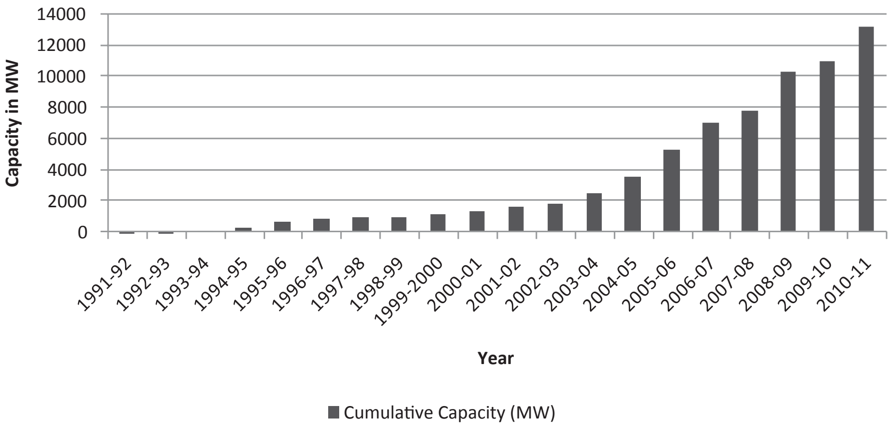

Fig. 9.1 Cumulative capacity grid-connected wind power (MW) in India

Table 9.10 Cumulative capacity achievement in renewable energy in India in MW (excluding large hydro), 2005–2011. (Source: MNRE Annual Report 2005–2006 and http://www.mnre.gov.in/ last accessed 10 January 2012)

Renewable Form	2005	2011[a]
Grid-connected		
Onshore wind	4434	14,989
Small hydro (≤25 MW)	1748	3154
Biomass/Cogeneration[b]	867	2862
Waste-to-energy	35	73
Solar PV	2.7	46
Biomass gasifier	1	–
Subtotal	7088	21,125
Off-grid[c]		
Biomass gasifier	70	141
Biomass/Cogeneration		328
Waste-to-energy	11	76
Solar PV systems (>1 kW)**	–	72
Subtotal	81	618

[a] As of August 2011
[b] Includes bagasse and non-bagasse
[c] In MW equivalent

Solar photovoltaic technology remains economically unviable for power generation in India, and solar electricity produced through photovoltaic conversion technology is 4–5 times more expensive than the electricity obtained from conventional fossil fuels.[7] However, solar remains an important technology choice in off-grid applications in remote and rural locations across India. More significantly, solar-based power (both grid-connected and off-grid) is expected to witness rapid growth today under the Solar Mission of the National Action Plan for Climate Change.

9.4 Energy Efficiency

9.4.1 The Macro Perspective

Notwithstanding the fact that the overall energy intensity of India's economic output has been falling over the past two decades, there remains considerable scope for further improvement. On aggregate, the energy intensity per unit value added for India is estimated to be 0.45 kgoe/$ (kilograms of oil equivalent per US dollar in 1990 constant prices), which is lower only in comparison with those for China at 0.58 kgoe/$ and Indonesia at 0.53 kgoe. The data in Table 9.11 on intensity of energy

[7] http://www.solarindiaonline.com/solar-india.html.

Table 9.11 Aggregate and sectoral energy intensity (kgoe/value added (in 1990 US$), 2007. (Source: IEA (2009) and UNSD: http://unstats.un.org/unsd/snaama/selbasicFast.asp)

Country or area	Total	Agriculture	Industry	Transport	Commercial and others	Total (kgoe/capita)
Australia	0.15	0.14	0.20	0.44	0.02	3641
Brazil	0.25	0.10	0.30	1.40	0.03	998
People's Republic of China	0.58	0.21	0.48	1.26	0.07	956
Germany	0.11	0.11	0.08	0.33	0.02	2831
India	*0.45*	*0.11*	*0.47*	*0.37*	*0.03*	*337*
Japan	0.09	0.05	0.07	0.30	0.03	2682
UK	0.10	0.05	0.09	0.29	0.02	2345
USA	0.17	0.08	0.13	0.83	0.03	5144

consumption of individual sectors (ratio of final energy consumption to value-added in the sector) show that India's energy intensity is somewhat higher than other countries of the world, pointing towards significant scope for energy efficiency improvement. Both the transport and commercial and services sectors depict favourable energy intensities, which are either lower or comparable to levels found elsewhere.

9.4.2 Demand-Side Efficiency

Aggregate data exhibit a decoupling of economic growth from energy consumption in that, while GDP grew by around 3 times, the primary energy demand only doubled over the period 1990–1991 to 2006–2007. Such aggregated analyses mask the underlying trends in end-use energy efficiency improvements. To this end, we attempt to track the energy intensity for different end-uses in individual sectors by relying on estimates presented in Planning Commission (2006), IEA (2007), de la Rue du Can et al. (2009a), and de la Rue du Can et al. (2009b).

In *agriculture*, the energy-intensity data point towards relative energy inefficiency. The bulk of energy used in agriculture is for water-pumping for irrigation and for running farm machinery, such as threshers and tractors. Tube-wells alone account for over one-third of total land under irrigation, and constitute the most energy-intensive operation. A significant number of water pumps use electricity (15 million), a much smaller number use diesel (6 million) and an even smaller number, a mere 7000, run on solar power (de la Rue du Can et al. 2009b). A higher proportion of electric pump sets could entail higher energy efficiency in this operation.

In the *industrial* sector, the focus is mainly on the energy-intensive sub-sectors, such as iron and steel, cement, fertilisers, pulp and paper, aluminium, etc. While specific energy consumption in key industrial sectors in India has shown a steady and significant decline over the period 1990–2005 (in the range of 10–33 % for the individual sectors), in comparison with best-level practices internationally, India still lags behind some countries (Table 9.12). On average, the estimations put

Table 9.12 Specific energy consumption (GJ/tonne of output). (Source: de la Rue du Can et al. (2009a, Tables 8, 15))

	India	India	India	Percent decline		EU-15	Japan	China	USA	Best practice
Sector\ Reference year	1990	2005	2020	(1990–2005)	(2005–2020)	2002	2004	2001	2001	–
Crude steel	42.0	28.3	27	33%	5%	17.8	23.3	25.6	20.1	17.8
Cement	3.6	3.1	2.9	15%	5%	3.7	4.3	6.0	5.8	1.9
Ammonia	55.0	43.0	40	22%	7%	35.5	–	41.7	37.1	28.0
Pulp & paper	35.0	24.0	23	31%	4%	–	–	–	–	17.0
Aluminium	399.0	365.0	344	9%	6%	–	–	–	–	144.0

1 GJ = 10^9 J

lowering of specific energy consumption at around 4–7% for the individual industrial sectors over the period 2005–2020.

By comparison, the Alternative Policy Scenario of IEA (IEA 2007) is more optimistic in that it puts the energy efficiency improvement in the iron and steel sector and in industrial motors at 15% over the Reference Scenario in the year 2030. The improvement in cement energy intensity is also put at a higher level of 3% per annum in the Alternative Case. Further, a World Bank study for India on the options for low carbon development (World Bank 2009) put the likelihood of energy efficiency improvement in industry during 2007–2020 at 15% for integrated steel plants, 13% for mini steel plants, aluminium, cement and fertiliser manufacturing, and around 7% for pulp and paper units.

In the case of *transport*, motorised vehicle ownership is growing rapidly, indicating a burgeoning of vehicle numbers in the years ahead, resulting in increased energy imports and a rising urban pollution. While most of the research projects a manifold increase in the stock of vehicles in the future, transport fuel efficiency gains of as high as 50% for motorised vehicles have been predicted by EGoIEP, which may be supplemented by a higher share of urban mass transport systems and enhanced share of railways and waterways (Planning Commission 2006). The Petroleum Conservation Research Association (PCRA) has been working towards evolving fuel efficiency standards for all vehicle types in association with the Bureau of Energy Efficiency (BEE), under the Energy Conservation Act of 2001.

The *other services* sector covers a wide spectrum of activities, from the more sophisticated ones in the information and technology sector to simple services such as those offered by repair and small retail outlets. The energy consumption in this sector has been growing rapidly, at 12% annually during 1990–2005. The primary drivers of energy demand in the sector include end-uses such as lighting, office equipment and space cooling. Estimates by de la Rue du Can et al. (2009a) put the average floor electricity intensity equal to 251 MJ/m^2 (69 kW h/m^2), which is low compared to developed countries. Energy intensities in buildings can be reduced by introducing energy conservation building codes (ECBC) in 2006 addressing end-uses such as lighting, space cooling, service water heating, and electric power distribution (BEE 2006). The analysis by de la Rue du Can et al. (2009a) indicates that savings in the range of 27–40 % could be achieved in an ECBC-compliant commercial building.

The estimates of *residential* energy consumption cover end-uses such as cooking, lighting, water heating, space cooling and heating, and powering household electrical appliances. In 2005, the National Sample Survey Organisation data show that in rural households there is a predominance of traditional fuels, such as wood (83 % of the total, almost entirely for cooking and water heating), while LPG and kerosene account for a mere 2 % each for this end-use, and a small share of electricity for other end-uses. In comparison, urban households derive a large share of cooking and water-heating from LPG (37 % of total urban consumption). Kerosene also finds its use for lighting in urban households. Electricity accounts for a large share of around 27 % in total urban household consumption for lighting and for running appliances (de la Rue du Can et al. 2009a). The key changes predicted by the study until year 2020 are: a significant increase in the share of electricity for lighting and running appliances in both the rural and urban residential sectors, a marked decline in the use of wood for cooking, and a significant increase in LPG use for cooking.

With the efficiency of fuel use for cooking and water heating placed at 13 % for wood, 40 % for kerosene and 60 % for LPG, significant efficiency gains can be reaped by switching to more efficient and modern cooking fuels. Further, efficiency of use of electricity for lighting and appliances depends on the diffusion of specific appliances (energy-efficient light bulbs, refrigerators, air-conditioners, geysers, etc.) and the annual unit energy consumption (UEC) per appliance (UECs are a function of the efficiency, capacity and the level of utilisation of the appliance). During the period 2000 and 2020, de la Rue du Can et al. (2009a) envisage that the UEC of refrigerators will rise (on account of a switch to bigger capacity, double-door or frost-free refrigerators) and that of air-conditioners will grow as well (due to enhanced unit cooling capacity and longer hours of use). However, the UEC of water-heating equipment (mainly geysers) will fall due to a decline in household size (Table 9.13).

In comparison, the Alternative Policy Scenario of the IEA (2007) assumes that, driven by labelling programmes, the energy efficiency of appliances will improve by an average of 30 % between 2006 and 2030. The Planning Commission (2006) envisions a reduction in electricity demand of 15 % through energy-efficient processes, equipment, lighting and buildings by the year 2031–2032.

9.4.3 Efficiency in Power Supply

The prevailing thermal efficiency of coal-based *power generation* in India is estimated to be around 27–30 % (Planning Commission 2006; IEA 2007), with substantial scope for improvement. The thermal efficiency of coal-based plants is the gross thermal efficiency, equal to the ratio of gross heat output to gross heat input. The best available plants in the world operate with super-critical boilers and derive a gross efficiency level of 42 % or even higher. In the Indian context it is possible to achieve a gross efficiency of 38–40 % for all new coal-based plants. With high

Table 9.13 UEC by appliance (kW h). (Source: de la Rue du Can et al. (2009b, Tables 5, 7))

	India	India	Europe	North America
Appliance\Reference year	2000	2020	2000	2000
Refrigerators	494	589	413	850
Air conditioners	2160	3800	1714	714
Air coolers	298	298	–	–
Washing machines	190	190	221	955
Fans	145	145	–	–
Television	150	150	124	136
Water heaters	617	598	2492	3823

priority placed on renovation and modernisation of the existing plants, both the Planning Commission (2006) and the IEA (2007) assume that under the Alternative Policy Scenario, the thermal efficiency of coal-based power units will increase by 1 % point. Further, the average thermal efficiency of future coal power plants will be increased to 39 %, with greater reliance on super-critical and ultra-super-critical units, and with accelerated R&D integrated gasification combined cycle (IGCC) technologies will become available by 2020.[8]

The investment in the *power transmission and distribution* (T&D) system has remained inadequate, resulting in system-wide aggregate technical and commercial losses of power of 34 % in 2004–2005 for the country as a whole. These can be ascribed to theft or pilferage, non-billing, inaccurate billing, inadequate collection and technical T&D losses. While these were reduced to around 30 % in 2006–2007, plugging these losses further will enhance the efficiency of the power supply system. The average technical T&D losses in OECD countries are 14 % (IEA 2007). As part of the low-carbon development trajectory for India, World Bank (2009) envisages reduction in technical T&D loss levels to 15 % in the year 2025.

9.5 Policy Initiatives to Promote Clean Energy and Energy Efficiency

Like other countries, policies to promote renewable energy generation are being implemented in India to reduce greenhouse gases, and also to reduce dependence on imported energy (energy security issues, as evident early on after the oil crisis in the 1970s).[9]

[8] The assumption of IGCC technologies being available as early as 2020 is often considered too optimistic in the Indian context, since research in this direction has not been able to tackle the problem of high ash content in the hot coal gas. We thank Prof. Parikh for pointing this out to us.

[9] For example, the Solar Energy Centre in India was established in 1982 under the Indian Ministry of New and Renewable Energy (then called the Department of Non-Conventional Energy Sources) to develop solar energy technology as a viable alternative energy system.

Renewable energy sources also provide the means to supply electricity to remote/rural areas that cannot be connected economically through the grid. This deprivation of energy to the poorer population due to lack of connectivity, i.e. *energy poverty*, requires concerted government efforts to provide non-conventional forms of energy in remote villages. Energy poverty in rural India is stark, with more than 70 % of the rural population using traditional inefficient biomass as the primary fuel, and lacking connectivity to grid electricity (Sengupta 2007). For developing countries like India, providing off-grid electricity has been a major motivating factor for renewables since the lack of access to electricity contributes to economic and social inequalities (Chou et al. 2008).

India adopted a comprehensive policy package to address the mitigation of climate change and move towards a low-carbon sustainable growth path through the National Action Plan on Climate Change in 2008. The programme contains eight national plans including two that exclusively address clean energy and energy efficiency, namely, the National Solar Mission and National Mission for Enhanced Energy Efficiency. Since wind power capacity growth has been reasonably good, and India has created a niche in the world wind technology market through the sale of wind turbines (Lewis 2007), the new effort aims specifically at solar power given that the country receives abundant direct solar radiation.

9.5.1 Initiatives to Enhance Renewables in the Grid-Power System

The National Tariff Policy 2006 aimed to promote renewable power generation through quotas, preferential tariffs, and guidelines for pricing "non-firm" power in India. The policy mandated the State Electricity Regulatory Commissions to fix a minimum percentage of Renewable Purchase Obligation (RPO) by utilities, based on regional availability of resources. Some Indian states have announced RPOs to boost growth in wind power generation.

9.5.1.1 Capacity/Generation Targets for Specific Renewable Forms

Since India has abundant solar resources equivalent to over 5000 trillion kW h annually,[10] there are now concerted efforts to promote the harvesting of this form of energy to meet India's escalating energy demand.

- The 11th Five-Year Plan has aimed at grid-connected solar power generation. The current capacity in solar power is about 50 MW, which is envisioned to increase to 20 GW by 2020.

[10] Most parts of the country receive 4–7 kW h of solar radiation per square metre per day with 250–300 sunny days or 3000 hours average in a year. India's Integrated Rural Energy Programme using solar energy currently serves 300 districts and around 2300 villages. http://www.solarindia-online.com/solar-india.html.

- The National Solar Mission[11] aims to achieve parity with coal-based thermal power by the year 2030, and interim grid parity by 2020. The aim is to make solar power commercially viable over the next two decades, such that solar power investors and generators investors would no longer face technical or financial constraints. The capacity goal for 2030 is set at 100 GW, constituting 10–12 % of total power generation (and interim capacity goal of 20 GW by 2020) (PMO 2009).
- Under the National Solar Mission, the government will support the setting up of dedicated manufacturing capacity of poly-silicon material as well as solar thermal collectors and receivers. Special Economic Zone-type incentives will be offered to establish solar technology manufacturing parks.

There are also plans to establish 60 "solar cities" that would reduce energy demand by 10 % with increased renewables and efficiency by 2012.

9.5.1.2 Fiscal Incentives for Renewable Energy Investment

- The national and state governments have offered capital investment subsidies of 20 % to support solar photovoltaic (PV) manufacturing in special economic zones.
- Generation-based incentives (GBI) have been proposed at ₹ 10/kW h for the first 3 years with reviews in subsequent years under the National Solar Mission. The GBI would be valid for 20 years (from the date of project commission/ generation) in order to ease the burden on utilities from fixed tariffs for solar power. The GBI will be paid by the Central government through state designated agencies in different states.
- Specific capital equipment and project imports will be exempt from customs and excise duties for solar power. Concessional loans will be given (10-year loans at 2 % interest) to off-grid solar PV of 100 W to 10 kW to displace diesel generators and UPSs and for invertors with a solar base.
- For wind power projects there are fiscal concessions of 80 % accelerated depreciation, concessional customs duty for specific critical components, excise duty exemption, income tax exemption on profits for power generation, etc. (MNRE 2009).

[11] The Mission has chalked out the goal achievement across three time periods, beginning with Phase 1 in 2009–2012, Phase II in 2012–2017, and Phase III in 2017–2020. Supportive policies include obligatory solar power purchase, fiscal investment incentives, subsidies and generation-based incentives, and R&D in manufacturing concentrated solar collectors and receivers.

9.5.1.3 Demonstration Projects

- The MNRE started a new demonstration programme, permitting utilities, generation companies and state nodal agencies to set up grid-connected solar photovoltaic plants of 25 kW to 1000 kWp capacity, for which the scheme supports 50 % of the basic cost of the plant, subject to a maximum of ₹ 10 crore per MWp (available to set up 4 MWp aggregate capacity projects in the country during the 11th Plan period).

9.5.1.4 Preferential Tariffs and Fiscal Incentives for Generation

- The National Solar Mission would require mandatory solar power purchase under RPO, maybe with 0.25 % in Phase I and increasing to 3 % in Phase III.
- State Electricity Regulatory Commissions in several states offer preferential tariff for purchase of power from wind power projects.
- Generation Based Incentives was initiated in 2007–2008 by the Ministry of New and Renewable Energy to attract independent wind power producers (limited to a capacity of 49 MW), who do not avail of the benefit of accelerated depreciation. The investors, apart from getting the tariff determined by the respective State Regulatory Commissions, would get an incentive of 50 paisa per unit of electricity for 10 years, provided they do not claim the benefit of accelerated depreciation (MNRE 2009).

The fiscal concessions and tax benefits seemed to have succeeded in enhancing the installed capacity of wind power in the country, with over 10 GW installed capacity in 2009.

9.5.1.5 Clean Off-grid Electricity

A noted earlier, renewable energy-based power has immense significance in a developing country like India for providing electricity to remote and rural areas where grid-access is too expensive or not feasible. In India, rural household-scale biogas plants have been promoted by the Ministry of Renewable Energy since the early 1980s. The ministry provides subsidies and financing for constructing and maintaining biogas plants, training, public awareness, technical centres, and support to local implementing agencies. The Khadi and Village Industries Commission also supports biogas plants. Village-scale mini-grids comprising solar–wind hybrid systems serve a few thousand households in dozens of Indian villages.

Under the Remote Village Electrification Programme, 4250 villages and 1160 hamlets had been electrified using renewables by 2009. India's Integrated Rural Energy Programme using renewable energy served over 300 districts and 2200 villages by 2006, with additional projects under implementation in over 800 villages and 700 hamlets in 13 states and federal territories (Ren21 2009). Solar PV applications have increased to more than 435,000 home lighting systems, 700,000 solar lanterns, and 7000 solar-power water pumps. India proposed to augment cooking, lighting, and motive power with renewables in 600,000 villages by 2032, starting with 10,000 remote unelectrified villages by 2012 (Ren21 2009).

9.5.2 The Mandate on Energy Efficiency and Initiatives[12]

One of the aim of the National Mission for Enhanced Energy Efficiency is to save energy through enhanced energy efficiency, especially in energy-intensive sectors of the Indian economy. The conservation of energy and enhancement of energy efficiency in India was legally mandated under the 2001 Energy Conservation Act. Subsequently, the 2006 Integrated Energy Policy provided a comprehensive approach to increase energy efficiency across all sectors. Energy efficiency measures are instituted through the central agency of the BEE and other state agencies.

Four types of initiatives have been implemented/planned, and energy savings amounting to 10 GW are expected by 2012. The four-pronged approach covers both industrial and household energy efficiency aspects, and includes:

- *Tradable energy saving certificates* for large energy-intensive industries. This market-based instrument is expected to provide an economic incentive to promote energy savings among the most efficient energy-users. Since the industrial sector is the largest consumer of commercial energy (about 40 %), energy saving in industry would also have a marked impact on reducing the demand-supply gap.
- *Accelerated proliferation of energy saving appliances* in selected sectors by making these products more affordable. For instance, the BEE introduced the "Bachat Lamp Yogana" under which households can exchange incandescent lamps for compact fluorescent lamps. In 2006, the BEE also mandated the energy-labelling scheme for appliances, and comparative star-based labelling for refrigerators, air-conditioners, etc. to provide information to consumers and promote energy-saving consumption behaviour. Some states have made the use of energy-saving devices like solar water heating, which saves on conventional energy, mandatory for hospitals, hotels and large government/commercial buildings.
- *Demand-side management of energy-efficiency in all sectors to save energy*. In 2007, energy audit was made mandatory for large energy-consuming units of nine industrial sectors.[13] Financial incentives to upgrade technology towards high energy efficiency in the industrial sector are important as such upgrading is expensive.

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[12] This sub-section draws heavily on the *National Action Plan on Climate Change*.

[13] The nine sectors include thermal power stations, fertilisers, cement, iron and steel, chlor-alkali, textiles, paper and pulp and railways.

- A voluntary Energy Conservation Building Code was also launched in 2007 to promote energy-saving design and planning in large commercial buildings. Commercial building construction emerged as one of the fastest growing economic activities with the growth of the service sector, and if all commercial space adhered to the Building Code, it is estimated that energy consumption could be reduced by 30–40 % in this segment.
- For residential buildings, financial incentives in the form of subsidies are also provided for installing solar water heaters to save on conventional energy as well as promote clean energy.
- *Fiscal instruments to promote energy efficiency.* Energy-efficient technologies require high up-front investment especially in terms of equipment. Accelerated depreciation up to 80 % in the first year for such equipment and tax incentives, like reduced value-added tax, are being considered.

9.6 Concluding Observations and Policy Recommendations

While we have addressed the promotion of clean energy and energy efficiency as twin goals of the energy policy for climate-change mitigation, they are increasingly addressed together. As evident in the discussion, initiatives to promote energy efficiency and clean energy have been integral to overhauling the older inefficient energy system and reducing the use of conventional energy. It is interesting to note that today smart grids form a new approach to low-carbon energy future, where integrated transport and electricity and heat/energy storage solutions deliver energy more efficiently and reliably (IEA 2009b). They also help integrate low-carbon renewable energy into existing networks to a greater extent, as well as with electric vehicles.

Although the energy system in India is yet to move into such an integrative mode, it has made modest progress in promoting clean energy. The recent policy instruments adopted by India, including feed-in tariff and obligatory renewable power purchase, to boost renewable energy forms of solar and wind power are similar to those adopted in OECD countries. However, these tools have featured only recently and some are yet to be implemented under the National Action Plan on Climate Change. Similarly the initiatives to enhance energy efficiency are critical to save energy, especially in the most energy-intensive industries, motorised vehicles, commercial buildings and household energy consumption patterns (considering the escalating diffusion of electrical appliances).

The new commitments of the Indian government to move the energy mix away from coal-based power by 2030 is complemented by both demand-side and supply-side instruments. The new generation-based incentives for solar and wind power, R&D incentives, as well as numerical targets for capacity installation and power generation can be expected to promote faster growth of these clean energy forms.

While sharing the global concern of mitigating climate change, policy initiatives in India will have to meet the challenge of balancing the divergent goals of global environmental sustainability and energy access at effective costs, with the available technological options.

Non-conventional energy from renewable sources has long been recognised as the most feasible form of energy for a large population that is otherwise deprived of energy, and the development of associated technology remains an important goal in the country. Coupled with global climate concerns, alternative clean energy today has obtained added significance, and clean renewable energy will form an integral part of our policy targets as we strive for inclusive growth in India.

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References

Chou WJ, Markandya A, Hunt A (2008) 'Assessment of policy instruments to internalize environmental related external costs in non-EU Member States', Costs Assessment for Sustainable Energy Systems (CASES) project, University of Bath

De la Rue du Can S, McNeil M, Sathaye J (2009a) India energy outlook: end use demand in India to 2020. 2009-0331 formal report. Environment Energy Technologies Division. Ernest Orlando Lawence Berkeley National Laboratory

De la Rue du Can S, Letschert V, McNeil M, Zhou N, Sathaye J (2009b) Residential and transport energy use in India: past trend and future outlook. 2009–02–26 formal report. Environment Energy Technologies Division. Ernest Orlando Lawence Berkeley National Laboratory

IEA (2007) World energy outlook 2007: China and India insights. International Energy Agency, OECD, Paris

IEA (2009) Renewable energy essentials: concentrating solar thermal power. International Energy Agency, Paris

IEA (2009a) Technology road map: wind energy. International Energy Agency, Paris

IEA (2009b) Global gaps in clean energy research, development and demonstration. International Energy Agency, Paris

IEA (2009c) Key world energy statistics. International Energy Agency, Paris

IPCC (2000) Methodological and technological issues in technology transfer. IPCC special report. UNEP and WMO, Bonn

IPCC (2007) Mitigation of climate change, intergovernmental panel on climate change assessment report 4. Working Group III

Lewis JI (2007) Technology acquisition and innovation in the developing world: wind turbine development in China and India. Stud Comp Int Dev 42(3–4):208–32

McKinsey (2009). Environmental and energy sustainability: an approach for India. McKinsey, Mumbai

MNRE (2009) Annual report 2008–2009. Ministry of New and Renewable Resources, Government of India, New Delhi

NATCOM (2004) India's initial national communication (NATCOM) to the United Nations Framework Convention on Climate Change (UNFCCC). Ministry of Environment and Forests, Government of India, New Delhi

Planning Commission (2006). Integrated energy policy: report of the expert committee, Government of India. Planning Commission, New Delhi
PMO (2009) National solar mission, national action plan on climate change. Prime Minister's Office, Government of India, New Delhi
REN21 (2011) Renewables 2011: global status report, renewable energy policy network for the 21st century. REN21 Secretariat, Paris
Sathaye J, Price L, de la Rue du Can S, Fridley D (2005) Assessment of energy use and energy savings potential in selected industrial sectors in India. LBNL-57293. Ernest Orlando Lawence Berkeley National Laboratory, Berkeley
Sengupta R (2007) High economic growth, equity and sustainable energy development of India. Discussion paper series 213. Kobe University, Japan
Sharma S, Bhattacharya S, Garg A (2006) Greenhouse gas emissions from India: a perspective. Curr Sci 90(3):326–334
Stern N (2009) Action and ambition for a global deal in Copenhagen, policy debate. Centre for Climate Change Economics and Policy and Grantham Research Institute for Climate Change and the Environment in collaboration with the United Nations Environment Program (UNEP), London
TEDDY (2009) TERI energy data directory and yearbook. TERI Press, New Delhi
UNEP (2009) Global trends in sustainable energy investment: analysis of trends and issues in the financing of renewable energy and energy efficiency, United Nations environment program and new energy finance (UNSD). National Accounts Main Aggregates Database. http://unstats.un.org/unsd/snaama/selbasicFast.asp
World Bank (2007) Growth and CO2 emissions: how does India compare to other countries? Background paper: India—strategies for low carbon growth
World Bank (2009) India: options for low carbon development: synopsis of a study by the World Bank for Government of India. World Bank, South Asia Region, India Country Management Unit, New Delhi

Chapter 10
Reluctant Embrace: South Africa and Renewable Energy

David Fig

10.1 Introduction

Despite the knowledge of the dangers of fossil and radioactive fuels, South Africa has made decisions to reinvest in developing these fuels more intensively through the building of enormous coal-fired power stations and commissioning a new nuclear fleet. Until recently, it has strongly backed the development of a local (pebble bed modular) nuclear reactor. As a result, it has not taken up the challenge of developing renewable energy sources very effectively.

The commitment to the introduction of renewables has been weak and tardy. South Africa has extremely good potential for the tapping of wind, wave and solar energy as well as of utilising more biogas and solid biomass. Its one limitation is the small potential for hydroelectricity, as its rivers are slow flowing, shallow and drought prone. South Africa is already experiencing stress on its fresh water resources. Countries with a high commitment to the installation of renewable energy include Spain, Germany and Denmark. South Africa is said to have higher solar and wind potential than any of these countries.

Why then is there such a strong adherence to fossil and nuclear fuels among its decision makers? Why is South Africa not recognising it could take advantage of its plentiful access to wind and solar power, and provide leadership on the African continent towards the development of sustainable energy systems?

This chapter will try and investigate the reasons for this slow uptake in renewable energy. It starts with an analysis of the country's energy profile in order to inform the reader of current energy and electricity use (Sect. 2). Some time is then spent understanding the nature of South Africa's current electricity crisis, and the pressures on government and the utility to deliver much more supply (Sect. 3). Existing policy on renewable energy will next be examined (Sect. 4), followed by a brief discussion on climate policy and an attempt at integrated energy planning (Sect. 4).

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From all the foregoing, the conclusion sets out to return to our initial question and provides a more consolidated understanding of why the country's commitment to renewable energy remains limited.

Before proceeding, it would be helpful to summarise what is meant by renewable energy. This refers to sources of energy that are not finite, and therefore are theoretically constantly available. The chief sources include wind, sun, waves, geothermal energy (energy available from beneath the earth's surface), tidal power as well as energy derived from plant and agricultural sources (biomass, biogas and biofuels). Furthermore, it is possible to extract landfill gases from waste disposal facilities. All these sources are at different levels of research, development and commercialisation. Solar energy can be derived from photovoltaic cells (e.g. on rooftops) or from concentrating solar collectors (towers collecting sun rays deflected off a series of mirrors or heliostats, some using molten salt for power storage).

10.2 South Africa's Energy Profile

10.2.1 South Africa's Energy Needs

South Africa is a relatively industrialised country, whose economic history can be periodised into successive phases each with the dominance of particular sectors:

I. From the mid-seventeenth to the late nineteenth century, it was a predominantly agrarian society with a mixture of commercial farms and petty commodity production, exporting much of its surplus (wines, wool, wheat, fruit, ivory, hides);
II. With the minerals revolution initiated in the 1860s (diamonds) and 1880s (gold), the economy began to be centred on extractive industries and their linkages with energy production. Fine and Rustomjee (1996) have referred to this as the minerals–energy complex, and show how it has retained importance even after secondary industrialisation;
III. From the 1920s, manufacturing became increasingly important in the economy, as part of import substitution stimulated by world wars and depressions. This phase saw substantial direct foreign investment availing itself of boom conditions in the 1960s, but when the political situation deteriorated and international sanctions bit more severely in the 1980s, the boom subsided, and disinvestment occurred;
IV. From the mid-1990s, coinciding with democratisation, South Africa experienced the return of transnational capital, and the consolidation of the service economy, including the finance sector, accompanied by the liberalisation of agriculture and manufacturing, while seeing something of a collapse of parts of these sectors, and a return to a minerals boom (especially platinum).

Since 2000, there has been an average annual growth of 3.4 % in the gross domestic product at market prices. This includes the −1.5 % decline in GDP for the year 2009 (Fig. 10.1).

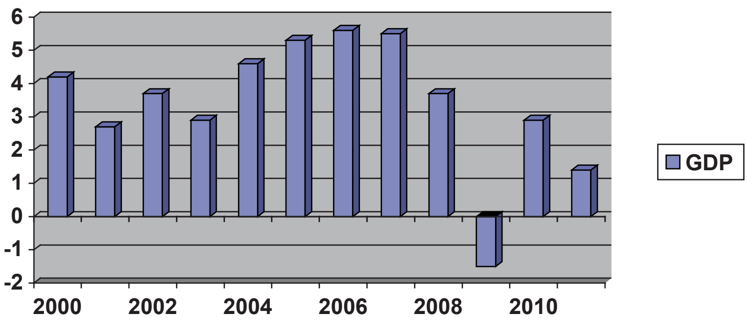

Fig. 10.1 South Africa, GDP annual increase/decrease at market prices, 2000–2011. (Source: Stats SA, 31 January 2012 (figures for 2011 are estimates))

As befits an 'emerging' economy, South Africa's electricity needs had been expanding until the recession that began in 2008.

This is linked to the country's industrial investment path as well as to the imperative to ensure that the bulk of the population of 50 million (2011 estimate) has access to affordable electricity. Most black people—urban and rural—were denied household access to the grid for most of the apartheid years and were forced to rely on coal, paraffin and biomass for energy provision (Eberhard and van Horen 1995).

Electricity is provided by a single parastatal utility known as Eskom Holdings Ltd., with the state being its only shareholder. It was formed as the Electricity Supply Commission in 1923, and over the years, swallowed up smaller municipal and private electricity firms to become a monopoly in the spheres of electricity generation and distribution (Christie 1984). From the 1980s, there were various intentions to privatise Eskom, and by the early 2000s, it was fully commercialised. It is no longer a nonprofit utility, but operates as a commercial entity (Gentle 2009). It falls under the government Department of Public Enterprises, rather than the Department of Energy. Since around 2005, it has been suffering from management and financial crises, and currently is having difficulty in seeking R 343 billion (US$ 46 billion) to finance new infrastructure.

Traditionally cheap and plentiful coal provides most of the country's electricity (over 90 %), making the country the 12th largest carbon emitter (between 1 and 2 % of global emissions) but without having had any Kyoto obligations. Coal reserves are said to amount to 53 billion t and have a life of around 200 years, making South Africa something of a prisoner of its fossil resources (Greenpeace Africa 2011a).

South Africa produces around 255 million t of coal annually (2010 figures), making it the fifth largest producer in the world (World Coal Association, 2012 Coal Statistics, http://www.worldcoal.org, downloaded 15 February 2012). Of this, 25 % is exported and 53 % used for energy generation. Coal provides around 77 % of all primary energy needs. Currently South Africa's electricity generating capacity is a nominal 39,154 MW. Of this, thermal coal stations have a capacity of 34,882 MW, nuclear 1930 MW, and hydro (including pumped storage) just 670 MW. In reality nuclear does not operate at full capacity, with an average of 1840 MW sent out.

Table 10.1 South Africa: total primary energy produced (*TPEP*) and total primary energy consumed (*TPEC*), 1990–2006, in quadrillion Btu (Quads). (Source: US Department of Energy, Energy Information Administration: South African Energy Profile (http://tonto.eia.doe.gov/country/country_time_series.cfm?fips=SF#prim (data to 2006 accessed 15 January 2010)), (http://www.eia.gov/countries/country-data.cfm?fips=SF (data for 2007–2008 accessed 31 January 2012)))

Year	1990	1991	1992	1993	1994	1995	1996	1997
TPEP	4.05	4.12	4.21	4.30	4.60	4.84	4.86	5.44
TPEC	3.36	3.52	3.75	3.72	4.06	4.09	4.12	4.51
Year	1998	1999	2000	2001	2002	2003	2004	2005
TPEP	5.52	5.43	5.56	5.59	5.5	5.9	6.1	6.1
TPEC	4.33	4.57	4.55	4.60	4.5	4.9	5.2	5.0
Year	2006	2007	2008					
TPEP	6.01	6.10	6.16					
TPEC	5.17	5.52	5.71					

The following table reviews South Africa's recent history with respect to total primary energy produced (TPEP) and total primary energy consumed (TPEC) (Table 10.1).

What accounts for the differences each year between TPEP and TPEC levels is largely the exportation of coal. South Africa is the world's second largest coal exporter after Australia.

Whilst there are claims that 70% of the population now has access to the national grid, the electricity is not always affordable in poor communities. This has led to increasing electricity cut-offs as newly connected households default on their payments. It should be noted that, with commercialisation of the utility, new users (mostly black and poor) are required to bear the full cost of the new infrastructure, while historic users (mostly white and affluent) live in areas where the infrastructural costs have long been paid off. Furthermore, access to electricity is less frequently through a billing system and more often through the installation of prepaid electricity meters.

A movement of the disconnected has been led by the Soweto Electricity Crisis Committee, which has been using its own electricians to reconnect up to 40 households a week (Alexander 2004; Fiil-Flynn 2001; Tables 10.2 and 10.3).

The industrial model that South Africa has adopted leads government to show more concern for the heavier electricity users. Organised in a lobby group, the Electricity Intensive User Group of South Africa, members consist of the major mining, steel, chemical, metallurgical, cement and pulp and paper firms which together account for 44% of the electricity consumed in South Africa (see http://www.eiug.org.za/membership for details). These firms have a strong influence over the state's electricity planning processes.

South Africa also encourages the siting of aluminium smelters within the country, despite the fact that is does not possess the raw material, bauxite. The industry is highly energy-intensive, and Eskom provides the transnational companies with cheap electricity in bulk (at a much lower rate than offered to the poor households

Table 10.2 South Africa: energy overview. (Source: International Energy Agency (*IEA*), *Key World Energy Statistics 2011, 2010, 2009 and 2006*. Paris: IEA)

Year	Population	Primary energy	Production	Export	Electricity	CO_2 emission
	Million	TW h	TW h	TW h	TW h	Mtoe
2004	45.51	1525	1814	279	226.5	343.4
2007	47.59	1562	1856	254	238.6	345.8
2008	48.69	1564	1895	203	232.2	337.4
2009	49.32	1675	1868	158	224.0	369.0
Change 2004–2009	8.4 %	9.8 %	3.0 %	−43 %	−1.3 %	7.6 %

Conversion rate: Mtoe (million tonnes of oil equivalent) = 11.63 TW h (terawatt hours). Primary energy includes energy losses

Table 10.3 South Africa: electricity consumption by sector 2010. (Source: IDASA Electricity Governance Initiative of South Africa 2010, p. 12)

Customer group	Electricity consumption (%)	Number of consumers
Residential	17	7,500,000
Agriculture	3	103,000
Commercial	13	255,000
Mining	15	1100
Industry/manufacturing	38	33,000
Transport	3	1800
Exports	6	7
Own use of distributors	5	–
Total	100	7,893,907

mentioned above). One such smelter was being encouraged as the 'anchor tenant' for the controversial new deep-level harbour at Coega, near Port Elizabeth, as part of the offset for a highly corrupt arms deal (Bond 2002, pp. 84–97). Together with the plants at Richards Bay, Saldanha Bay and Mozal in Mozambique, this development is tantamount to the bulk export of cheap electricity, despite cries of a dearth of capacity. Furthermore it encourages international use of South Africa as a pollution haven, since the plants are said not to meet standards in the EU and Japan.

10.2.2 Stresses on the Electricity Supply

Peak electricity demand is already reaching over 36,000 MW on the coldest July day, out of a potentially available 39,154. For at least a decade the growth in demand has prompted the monopoly utility Eskom to argue that by the year 2007 there would be severe strain on the system. The government did not respond to these alerts, since it had plans to privatise all or parts of the utility, and did not feel that it should allocate new public funds for infrastructural development but rather wait for the private sector to invest. These plans have not materialised, partly due to a public backlash against privatisation of state assets, and partly due to the reluctance of the private sector to invest in an electricity company whose tariffs were regarded as too low to generate much profit for business. Thus, without either private or public investment in 'new build', the reserve margin between demand and potential supply grew smaller. The preference is for a 15 % reserve margin to allow for some down time in the system due to maintenance and logistic issues. This reserve margin was gradually being eroded to a critical minimum.

This concern, along with power cuts (see Sect. III), has stimulated Eskom, the national electricity utility, to embark on a programme to extend supply. This includes:

- Placing mothballed thermal stations back in production (3800 MW)
- Adding two diesel-fired open-cycle gas turbine stations in the Western Cape province
- Constructing two enormous new coal-fired power stations (9576 MW)
- Adding a pump storage station at Ingula in the Drakensberg range
- Reviving plans to add to the current nuclear capacity (a planned extra 9600 MW)
- Constructing a concentrating solar power plant (adding 100 MW), the only renewable energy plant on this list

South Africa's and Africa's only nuclear power station is situated at Koeberg, some 25 km north of Cape Town. Its two reactors provide most of the electricity used in the Western Cape province, which is the most distant from the country's coalfields. Part of the argument which Eskom used to justify their construction was the cost and great inconvenience of railing coal in bulk to the Western Cape. However the acquisition of nuclear reactors prompted the apartheid regime to launch a uranium enrichment programme which was ostensibly aimed at providing nuclear fuel for Koeberg, but in fact was used for the proliferation of nuclear weapons. The weapons programme was dismantled in 1990 (see Fig 1998).

From the late 1990s, South Africa attempted to develop a high temperature reactor, the pebble bed modular reactor (PBMR). By 2010, the state had placed almost R 9 billion at the disposal of the PBMR company for research and development purposes. To construct the first demonstration plant and the fuel fabrication plant cost an extra R 22 billion. Designing the PBMR proved somewhat problematic, and by 2010, it was on its fifth redesign and second environmental impact assessment process. Building of the demonstration plant was postponed numerous times and was not expected before 2020, with the earliest commercial plant due around 2025 (Fig 2010, p. 32). However, the PBMR received a shock after the March 2010 budget, when the government announced that it would not place further taxpayer money at the company's disposal. The company first announced it would downsize and dismiss 75 % of its 800 personnel. Westinghouse, which has a small investment in the company, agreed to tide it over with some funds, but by August 2010, the government cancelled the programme in full (Fig 2010). It is now more interested in conventional large-scale pressurised water reactors.

Eskom's ambitious recapitalisation plans, cost R 343 billion in 2009, are facing enormous problems as the company is undergoing a series of crises. The first of these is a severe financial crisis, which has resulted from some of the following factors:

a. Through most of its existence, Eskom has charged some of the lowest rates globally for its electricity. This is because it has relied on cheap labour in the coal mines, as well as the exclusion of externalities (especially health and environmental clean-up costs) from the price. Some of the cheapest rates are accorded to the owners of aluminium smelters, and to South Africa's coal-to-oil synfuels industry.
b. From the 1980s, when Eskom generated an electricity surplus, it stopped investing in new power stations, and mothballed some of its existing stations. From 1994, there was significant growth in the economy, and supply and demand started to converge. However, because of the uncertainty of the role of public versus private investment in electricity, further infrastructural investment was neglected and an enormous backlog mounted.
c. Eskom was unable to raise sufficient capital by adjusting its tariffs to cover the investment shortfall. For one thing, it had to apply to the National Energy Regulator, which is a statutory body established in 2004 to regulate electricity, petroleum and natural gas. In an application for a 53 % increase for 2009, the regulator had only allowed 15 %. In the most recent application for the period 2010–2013, Eskom applied for annual rises in tariffs of 45 % per year. Because of a public outcry, including from trade unions, environmental groups and even the African National Congress (ANC), the application was modified to a 35 % increase for three successive years. The regulator ultimately granted increases of 25 %. Although this means that tariffs are set to double within 3 years, the expected revenue for Eskom amounts to nowhere near enough to cover its operational or capital expansion plans.
d. Eskom's credit ratings have been reduced significantly. In August 2007, credit ratings agency Fitch reduced Eskom's outlook for its long-term local currency issuer default rating (IDR) and national long-term rating to 'Negative' from 'Stable' (*Engineering News*, 2 August 2007). A year later Moody's Investor Services downgraded the organisation's foreign and local currency credit rating to Baa2, with a negative outlook. Moody's reasoned that Eskom's credit profile had deteriorated due to it trying to lever its balance sheet to fund its capital investment programme, and the lower tariff increases granted by the regulator (*Moneyweb*, 11 August 2008). The head of Fitch's energy team in Europe, Andrew Steel, stated in August 2009 that Eskom's credit rating was expected to deteriorate for the following 2 years.
e. For the first time in its recent financial history Eskom reported a loss of R 9.7 billion in the 2009 financial year.

How will Eskom raise the R 161 billion shortfall needed for what it calls its 'new build' programme? Part of the answer is to approach the World Bank for development finance. Eskom applied for a loan of R 28 billion (US$ 3.75 billion) to cover the construction of the 4800 MW Medupi coal-fired power station in Limpopo province, a 100 MW concentrating solar power station at Upington in the Northern Cape province, and a roll-out programme of solar photovoltaic roof panels.

This application drew considerable anger among civil society organisations, which formed a coalition to fight the loan on the grounds that it will further entrench South Africa's commitment to coal (Khanyile 2009, pp. 33–34). Opposition political parties objected to the fact that the contract for the boilers to Medupi has gone to Hitachi, whose South African subsidiary is quarter-owned by the ruling African National Congress, which will hence be a beneficiary of the World Bank loan. The Hitachi contract was approved at a meeting of the Eskom board chaired by former environment minister Mohamed Valli Moosa, who was then also a member of the ANC national executive and of its finance committee. Arguing that this represented a clear conflict of interest, and amounted to corruption, the civil society coalition and opposition parties attempted in vain to fight the loan (Bond 2012, p. 167; Hallowes 2011, p. 247).

Temperatures on the question rose, as different parties tried to lobby the World Bank and its investor nations. GroundWork, the South African affiliate of Friends of the Earth, coordinated 65 civil society organisations in opposing the loan.

Pravin Gordhan, the South African minister of finance, wrote an op-ed in the *Washington Post* ('Why coal is the best way to power South Africa's growth', 22 March 2010) justifying the loan on the grounds that the Medupi power station was vital to South Africa's energy security. President Zuma visited a number of key Western governments, asking them to back the loan. For their part, the World Bank governors approved the deal, despite a general disinclination of the Bank to continue funding fossil fuel and nuclear projects, and despite the abstaining of the USA, the UK, Netherlands, Norway and Italy in the vote (*The Guardian*, 9 April 2010).

10.2.3 South Africa's Renewable Energy Potential

During the UN World Summit on Sustainable Development held in Johannesburg in 2002, Brazil attempted to introduce a mandatory target for all nations to adopt renewable energy as at least 10 % of their electricity output. However, this proposal was never accepted, and most countries have gone forward at their own pace. South Africa declared its own target at 10,000 GWh by the year 2013. This is an equivalent of about 4 % of the energy currently generated. It is nowhere near the level of ambition of a country like Spain which set a target of 30 % by 2010, and which exceeded this by over 4 % in 2009. The overall EU target is 20 % by 2020. Wind power alone accounts for 19 % of Danish, 13 % of Spanish and Portuguese, and 7 % of German and Irish electricity. Despite its relative modesty, South Africa remains quite far from reaching its own target.

Although the government is supporting limited programmes on the development of wind and solar power, these are still in very preliminary stages, despite the country's abundance of both sources. Further programmes on energy efficiency, energy

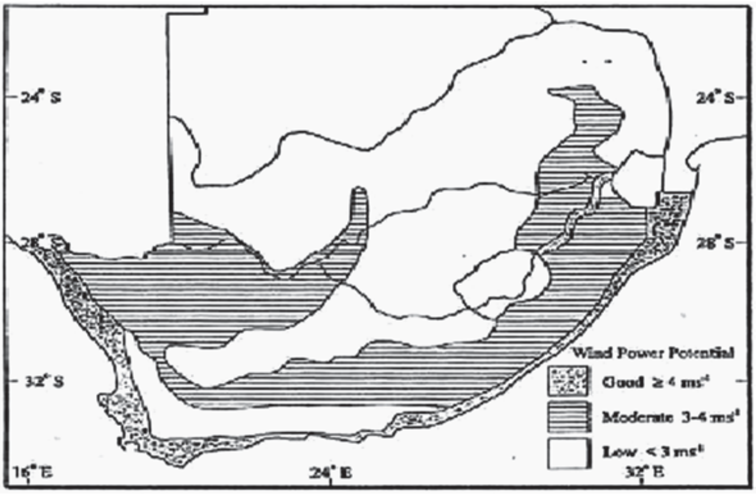

Fig. 10.2 South Africa: wind power potential

conservation and demand-side management have also been launched, but also with limited results. Often, innovative projects are left to the community of nongovernmental organisations and private energy consultancies. Limited funds set aside for development of renewable energy have proved too difficult to access, and some have been withdrawn.

When analysing the potential of key categories of renewable energy, different research comes up with different answers as to how much of it can be used. For example, Eskom claims that only 1000 MW of wind power can be harnessed, whilst researchers Banks and Schäffler, using government figures, claim an estimate of 50,000 MW while other estimates are as high as 70,000 MW (Banks and Schäffler 2005, p. 23; Eskom 2006, p. 40; McDaid 2009, p. 203). Doctoral research by Hagemann (2008) shows that South Africa's *wind* resource is higher than previously put forward by researchers and ranks amongst the windiest in the world (Szewczuk 2010; Figs. 10.2 and 10.3).

South Africa's *solar* potential is significant, and said to be amongst the highest in the world. Solar radiation levels range between 4.5 and 7 kW h/m^2, compared to about 3.6 kW h/m^2 for parts of the United States and about 2.5 kWh/m^2 for Europe and the UK. A surface area of 75 m^2 per person would be sufficient to meet every person's energy demands (Banks and Schäffler 2005, p. 141; McDaid 2009, p. 203). Barry McColl, Eskom's technology, planning and strategy manager, stated on the sidelines of an International Solar Energy Society Congress in Johannesburg in August 2009 that the country had the potential to generate 58,000 MW of solar power (Salgado 2009).

Unlike neighbours to the north and east, South Africa's *hydroelectric* potential is rather limited, due to its rivers being too unreliable as an energy source. Some hydro is imported (from Cahora Bassa in Mozambique) and there is also limited use of

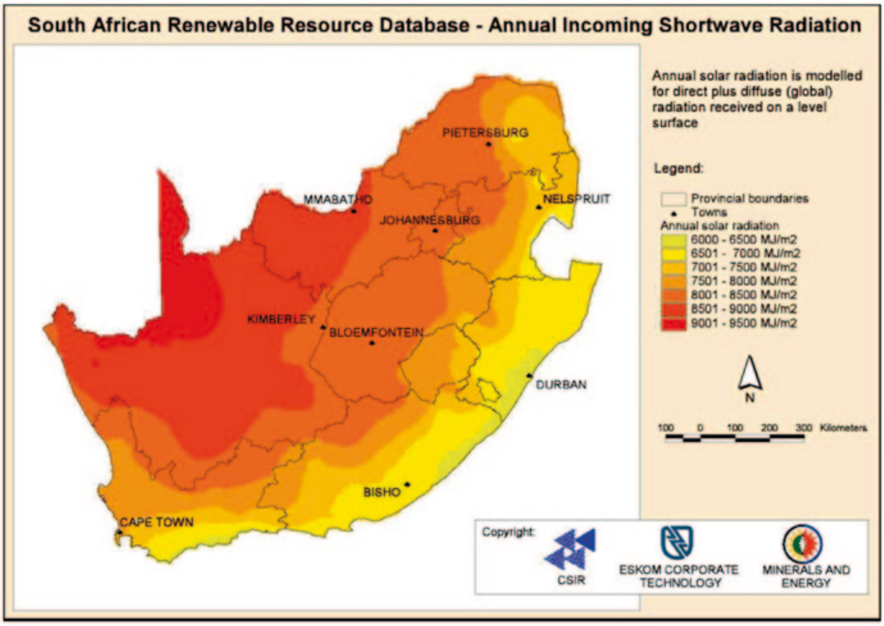

Fig. 10.3 South Africa: annual direct and diffuse solar radiation. (Source: CSIR, Eskom, Department of Minerals and Energy 2001)

pump storage, which helps to regulate peak demand. There are also future plans to exploit the Inga Falls area in the Democratic Republic of Congo, potentially a vast source of hydro power. Initially, this was set to be organised by a regional power pool including Angola, Botswana, Congo, Namibia and South Africa. However, in recent months, the Congolese government has announced its preference to exploit the Inga complex alone. The Inga 3 power station will be built by BHP Billiton, the mining giant, which plans to generate 2500 MW of power, partly to provide for its own aluminium smelter planned to be close to the Inga Falls.

South Africa has hence to rely mainly on solar and wind power, with other categories of renewable energy also playing a role. The potential of the key categories has been quantified by Schäffler in Table 10.4.

The Worldwide Fund for Nature, South Africa has produced a study indicating that, with the appropriate political will, by 2030, 50 % of South Africa's electricity could be generated by renewable sources (WWF-SA 2010).

10.2.4 Energy Governance in South Africa

The governance of energy in South Africa is somewhat fragmented, partly because Eskom falls under the Department of Public Enterprises, and not the Department of Energy (prior to May 2009, this was the Department of Minerals and Energy). Climate policy is undertaken by the Department of Environment (now merged with

Table 10.4 South Africa: potential of various categories of renewable energy. (Source: Based on Jason Schäffler, presentation on wind and solar to South African National Energy Association, Johannesburg: Sustainable Energy Society of Southern Africa, 4 June 2009, slide 35/52)

Category	Current energy (TW h)	Total potential (TW h annually)	Maximum scenario (TW h annually)
Hydro	1	15	43 if imports used
Wind	–	106	80
Solar PV	–	–	85
Solar thermal	0.5	–	56
Solar thermal electric	–	–	184
Wave, geothermal, ocean	–	70	70
Biomass	106	44	94
Landfill gas	–	10	10

Water Affairs). Thus while the Department of Energy has formal responsibility for generating the country's energy policy, in practice Eskom has a much larger budget and has enjoyed in recent years relative autonomy to determine many of its own policy directions, and thus to a large extent shape the country's priorities (IDASA Electricity Governance Initiative 2010, pp. 15–22 contains a more detailed analysis of interdepartmental conflict).

With the rise of the regulator, and the experience of financial and leadership crises, Eskom is no longer the chief locus of electricity policy. Under the Zuma presidency, since November 2009, policy has been placed in the hands of an Inter-ministerial Committee (IMC), led by the minister of public enterprises. The IMC is charged with coordination of electricity policy and with oversight of the Integrated Energy Plan 2010.

The Department of Energy (DoE), under minister Dipuo Peters, is less adept at leading the formulation of energy and electricity policy. As already mentioned, it is Eskom that is promoting policies and leading projects on demand-side management, renewable energy and energy efficiency. Yet the DoE is constitutionally responsible for managing entities such as the energy regulator, the nuclear regulator, the Central Energy Fund and the Nuclear Energy Corporation. It is the DoE that is busy revising the national policy on renewable energy. Given its weak capacity, it has been inviting consultants to write the relevant policy documents.

10.3 South Africa's Electricity Crisis

Much of the predicted shortfalls in electricity supply have become manifest in the past few years, especially as the reserve margin between supply and demand has foreshortened.

The crisis began with a series of power cuts in the Cape Town area at the end of 2005 (Hallowes and Munnik 2007, pp. 36–67). These cuts were attributed to the mismanagement of the Koeberg nuclear power station (NERSA 2006). Amongst a series of incidents which closed down one of the reactors, it transpired that an 8 cm bolt had wrongfully been left in the generator of Unit 1 and that the damage would take a few months to correct. The 5-month routine shutdown of Unit 2 for refuelling from April 2006 led to further dramatic power cuts at the start of the Western Cape winter. The cuts, which affected industry, services and households, led to significant economic losses, especially for the province's agricultural and food processing industries.

The lessons of the 2005/2006 regional outages were by no means learned by the system. By late January 2008, the whole country was being subjected to random power cuts, said to be required to prevent the collapse of the entire national grid. Industry, including mining, was asked to take a 20 % cut in electricity supply, and households 10 %. These economic disruptions were at the time said to be likely to last for at least a decade, while the country waited for new generation plans to be realised. After 2 months, the utility announced that the cuts would henceforth be carefully scheduled, with each neighbourhood timetabled to experience 48 h of darkness spread over a month. In April 2008, as suddenly as the outages had begun, they were terminated, and the country began to get back to normal. Since that time, demand has been reduced by the economic recession, but Eskom has issued warnings that power cuts (which it calls 'load shedding') are likely to return in 2011.

The generalised outages were partly a result of the failure to invest steadily in new infrastructure to offset the rise in demand. However, there were also conjunctural issues. Eskom had failed to hedge properly in coal, and experienced acute shortages of supply. In addition, many of the coal deliveries had arrived wet, due to an excessively rainy summer. This meant that the coal could not be used effectively for power generation.

Angry parliamentarians and citizens have also been questioning the actions of the relevant officials over the series of outages, especially critical of the massive bonuses granted to Eskom's top management. However, Eskom has been using public disquiet over the power cuts to create a moral panic in favour of a return to burning fossil fuels and uranium. It has argued that these fuels are the only ones that can support base load electricity production, and that renewable energy sources are too intermittent and expensive to be reliable.

These arguments have been bought by government, as reflected in recent statements by ministers of public enterprise and energy. Emphasis has been placed on seeing that the Medupi and Kusile power stations come to fruition, and that South Africa adds a number of conventional nuclear reactors to its power configuration.

This comes at a time when the Koeberg reactors are reaching the midpoint of their design life. The power stations have been operating since 1984 and, like other Framatome/Westinghouse pressurised water reactors, have a lifespan of between 40 and 50 years before needing to be decommissioned. Reactors are only as safe as the reliability of their operators, and it seems that the spate of personnel changes accounted for the increasingly inexperienced management and operational decisions which led to the 2005/2006 outages. This can hardly augur well for the addition of a new fleet of reactors.

However the electricity crisis has also generated new interest in the potential of renewable energy, and a slightly more vigorous attempt to meet the modest targets set in 2002.

10.4 South Africa's Policy on Renewable Energy

10.4.1 Renewable Energy White Paper

The then Department of Minerals and Energy in 2003 published a *White Paper on Renewable Energy*. This turned into policy, the 10-year target, which had been devised at the previous year's UN World Summit on Sustainable Development, namely: 10,000 GW h (0.8 Mtoe) renewable energy contribution to final energy consumption by 2013, to be produced mainly from biomass, wind, solar and small-scale hydro. The renewable energy is to be utilised for power generation and non-electric technologies such as solar water heating and biofuels. This is approximately 4 % (1667 MW) of the estimated electricity demand (41,539 MW) by 2013. This is equivalent to replacing two (2×660 MW) units of Eskom's combined coal-fired power stations (DME 2003, p. 25).

The *White Paper* acknowledged that investment in renewables was risky, and needed support through the careful nurturing of pilot projects. It established the principle of full cost accounting and acknowledged that costs of fossil and nuclear fuels did not include the environmental externalities and social impact costs. However, even were these costs to be included for renewable energy sources, they would still need market support until economies of scale and investor confidence could be established. For this, the government would need to establish appropriate financial and legal instruments. It considered some of the financial instruments already implemented in other countries, but did not conclude on any specific option for South Africa.

Within a few years of the publication of the White Paper, the recently established regulator considered some of the available options for the appropriate financial instruments. These included direct subsidies (such as tax credits) to the investor, guaranteed feed-in tariffs higher than for conventional power (which allow the investor to plan more accurately), and a tendering system (for each block of power allocated to renewable energy). It was decided that the feed-in tariffs would be more effective, as tendering had often led to corruption and the crowding out of smaller investors.

In 2009, the National Energy Regulator published its feed-in tariffs for selected renewable energy sources (NERSA 2009a, b). These tariffs were revised downward 2 years later. Both tariffs are reproduced in Table 10.5.

Whilst the setting of these feed-in tariffs was a step forward in stabilising the market for renewables, investors have complained that until they had promises to purchase from Eskom, the level of uncertainty impeded the initiation of projects on the ground. Until these power purchase agreements materialise, private investment in the renewable sector are less likely to be forthcoming.

Table 10.5 South Africa: renewable energy feed-in tariffs, 2009 and 2011. (Source: NERSA, *South Africa Renewable Energy Feed-In Tariff (REFIT), Regulatory Guidelines* 26 March 2009 and *Renewable Energy Feed-In Tariffs, Phase II*, 29 October 2009. NERSA, *Review of Renewable Energy Feed-In Tariffs*, March 2011)

Renewable energy source	Feed-in tariff per kilowatt-hour, 2009	Revised feed-in tariff to nearest cent, 2011
Concentrating solar power trough without storage	R 3.13	R 1.94
Grid-connected solar PV-producing > 1 MW	R 3.94	R 2.31
Concentrating solar power with 6 h storage	R 2.31	R 1.40
Solid biomass	R 1.18	R 1.06
Biogas	R 0.96	R 0.84
Landfill gas	R 0.90	R 0.54
Wind	R 1.25	R 1.15
Small hydro	R 0.94	R 0.67
Wave, geothermal and tidal energy	Excluded for the present	

Apart from the REFIT tariff, the government generated plans to stimulate co-generation of electricity by private firms for feeding into the grid. For example, these could include the conversion of heat to electricity in some of the steel and petrochemical industries, or the conversion of bagasse (solid wastes) from the sugar industry into energy, a process already under way in Mauritius.

To stimulate research, development and demonstration of renewable energy technologies, the government's Central Energy Fund has established the South African National Energy Development Institute (SANEDI). SANEDI's role is to develop renewable energy resources, energy efficiency programmes, energy technology research and sustainable housing and transport solutions. It is utilising state donor and private funds to accelerate key projects with a view to rapid creation of jobs. Despite having a very wide brief, its involvement in renewable energy development is substantial. Key projects include the development of solar photovoltaic products (including thin film technology), ocean energy technologies, and concentrating solar power (Nassiep 2009).

Also recently created has been the South African Renewables Initiative, a government agency aimed at facilitating long-term finance for the development of renewable energy generating projects. It seeks to do this by creating low-cost loans, developing risk mitigating instruments, and accessing development aid and government grants. While costs of renewables and finance remain high, the aim is to create instruments that will assist project developers to leverage development finance more easily (SARi 2010).

The government's feed-in tariff programme proved somewhat problematic. Two years after the tariffs were introduced, they were deemed too high, and the regulator, NERSA, dropped their rates in 2011 (see Table 10.5). However, during the course of the same year, the idea of feed-in tariffs was rejected entirely, and instead, the government instituted a plan to oversee bids from independent power companies to provide up to 3725 MW of electricity by 2017. In all, 53 bids were received in the first round of bidding in November, and after evaluation, the bids were whittled down to 14, announced during the UN climate talks in Durban in December. These are to be confirmed after financial and environmental assessment by June 2012. Bids were received from Chinese, European, US and Indian companies, with a stipulation that 40 % South African partnership is required (*Mail & Guardian Online*, 14 November 2011, 7 December 2011; *Wall Street Journal*, 2 December 2011).

Trade unions have responded, criticising the bidding process as being skewed against smaller firms, cooperatives and communities, who find it more difficult to access capital and technology (*Business Day*, 7 February 2012). NUMSA, the metalworkers' union, has formed worker committees to research the potential of renewal energy and energy efficiency.

10.4.2 South Africa's Climate Commitment

On the eve of the Copenhagen climate change conference in December 2009, the South African government announced that the country will make absolute emissions reduction of 34 % below business-as-usual by 2020 and 42 % by 2025 (Wills 2010).

This would enable South Africa's emissions to rise for the next decade, peak between 2020 and 2025, stabilise for 10 years and then decline in absolute terms. Such commitments are conditional on a 'fair, ambitious and effective outcome' to the international climate negotiations and on receiving financial and technical support from the international community.

However, a further hidden conditionality is obtaining support for this process from the South African business community to comply with these reduction efforts. Without this commitment, reaching the targets will not be feasible.

South Africa was one of the only countries to state a clear emissions reduction target at Copenhagen. The negotiations at the 15th conference of the parties to the UN Framework Convention on Climate Change failed to stick to the Bali roadmap and design a follow-up to the emissions reduction commitments laid out in the Kyoto Protocol.

South Africa's targets were announced over the heads of climate change stakeholders, including business and other sectors, and therefore may be difficult for the government to sell. While they are by no means a radical solution, and even concede that in the short-term emissions of greenhouse gases will rise, they do not represent a position taken after extensive consultation. The government did hold a Climate Summit in March 2009, at which it considered the options placed before it by the results of the Long-Term Mitigation Scenarios (LTMS) developed for the Department of Environmental Affairs and Tourism (South Africa, DEAT 2008). The LTMS options, however, are controversial (see Hallowes 2008) and no specific scenario was formally adopted by the Summit. Stakeholders were told that South Africa would develop its climate policy in the aftermath of the Copenhagen negotiations when the global trends appeared clearer.

Table 10.6 South Africa: largest emitters of greenhouse gases. (Source: Carbon Disclosure Project 2010)

Firm	Nature of business	Emissions, in million metric tonnes of CO_2 equivalent	Percentage of total GHG emissions in South Africa (%)
Eskom	Electricity utility	220	50
Sasol	Synfuels	61	14
Arcelor-Mittal	Steel production	12.4	2.8
BHP Billiton	Mining	4.5	1
Anglo American	Mining	3.4	0.8

GHG greenhouse gas

South African business has been caught up in the rhetoric of sustainability, and has been influenced by global trends towards engaging in social and environmental responsibility, through improving sustainability reporting, strategic philanthropy and the greening of some of its practices. Some of this has been guided by a series of reports emanating from the Institute of Directors under the leadership of Judge Mervyn King (King Committee 2009). Owing to the lack of binding legislation in South Africa, measuring and voluntarily reporting on emissions has been left to the remit of companies on the Johannesburg Securities Exchange (JSE) Top 100 as part of the Carbon Disclosure Project, as well as environmentally conscious companies recognising their responsibilities in this respect. In 2009, 68 % of the JSE top 100 voluntarily disclosed their carbon emissions, ranking only behind Brazil in disclosure response globally.

However, at the same time, because of the structure of South African industry, some 36 firms comprising the Energy Intensive User Group, are responsible for 44 % of electricity use, and hence for significant emissions. By virtue of being quoted in the JSE Securities Exchange Top 100, many of these firms are required to disclose their greenhouse gas emissions (Table 10.6).

It is questionable whether these and others of the most intensive carbon-emitting firms will accede willingly to the targets established in the run-up to Copenhagen.

The issuing of a National Climate Change White Paper in 2011 (South Africa, DEA 2011) raised a national debate about its contents. On the one hand it seemed to acknowledge the imperatives of reversing the negative impacts of climate change as manifested in the country, but was criticised for containing lukewarm and contradictory proposals, as well as a number of 'false solutions' to address the problem (Cock 2011).

While not explicit about the country's nuclear programme, there is no attempt to unpack the impact of an expanded nuclear fleet on climate. Whilst the reactors do not emit large amounts of carbon, the nuclear fuel chain, including mining, milling, conversion, enrichment, reactor construction, transport, reprocessing and decommissioning are all high consumers of fossil fuels (Greenpeace Africa 2011b).

While South Africa hosted and presided over the 17th Conference of the Parties to the UN Framework Convention on Climate Change, the Durban meeting failed to firm up mandatory global commitments to emissions reductions nor did it establish the successor instrument to the Kyoto Protocol. Instead it marked the increasing inability of the multilateral system to make a decisive impact on one of the era's most telling global problems.

10.4.3 Energy Efficiency and Demand-Side Management

The efforts to increase efficiency and reduce electricity demand go hand-in-hand with the move away from the burning of fossil fuels, and, as such, bear a strong relation to the introduction of renewable sources of energy.

While the national utility, Eskom, has taken some steps in this regard, its overall ethos of seeking to satisfy the power needs of energy-intensive users of electricity may compromise many of the efforts so far made in areas of efficiency and demand reduction.

Eskom's Integrated Demand Management department has taken important steps to sensitise different sectors of the economy in demand reduction and in supporting the switch to more efficient and energy-saving technologies. This includes attempts to change building codes, provide subsidies for solar water heating projects, and the encouragement by industry of a 15 % demand reduction. The Department of Trade and Industry (DTI) has a National Cleaner Production Centre which encourages the use of less energy and harmful chemicals in manufacturing. The Department of Energy has been charged with building on the experiences of Eskom and the DTI and developing an 'aggressive energy efficiency programme in industry' (South Africa, DEA 2011, p. 31).

10.4.4 South African Industrial Policy

Industrial policy has tended to favour the larger users of electricity, such as the mining houses, the steel plants, the smelters and refineries, and coal-to-oil conversion plants. Incentives are still provided to some industries such as motor, textile and clothing manufacture. Industrial policy has for the most part not taken into account the need to decarbonise the economy, nor has it favoured energy efficiency approaches. Instead of better planning and providing incentives for smarter and greener industrial expansion, it continues to emphasise traditional approaches favouring the needs of the expanding 'minerals–energy complex' and expects the utility to meet the resulting increased demand for energy.

Under President Zuma, a new ministry of economic development has been created, with a former trade union official, Ebrahim Patel, as minister. However, this ministry is still trying to find its feet, and in planning terms may lose out to a more powerful and orthodox planning commission located in the presidency, led by the former finance minister, Trevor Manuel. Mired in potential conflict, it seems unlikely that either body can ensure that South Africa will 'leapfrog into the solar age', as Wolfgang Sachs recommended at the Johannesburg UN world summit on sustainable development in 2002 (Sachs 2002).

In February 2010, the Department of Trade and Industry issued the second Industrial Policy and Action Plan (IPAP2). This has placed some stress on 'green' jobs in the renewable energy sector (within the very low target set in 2002). However, at the same time the plan endorses commitments to extending the nuclear fleet, providing incentives for the localisation of nuclear services, and aims at subsidising electric cars (to run off mostly coal-fired electricity instead of liquid fuels). IPAP2 only makes brief mention of climate change, and contains insufficient discussion of the constraints that might be placed on industry by sharp rises in electricity prices. Nor does it deal with the implications of the declaratory commitments by government on the question of climate change raised in the previous section.

Industrial policy will only make sense if energy and climate considerations are factored more significantly into its substance, rather than being an add-on.

When he came to power in 2009, President Zuma created a Department of Economic Development (EDD), placed under former trade unionist Ebrahim Patel, and, within the Presidency, a National Planning Commission, placed under former finance minister Trevor Manuel. Both were charged with the production of visions and plans for national development.

The EDD plan is entitled the 'New Growth Path', and although it attempts to expand employment opportunities, it does not diverge from orthodox development planning and fails to provide any vision for restructuring the economy along more sustainable lines. It sees the 'green economy' as a job-creation driver, but instead of advocating innovation and national leadership around a smarter, greener approach to manufacturing, it merely repackages existing low-level government commitments. It does call for "comprehensive support for energy efficiency and renewable energy … including appropriate pricing policies, combined with programmes to encourage the local production of inputs, starting with solar water heaters" (South Africa, EDD 2011, p. 13, 35).

The National Planning Commission advocates a low-carbon economy, recognising the need for structural transformation away from an energy-intensive resource dependent model, and arguing for a 'just transition' with adequate retraining, innovation and trade-offs being put in place. It is somewhat cautious about plans for a nuclear roll-out, although favouring the development of shale gas (a fossil fuel, based on climate-harmful methane) in its place (South Africa, National Planning Commission 2011, p. 147, 179 ff.).

Debate about a 'green economy' has been quite intense, with the government convening a Green Jobs Summit in May 2010 (South Africa, Department of Economic Development et al. 2011) and the DED signing a Green Economy Accord with the Congress of South African Trade Unions in November 2011 (*Business Day*, 18 November 2011). Sceptical of government plans, over 40 civil society organisations have developed a campaign to combat unemployment and climate change through advocating the creation of a million climate jobs (Dada 2011).

The challenge of job creation remains a key question in current recessionary conditions. It should be noted that, in their research, Agama Energy (2003, p. 12) estimated that if renewables were to generate 15 % of all electricity by 2020, an additional 36,400 jobs would be created in South Africa. The Industrial Development Corporation and associates predicted that by 2025, 130,000 direct jobs would have been established in the ever-expanding area of green-energy production (Maia et al. 2011, p. 4). Rutovitz places the potential for direct jobs generated by renewable energy by 2030 in South Africa at 78,000, with an extra 33,700 generated if manufacturing capability is optimised (2010, pp. 2–3, 31).

10.4.5 Integrated Resource Plan for Electricity in South Africa

Electricity policy and planning processes have seldom been transparent or inclusive. A case in point is the Integrated Resource Plan (IRP) for electricity over the next 20 years. This was designed by Eskom and the Department of Energy, which proposed the core elements of the IRP in September 2009, which were leaked to the press in January 2010 (Mail and Guardian 2010).

In December 2009, the government gazetted a 5-year IRP, as an interim measure before having to consult more broadly on the long-term implications of electricity policy (South Africa, Department of Energy 2009). The draft plan accentuated the risks of renewable energy, without being honest about the long-term risks of coal dependency, which include climate change, severe pollution and health problems, acid mine drainage, hedging difficulties, massive water use, as well as contractual and delivery problems. The plan also failed to analyse the full scope of demand-side management of electricity use.

Basing its energy planning projections on the Long-Term Mitigation Scenarios which allowed for peak-plateau-decline (Raubenheimer 2011; Winkler 2010, p. 204), the IRP proposed a 'revised balanced scenario' in October 2010, which allowed for the expansion of South Africa's new electricity generation build by 9.6 GW of nuclear, 6.3 GW of new coal, 11.4 GW of renewables, and 10 GW of other sources by 2030. A further round of public consultation led to the final adoption of a so-called policy-adjusted scenario, taking into account questions of finance, costs and jobs, but retaining the commitments to nuclear, energy efficiency, demand-side management, and emissions constraints contained in the earlier scenario (South Africa, Department of Energy 2011).

The electricity IRP is supposed to be informed by an Integrated Energy Plan, which has to be undertaken with full public participation, mandated under the National Energy Act of 2008. To date little has been done to engage the public in conformity with the Act. Without public engagement and scrutiny on such a key set of questions, planning is likely to reflect the views of a narrow group of stakeholders and substitute for the national interest.

10.5 Conclusion

From what we have seen, renewable energy has a great deal of potential in South Africa, and some key demonstration projects have been initiated. However the national target of 10,000 GWh set at the WSSD seems extremely modest, and may not even be reached within the target date of 2013.

Table 10.7 South Africa: current and projected costs in 2030 of energy sources in kilowatt-hours. (Source: NERSA, *South Africa Renewable Energy Feed-In Tariff (REFIT), Regulatory Guidelines* 26 March 2009 and *Renewable Energy Feed-In Tariffs, Phase II*, 29 October 2009)

Energy source	Current cost, 2010 (R)	Projected cost, 2030 (R)
Coal	0.51.9	1.66
Nuclear	0.72	1.76
Landfill gas	0.90	0.72
Biogas	0.93	0.87
Wind	1.25	0.89
Biomass	1.18	0.89
Open-cycle gas turbine	2.51	4.23
Solar PV	3.94	3.59
Concentrating solar	3.15	1.88

Blame must be placed on government energy planning, which suffers from a deficit of strategic coordination, bureaucratic inertia, financial and managerial crisis, and a failure to streamline an enabling environment for investment, despite a plethora of plans. Politically the government strongly favours coal and nuclear as investment priorities, mistrusting the ability of renewable sources and demand-side management to provide base-load solutions.

Numerous constraints have been identified in relation to the implementation of renewable energy projects, including the questions of finance and operating costs (Fakier and Nicol 2008). In some cases, the costs of renewables will over time catch up with the upward trajectory of the price of coal and nuclear, providing a more competitive set of prices (see Table 10.7).

It is clear that because of financial constraints reviewed in Sect. 2.2 of this chapter that the utility Eskom cannot afford to remain a monopoly. Some years ago, the South African cabinet decided that independent power production should be encouraged, and should share the electricity market with Eskom by means of a 30% stake. This was reiterated in the 2010 State of the Nation address in parliament by President Zuma on 11 February (Zuma 2010).

Coordination of renewable energy policy, however, remains fragmented. While there is a new push for 'green' jobs in industrial policy, and a desire to raise funding for the Upington CSP project, in general there is no single entity driving renewable energy policy and removing bureaucratic problems for investors. The Department of Energy is mired in problems such as a skills deficit, and some of its key bureaucrats facing probes for conflicts of interest within the energy sector (Jordan 2011).

The Interministerial Committee driving electricity policy still favours unsustainable fossil and nuclear solutions. The government seems to lack the in-house capacity to drive the sorely-needed revision of the *2003 Renewable Energy White Paper*, and has resorted to the use of consultants for this.

One major gap in the process of developing renewable energy is the absence to date of power purchase agreements with Eskom or its independent competition. The Department of Energy blames this on the failure of the Interministerial Committee to determine Eskom's funding model, while the regulator denies that the decision is dependent on the IMC. The matter is confused by the uncertainty around how the independent power producer(s) will be structured.

Meanwhile Eskom claims that what is needed to get the renewable energy industry going is a decision by energy minister Peters on which institution will purchase independently produced energy, then approval by the regulator, and then the setting by the DoE of targets for each renewable energy source. NERSA also needs to finalise the power purchase agreements (Gosling 2010). Until these steps are implemented, investors will be less forthcoming in supporting renewable energy projects.

There are a number of opportunities for changes in attitude and implementation. These include the various policy processes (Integrated Energy Plan, revised Renewable Energy White Paper, further discussions on climate and industrial policy, and so on), which need to be more transparent and inclusive of the various stakeholders. This sets South Africa at a crossroads: will it continue as a prisoner of its coal and uranium reserves, or will it be able to take responsibility for demonstrating a commitment to global citizenship favouring more socially, economically and environmentally sustainable solutions in the years to come?

References

Agama Energy (2003) Employment potential of renewable energy in South Africa. Johannesburg: sustainable energy and climate change project of Earthlife Africa

Alexander P (2004) Anti-globalisation movements, identity and leadership: Trevor Ngwane and the Soweto Electricity Crisis Committee. Paper presented at the annual meeting of the American Sociological Association, San Francisco

Banks D, Schäffler J (2005) The potential contribution of renewable energy in South Africa. Johannesburg: sustainable energy and climate change project of Earthlife Africa.

Bond P (2002) Unsustainable South Africa: environment, development and social protest. University of Natal Press, Pietermaritzburg

Bond P (2012) Politics of climate justice: paralysis above, movement below. University of KwaZulu-Natal Press, Pietermaritzburg

Carbon Disclosure Project (CDP) (2010) South Africa JSE 100. CDP, London

Christie R (1984) Electricity, industry and class in South Africa. State University of New York Press, Albany

Cock J (2011) What colour is the National Climate Change White Paper? http://www.climatejobs.org.za/documents/campaign-research/177-national-climate-change-white-paper-by-jacklyn-cock.html. Accessed 20 Feb 2012

Dada R (ed) (2011) One million climate jobs. One million climate jobs campaign, Cape Town

Eberhard A, van Horan C (1995) Poverty and power: energy and the South African state. Pluto, London

Electricity Governance Initiative of South Africa (2010) The governance of power: shedding light on the electricity sector in South Africa. Institute for Democracy in South Africa (IDASA), Pretoria

Eskom (2006) Eskom and renewable energy: global solutions for future power needs. Afr Wildl 60(2):38–41

Fakier S, Nicol D (2008). Investigation: obstacles and barriers to renewable energy in South Africa. Department of environmental affairs and tourism, Pretoria

Fig D (1998) Apartheid's nuclear arsenal: deviation from development. In: Cock J, Mckenzie P (eds) From defence to development: redirecting military resources in South Africa. International Development Research Centre, Ottawa, pp 163–180
Fig D (2010) A nuclear rethink? The rise and demise of the pebble bed modular reactor. Institute for Security Studies, Pretoria
Fiil-Flynn M, The Soweto Electricity Crisis Committee (2001) The electricity crisis in Soweto (Municipal Services Project (MSP) Occasional Papers Series, No. 4). MSP, Cape Town
Fine B, Rustomjee Z (1996) The political economy of South Africa: from minerals-energy complex to industrialisation. Westview, Boulder
Gentle L (2009) From Escom to Eskom: from racial Keynesian capitalism to neo-liberalism, 1910–1984. In: McDonald D (ed) Electric capitalism: recolonising Africa on the power grid. Earthscan, London, pp 50–72
Gosling M (26. Feb. 2010) Renewable energy's bumpy road. The Star
Greenpeace Africa (2011a) The true cost of coal in South Africa. Greenpeace Africa, Johannesburg
Greenpeace Africa (2011b) The true cost of nuclear power in South Africa. Greenpeace Africa, Johannesburg
Hagemann K (2008) Mesoscale wind atlas of South Africa. Unpublished PhD Thesis, University of Cape Town
Hallowes D (2008) A critical appraisal of the long term mitigation scenarios. Johannesburg: sustainable energy and climate change project of Earthlife Africa
Hallowes D (2011) Toxic futures: South Africa in the crisis of energy, environment and capital. University of KwaZulu-Natal Press, Pietermaritzburg
Hallowes D, Munnik V (2007) Poisoned power. GroundWork, Pietermaritzburg
Jordan B (20. Jan. 2011) R1m Green Energy Project abandoned. Sunday Times (Johannesburg)
Khanyile S (2009) Research on Eskom and the world bank. In: Dada R (ed) The new nexus of power and accountability in South African energy. Institute for Security Studies, Pretoria, pp 33–34
Maia J, Giordano T, Kelder N, Bardien G, Bodibe M, Du Plooy P et al (2011) Green jobs: an estimate of the direct employment potential of a greening South African economy. Johannesburg: Industrial Development Corporation, Development Bank of Southern Africa and Pretoria: Trade and Industry Policy Strategies
Mail and Guardian (2010, Jan. 8) Eskom's Secret Tariff Plan revealed. http://www.mg.co.za/article/2010-01-08-eskoms-secret-tariff-plan-revealed. Accessed 5 March 2010
McDaid L (2009) Renewable energy: harnessing the power of Africa? In: McDonald D (ed) Electric capitalism: recolonising Africa on the power grid. Earthscan, London, pp 202–228
Nassiep K (2009, Oct. 1) Presentation on SANERI/SANEDI to Global Labour University, Johannesburg
National Energy Regulator of South Africa (NERSA) (2006) Investigation into the electricity outages in the Western Cape for the period November 2005 to March 2006. NERSA, Pretoria
National Energy Regulator of South Africa (NERSA) (2009a, March 26) South Africa renewable energy feed-in tariff, regulatory guidelines. NERSA, Pretoria
National Energy Regulator of South Africa (NERSA) (2009b, Oct. 29) Renewable energy feed-in tariffs, phase II. NERSA, Pretoria
Raubenheimer S (2011) Facing climate change: building South Africa's strategy. Institute for democratic alternatives in South Africa, Pretoria
Rutovitz J (2010) South African energy sector jobs to 2030: prepared for Greenpeace Africa by the Institute of sustainable future, University of Technology, Sydney. Greenpeace Africa, Johannesburg
Sachs W (ed) (2002) The Jo'burg Memo: fairness in a fragile world: memorandum for the world summit on sustainable development. Heinrich Boell Stiftung, Berlin
Salgado I (2009, Oct. 13) Eskom seeks equity partner for demo solar plant. Business report
South Africa, Department of Economic Development (EDD) (2011) A new growth path: the framework. EDD, Pretoria

South Africa, Department of Energy (2009, Dec. 31) Notice No. 1243, Electricity Regulation Act 2006: determination regarding the integrated resource plan and new generation capacity. Government Gazette, Pretoria

South Africa, Department of Environmental Affairs and Tourism (DEAT) (2008) Long term mitigation scenarios for South Africa. DEAT, Pretoria

South Africa, Department of Environmental Affairs (DEA) (2011) National climate change response white paper. DEA, Pretoria

South Africa, Department of Minerals and Energy (DME) (2003) White paper on renewable energy. DME, Pretoria

South Africa, National Planning Commission (2011) The National Development Plan: vision 2030. The Presidency, Pretoria

South African Renewables Initiative (SARi) (2010) Unlocking South Africa's green growth potential. Department of Trade and Industry, Pretoria

Szewczuk S (2010, Aug. 11–12) Wind atlas for South Africa: wind measurements and micro-scale monitoring in the papers of the 7th international conference on the Industrial and Commercial Use of Energy (ICUE), Cape Town, pp 187–193

Wills A (2010, March 23) International climate change negotiations: Copenhagen 2009. Presentation to Amandla Forum, Johannesburg

Winkler H (2010) Taking action on climate change: long term mitigation scenarios for South Africa. University of Cape Town Press, Cape Town

Worldwide Fund for Nature-South Africa (WWF-SA) (2010) 50 % by 2030: renewable energy in a just transition to sustainable electricity supply. WWF-SA Living Planet Unit, Johannesburg

Zuma J (2010) State of the nation address. http://www.info.gov.za/speeches/2010/10021119051001.html. Accessed 12 Feb 2010

Part III
Technology and Innovation

Chapter 11
Evolution and Dynamics of the Brazilian National System of Innovation

José E. Cassiolato

11.1 Introduction

The analysis of the Brazilian National System of Innovation (NSI) departs methodologically from the broad understanding of the NSI framework. This methodology is schematically presented in Fig. 11.1 that shows the NSI framework in the two approaches, the narrow and the broad. Some authors tend to focus on the innovation system in the narrow sense. In this vision, the NSI concept is a follow-up to earlier analyses of National Science Systems and National Technology Policies. To authors that follow this approach, the key issue is to map indicators of national specialization and performance regarding innovation, research and development (R&D) efforts and science and technology (S&T) organizations. The policy issues raised are typically related almost exclusively to explicit S&T policy focusing on R&D and interactions between the scientific and technological infrastructure and the productive sector. The analysis may include markets for knowledge—intellectual property rights and the venture capital aspects of financial markets, but hardly the broader set of institutions affecting the innovation system (such as macroeconomic implicit policies for innovation, the financial system, cultural, historical processes that underlie it, etc.) and shaping competence building in the economy (such as education, training, industrial relations, and labor market dynamics) (Cassiolato and Lastres 2008).

Although it brings important information regarding the NSI, the narrow version provides only an incomplete account of its structure and evolution. The broad approach is inclusive, incorporating the narrow dimension and going beyond it (Freeman 1987; Lundvall 1992). A broader and systemic understanding of the innovation process is instrumental to avoid an overemphasis on R&D, encouraging policy makers to take a far-reaching perspective on opportunities for learning and innovation. Emphasis is put on interactions and on the role of historical processes,

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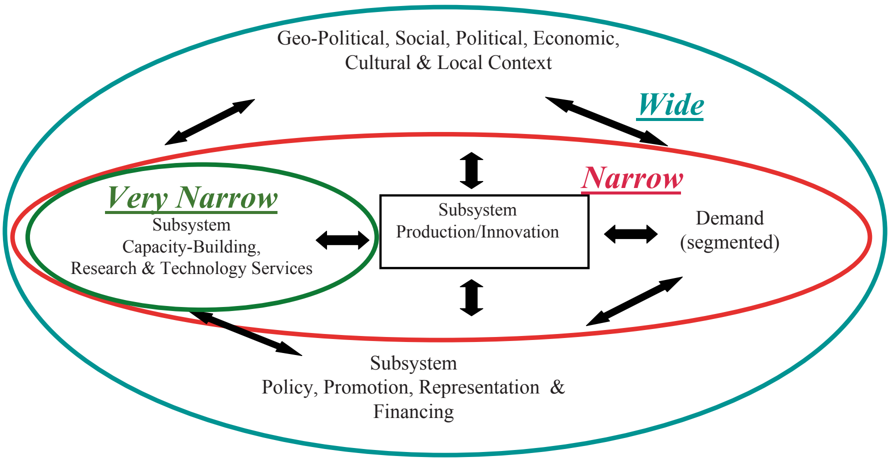

Fig. 11.1 The broad, narrow, and very narrow versions of the NSI approach

which account for differences in socioeconomic capabilities and for different development trajectories and institutional evolution, creating systems of innovation with very specific local features and dynamics.

It is precisely such production-centered approach to NSI which, in our view, makes it relevant for understanding it in the context of developing countries and it is in this way that it will be used for a brief analysis of the Brazilian innovation system during the last few decades. It includes the:

- production (from raw materials to the commercialization of goods and services) and innovation subsystem;
- capacity-building subsystem including the education, research, and technology infrastructure;
- policies, representation, and financing subsystem;
- role of demand (including income distribution, structure of consumption, social organization, social demand, basic infrastructure, health, education).

We start with some brief historical notes. Since the first arrival of Portuguese colonizers in 1500 up to the early nineteenth century, Brazil was ruled directly by the Portuguese crown as a colony. The Portuguese exploitation in most cases acted against the development of local capabilities as the crown not only forbade the setting up of all production activities that were either available in Portugal or subjected to exchange with Portuguese commercial partners, but also impeded the establishment of any academic or research institution in its colonies. At the same time, exploitation of some local resources needed technical development that was not available elsewhere. The most significant case was the production of sugar from sugarcane. In this sector, an early development of local machinery was needed and one may argue that even the present success of Brazilian production of alcohol from sugarcane is the result of a technological trajectory that started back in the seventeenth century. But from an institutional point of view, it was only when the

Portuguese crown moved to Brazil in 1808 that attempts were made to organize some experimental research, particularly in botanics with the setting up of Botanical Gardens in Rio de Janeiro (still today considered as one of the five more complete in the world) and in the Amazon.

It was only in the second-half of nineteenth century that things gradually changed as monarchy and slavery gradually collapsed. The first undergraduate school in engineering was set up in 1874 (the Rio de Janeiro Politechnic School). Also technical centers in natural sciences (Emílio Goeldi Museum, in Para in 1885), agricultural research (the Campinas Agronomics Institute in 1987), and health and hygiene (the São Paulo Bacteriology Institute in 1893, the Butantã Institute in 1899, and the Federal Seropathy Institute—later on the Oswaldo Cruz Institute—in 1908) were set up. But these technical training and research centers in the areas of health and agriculture were only created insofar as they were instrumental to guarantee the economic specialization of Brazil, anchored in the production of two basic crops for export (coffee and sugarcane) with the need to control agricultural plagues and to improve planting and harvesting methods. With an economy with hardly any manufacturing industry and heavily concentrated on the exploitation of some agricultural products and on commerce and trade, there was hardly any need for scientific and technological knowledge.

During the 1920s, universities started to be created. Six public state universities were created during that decade. High level teaching and research in areas such as physics, biology, and chemistry were accomplished with the "importation" of senior European researchers running from Nazi Germany and fascist Italy.

The colonization marked profoundly the evolution of the country. For example, with more than 56,000 plant species (excluding fungi), Brazil has one of the richest floras of the world—almost 19 % of the world flora Such diversity is distributed into six different biomes. The importance of the unspoiled biomes in Brazil is very high in a period of the world history when a preoccupation with sustainable development is high in the geo-political and economic agenda. Only recently the importance of knowledge possessed by local indigenous communications started to be recognized and is gradually entering into the S&T agenda.

Full institutionalization of the system only unfolded after the Second World War, as Brazil engaged in an industrialization process. The Brazilian NSI evolved from 1950s to 1970s as the country was changed from traditional supplier of raw materials and some crops to an economy based on manufacturing. But the system is profoundly marked by the specific social and political conditions of the country. Social demand referring to basic infrastructure, health, and education create specific problems and the heterogeneity of demand requires different types and levels of capabilities and technologies.

The chapter is organized as follows. Section 11.2 will discuss the production and innovation subsystem. Section 11.3 will discuss the subsystem of capabilities building, research, and technological services. This subsystem refers to the infrastructure of S&T and training. Section 11.4 will concentrate in an analysis of the subsystem of policies, funding, and regulation. This refers to the role of the State in its different dimensions, that is as a regulator, as a promoter, and as provider of rules of the game. Finally, the role of demand in the Brazilian NSI, in particular how income concentration, inequality, and heterogeneity affects it and how the specificities of the system influence the demand will be presented.

11.2 The Brazilian Production and Innovation Subsystem

The Brazilian economy has experienced significant structural change since the end of the Second World War when Brazil was a country specialized in the production of some few export crops, namely coffee and sugarcane. From the 1950s to the late 1970s under a strategy based on import substitution, Brazil was transformed into an industrialized country. Since then, manufacturing activities lost some ground and services and agribusiness sectors grew in importance. In the more recent period, more traditional sectors (as textile and apparel) and also those more intensive in technology have lost room to activities related to the production of energy and export-intensive commodities. The services sector acquired even more relevance in the production structure, being a source of dynamism in the Brazilian economy. Although indicators for these activities are scarce, it is argued that there are strong indications that the country has developed high productive and innovative capabilities in these activities. A similar movement is observed regarding the agribusiness sector which expanded its participation in the economy through both the development of strong innovative and productive capabilities and the specialization in production of export-intensive goods. Noteworthy are the strong interactions developed between the agro-industrial sector, the production structure, and the scientific and technological structure.

A preliminary caveat should be made which is of relevance for understanding the Brazilian production and innovation subsystem. It refers to the high heterogeneity, both interindustry and intraindustry, found in the Brazilian economy which renders official and traditional indicators (which are formulated with basis on a weighted average showing, thus, a high dispersion around the mean) of innovativeness inadequate.

Even though Brazil presents low levels of innovativeness if traditional indicators are used, it has got scientific excellence and innovation successes in sectors and innovation systems that are not well covered by such indicators, such as services (particularly related to natural resources, energy, and agriculture) and areas that are specific of its biomes. Some authors (Bound 2008) have characterized Brazil as a "natural knowledge-economy" as some of its more important scientific and innovative successes are related to its natural resources, endowments, and geography.

A last relevant dimension to be analyzed in the Brazilian production and innovation subsystem refers to the labor market. The systemic vision of innovation takes a direct correlation between the relevant characteristics of the labor market, in terms of both the capabilities of the work force and the efforts toward capabilities building, and the innovative performance of the system as a whole.

11.2.1 Characterization and Evolution of the Brazilian Production Structure

The Brazilian production structure, traditionally agrarian, underwent deep changes from the mid-1940s onward, with the intensification of the process of industrialization through imports substitution which aimed at implementing industrial sectors engaged in the manufacturing of nondurable goods. Alongside this first and more intense industrialization wave, the consolidation of the services and agricultural sectors takes place as relevant sources of employment and income generation (Fig. 11.2).

Two periods marked the evolution of the Brazilian economy since the late 1940s. The first, which lasted until the beginning of the 1980s, was characterized by the growth in participation of manufacturing and extractive industries in the GDP and by the reduction in participation of services and agricultural sectors. Regarding the industrial sector, it is worth noting that, at the beginning of the period, manufacturing of durable consumption goods was established. It is worth emphasizing the importance of the State intervention for the implementation of the industrial segment of durable goods, making use of several policy mechanisms, such as fiscal incentives for attracting automotive multinational companies to the country. The State's strategy consisted in dynamizing the manufacturing industry, in view of chain effects—both forward (inputs) and backward (distribution)—triggered by the setting up of durable goods manufacturing sectors.

After durable consumption goods were set, the final phases of import substitution policies were carried out throughout the 1970s. Through the II PND (National

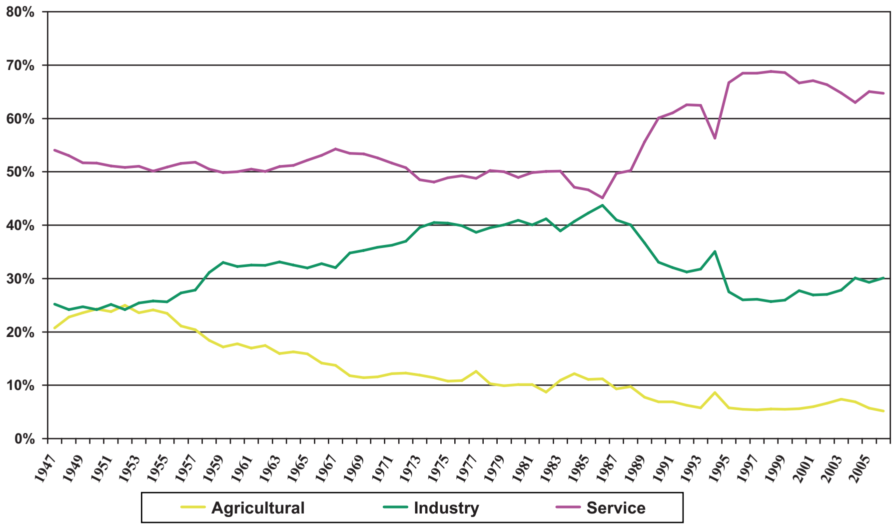

Fig. 11.2 Brazil's share of services, industry, and agriculture in GDP (1947–2005). (Source: IBGE 2006)

Development Plan-1975–1979)2- whose objective was to complete the industrial structure and create export capacity for basic intermediate goods—the government coordinated a new phase of public and private investment in industries producing intermediate goods (such as petrochemicals, ferrous and nonferrous metals, fertilizers, paper, and pulp) and capital goods and public investment in the infrastructure (energy, transport, and telecommunications) (Cassiolato 1992).

At the end of the 1970s, the Brazilian economy had acquired an almost complete industrial structure. According to the 1980 Brazilian industrial census, chemical, and metal–mechanical (including capital goods, consumer durables, and the auto industry) industries which represented 47.5 % of the total industrial production in 1970, were in 1980 responsible for 58.8 % of industrial output. The resulting industrial structure was not so different from that of most Organisation for Economic Co-operation and Development (OECD) economies.

A feature of capitalist development in Brazil in the second half of the twentieth century was the significant role of the state in stimulating industrialization. This role was of a facilitating type, giving favorable conditions for foreign capital to be attracted and providing the necessary infrastructure. Public sector expenditure grew from 20 % of GDP in 1955 to 27 % in 1962. Gross investment from the public sector, which was responsible for 25 % of gross fixed capital formation in 1955, represented 39 % in 1962 (Silva 1971) and grew to 43.7 % in 1979. In 1974, 19 out of the 20 largest corporations in Brazil and 45 of the 100 largest were state-owned (Cassiolato 1992).

The main element guaranteeing the economic dynamism of the period was a high degree of "organic solidarity" between the productive activities of the state and multinational corporations: the state supplied the internal market with basic inputs and external economies at low cost; multinationals used these facilities to expand in the internal and external markets (Cassiolato 1992). The first wave of import substitution of the 1950s relied heavily on foreign investment, particularly in the car industry. As pointed out by Suzigan et al. (1974), the leading sectors of the 1966–1973 industrial growth were transport equipment (particularly the auto industry), electrical engineering, mechanical engineering, the chemical industry, and nonmetal mineral processing. Foreign capital was dominant in the first three sectors (Cassiolato 1992).

In the second period that started in the beginning of the 1980s, a sharp decline in the relative participation of industry in GDP is observed, concurrently to the increase in participation of the services sector. There are two relevant movements of Brazilian economy. First, from the 1980s on, the country plunged into a strong fiscal–financial crisis, triggered by the raise of international interest rates resulting from the second oil shock, which increased the Brazilian external debt, which in 1980 was approximately 25 % of GDP and two and a half times the value of exports The outcome was an external constraint of the trade balance that restricted and began to determine the strategies of economic growth. It culminated in intensification of protectionism and in cutting resources for financing both the industry and the science and technology system (Zucoloto and Toneto 2005).

When the State, plunged into a fiscal–financial crisis, Brazilian economy underwent a long period of stagnation. Domestic private agents were unable to maintain the investments levels required by industry as they sought to appreciate their financial portfolios, becoming creditors of the State. Poor growth rates observed during the 1980s and 1990s. From the end of the 1980s and during the 1990s, institutional economic reforms were adopted, including markets deregulation, privatization, and trade liberalization. The adoption of such reforms was based on the argument that import competition in products would suffice for enhancing the competitive capacity of national firms. In fact, a significant reduction in the number of employed people, activities outsourcing; specialization of production; and growth of input imports were observed (Zucoloto and Toneto 2005). Implemented strategies did not succeed in the development and the incorporation of new technologies, so that the technological backwardness of Brazilian industry was kept.

11.2.2 Innovation Processes in Brazil: What the Figures Show[1]

11.2.2.1 The Analysis on Data Regarding Innovative Processes in Brazil: A Critique

This section aims at identifying the characteristics assumed by the innovative processes in the Brazilian productive subsystem. Figure 11.3 presents the average innovation rate[2] of Brazilian industry, during the period, based on data by the Industrial Survey on Technological Innovation (PINTEC). It is observed that industry's average innovation rate raised from 31.52 % in 2000 to 34.41 % in 2005. These figures are inferior to the rates presented by most of OECD countries, though very similar to those of countries like Spain and Portugal, for instance.

A major part of the firms' innovations consists of the introduction of products and processes that are new just for the firms, once they exist in the market and in the sector of operation. In other words, a significant part of the processes that are characterized by PINTEC as innovations, are in fact an outcome of the dissemination of innovations made through the efforts of a third part. Taking this characteristic

[1] Innovation Surveys in Brazil are based in the Oslo Manual. Since 2000, IBGE implements biennially this survey—"Pesquisa Industrial de Inovação Tecnológica" (PINTEC). PINTEC is a survey conducted through sampling directed exclusively to extractive and to manufacturing industries. It investigate whether these enterprises have introduced some new kind of product or process, the degree of innovativeness of this product/process, the innovative efforts developed by these firms (in terms of expenditures with R&D, acquisition of equipment, training, etc.), the relevant sources of information for learning, the cooperative strategies, etc. Therefore, for the reference years 2000, 2003, and 2005, Brazil has systematized information on the innovative processes developed in industry.

[2] According to criteria established by PINTEC/IBGE, "innovation rate" is the percentage of firms that introduced innovation in relation to the universe of firms in each production segment, in the 3 years previous to the survey. The survey carried out in 2000 sought to identify the introduction of innovations in either products or processes between 1998 and 2000.

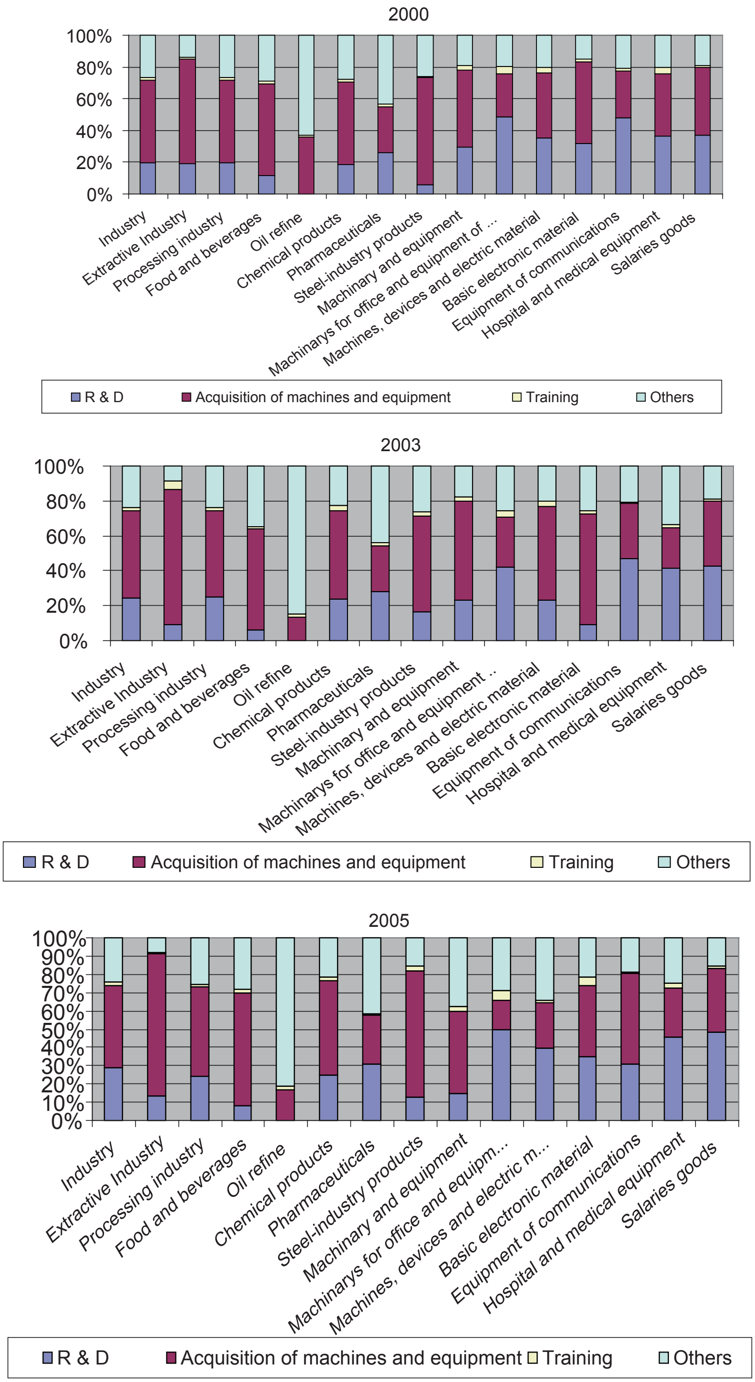

Fig. 11.3 Expenditure with innovative activities in Brazilian firms (2000–2005). (Source: PINTEC/IBGE)

Table 11.1 Brazil—innovation indicators activities—extractive and manufacturing industries (2000–2005). (Source: PINTEC/IBGE)

Activities	2000 (%)	2003 (%)	2005 (%)
Innovation rate			
Industry	31.52	33.27	34.41
Extractive industry	17.19	21.97	23.08
Manufacturing industry	31.87	33.53	33.57
Cooperation rate			
Industry	11.04	3.75	8.46
Extractive industry	24.63	2.71	12.85
Manufacturing industry	10.86	3.77	7.14
Expenditure with innovative activities over sales			
Industry	3.84	2.46	3.04
Extractive industry	1.47	1.61	1.80
Manufacturing industry	3.89	2.48	2.80

into account, the innovation rate in Brazil is even lower. However, we must highlight that the referred average innovation rate does not take into account the high heterogeneity of Brazilian industry, neither considers the different weights held by the industrial sectors within the production structure of the country. These facts become clear when we analyze annex Fig. A.3. A strong discrepancy is observed between the sectorial innovation rates, which reach high values in some production segments. In activities related to information technology equipment, for instance, the average innovation rate is close to 70 % (Table 11.1).

Innovative efforts by the Brazilian firms (Table 11.1) are considerably reduced. This decline of innovative efforts refers to the implementation of defensive strategies by firms in a moment when the country underwent economic troubles. In the face of difficulties, firms choose reducing their expenditures with innovation trying to keep their competitiveness by means of costs reduction.

The analysis on the kind of innovative expenditure made by firms (annex Fig. A.3 and Fig. 3.4) shows that they concentrate their strategies on acquiring machinery and equipment and, to a much lesser extent, on carrying out R&D activities, thus reducing the innovative dynamism of industry. Furthermore, efforts related to training and qualification of human resources (HR) are very low in Brazil and much inferior in comparison to most of the developed countries (Figs. 11.3 and 11.4).

Regarding cooperative strategies implemented by innovative enterprises, the information provided by Table 11.1 suggest a strong fluctuation of the rate of cooperation during the studied period, with a sharp decline in 2003, due to the strong economic retraction[3]. Nevertheless, even when the cooperation rate attained

[3] In periods of crisis, the rate of cooperation usually drops, and rises in the period of economic recuperation.

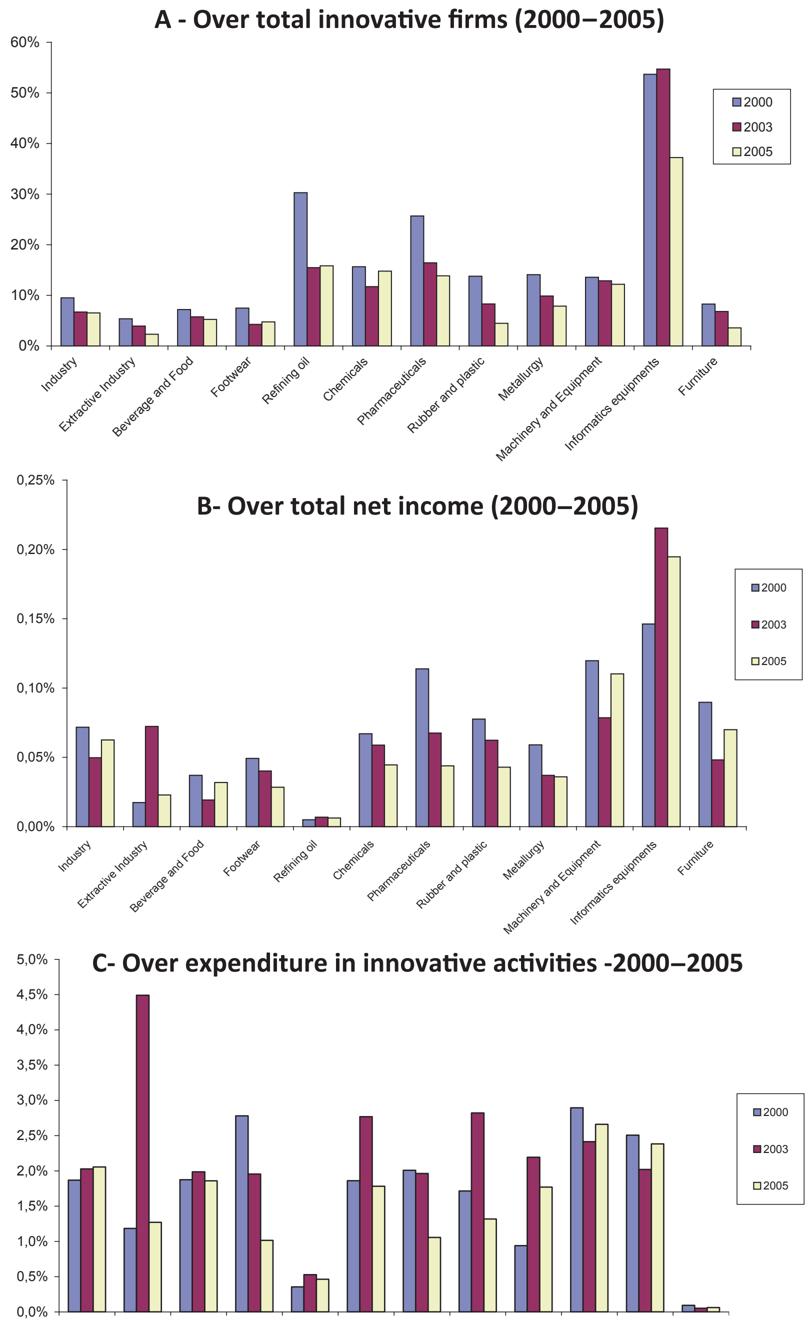

Fig. 11.4 Innovative firms with expenditures in training. **a** Over total innovative firms (2000–2005). **b** Over total net income (2000–2005). **c** Over expenditure in innovative activities (2000–2005)

its highest index (11%) in 2000, the level of cooperation of Brazilian enterprises is still considered low in comparison to international patterns. We must recall that, just like the rate of innovation, this cooperation rate is also an average value and, therefore, requires prudence in its analysis, due to the heterogeneity of implemented cooperative strategies, be it in different sectors or within a same sector.

The use of PINTEC as a basis for assessing the Brazilian NSI presents some problems. The first of these is the fact that figures refer to average values of either industry altogether or broad segments within it, without capturing the high heterogeneity that involves size of the establishments and their geographical location.

These analyses provide biased and mistaken conclusions, inducing researchers to believe in the incipiency of Brazilian NSI, when in fact this "low dynamism" relates to some sectors, whereas in others the movement is analogously opposed. This fact brings the need to carry out more detailed analyses, with focus on specific cases, both in terms of sectors and in terms of regions, which take into account these specificities[4].

The second source of bias created by PINTEC regards to the fact that data only capture the movements relative to the extractive and manufacturing industries, and not to the services sector and agroindustry. Both sectors excluded present high participation in the composition of Brazilian GDP and take specific characteristics regarding their respective innovative processes. Therefore, analyzing the characteristics of the Brazilian innovative processes with basis only in PINTEC is neglecting the relevance and the innovativeness of these subsystems. The next two subsections aim at integrating these two sectors to the analysis and evidence their dynamism.

11.2.2.2 Innovative Processes in the Brazilian Agribusiness Sector

The agribusiness sector developed strong productive and innovative capabilities due to the coordinated efforts of the various areas, as much technical as political and productive ones. An example of an implemented technological development regards to agriculture exploration in the semiarid lands of the Brazilian Northeast region. During a long period, it was believed that this kind of soil was inappropriate for agricultural exploration. However, since the technological developments were implemented, this territory became productive, through the introduction of various cultures as, for instance, grapes[5]. Also emblematic are the adaptations made through genetic improvement of several cultures, such as in cotton and fruits like melons. *Empresa Brasileira de Pesquisa Agropecuária* (EMBRAPA), the country's premier agricultural research agency, developed a number of varieties aimed at climatic and soil specificities of the different regions of the country. The high degree of technological advances led Brazil to export part of the technology to other countries as, for instance, the sub-Saharan Africa.

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[4] In this sense, Sect. 11.4 draws some characteristics regarding the heterogeneity present in the innovative production system in Brazil.

[5] Due to the climatic conditions it is possible to attain three harvests per year of the grape planted in the Brazilian Northeast.

Brazil is the world leader in meat and soy exports. These results are also directly correlated to genetic researches developed by EMBRAPA with grains and, specially, with animals. The agroindustrial production subsystem presented an impressive growth during the last years with a relevant part of this vigor associated to the progressive expansion in exports of food, inputs for the production of renewable energy, and inputs of agricultural production. This growth and modernization was possible because of a greater systemic integration between economic agents, especially suppliers of machines and equipment and of inputs and fertilizers, with research institutes and with agricultural productive units.

Also worth noting is that the productive integration was not limited to the various suppliers, but happened also between the productive units. Brazil has a system of national and regional agrarian research that allows the country to attain competitive gains in the production of inputs of vegetal origin and food. The fundamental anchor of this R&D system leans on genetic research, mainly directed by EMBRAPA.

Agroindustrial activities create positive spillovers which disseminate the innovative dynamism to other productive segments. In manufacturing industry, the chemicals segment and, especially, the segment of agrarian machines and implements are furthered for developing new technologies demanded by the advances in agroindustry. Perhaps the most emblematic example would be the services sector, where a series of technological advances were incorporated and developed due to the needs of agroindustry, as for instance efficient logistics systems that allow products to reach their markets with guaranteed quality and durability.

11.2.2.3 Innovative Processes in the Service Sector

Innovation in the services sector began initially with the development of bank automation in the beginning of the 1980s. Two facts are noteworthy regarding the service subsystem: the first one refers to the strong weight of this sector in the Brazilian economy. A second fact is that this sector disseminates innovations, providing for synergies and spillovers all along the national production structure. In this regard, the sector of software development is emblematic. In the context of an economy increasingly "based on knowledge," the importance of software production comes not only from its role as an instrument that enables the incorporation of knowledge in products, services, and systems, but also from its intrinsic importance for the diffusion of information and communication technologies among organizations, institutions, and the general society.

The software sector plays a fundamental role in processes of learning and development of capabilities both within a firm and between firms, creating significant productivity gains in industry (involving aspects related to industrial automation, production control, purchasing, inventory, logistics, and others) and in the service sector (particularly in the segments of financial services, education, public services and transports, among others). Even in traditional segments as textile, footwear, fishing, and agriculture, the use of software applications may dramatically enhance productivity, allowing products differentiation and adding greater value to production and to exports. In the beginning of this century, software production activities in Brazil equated the seventh major world market in terms of domestic sales. Between 1991 and 2001, the participation of the software industry in the GDP more than tripled, from 0.27 to 0.71 %. All along this trajectory, expressive investments were made in accumulating productive and technological competencies and in developing interindustrial connections regarding several activities. It allowed the formation of both a specialized labor force and an expressive infrastructure, thus creating important stimulus to the emergence and consolidation of new businesses in the sector.

Evidence suggests that the service sector in Brazil develops a virtuous cycle of interaction with universities and research groups, providing for dynamic modes of learning and cooperation and leading to the enhancement of innovative performance (Rapini 2004). According to the author, micro and small service enterprises interact proportionally more with universities and research groups. The service subsystem also accounts for the diffusion of knowledge to several other production subsystems. The evidence of high degrees of cooperation in this system reinforces the hypothesis that it is quite dynamic and innovative.

The subsystems of activities related to energy, particularly petroleum extraction and manufacturing, registered a significant growth in their participation in the industrial output. The major enterprise in this sector is PETROBRAS, which accounts for most of the production. PETROBRAS holds cutting edge technology in many segments, being world leader in petroleum extraction in deep waters wells. The capacities developed by the company derive from strategies for operating in partnership with a great number of suppliers and service providers, located both in Brazil and abroad. Nearly 40 % of PETROBRAS expenditures with contracts refer to hired services. Thus, PETROBRAS plays a role of boosting, dynamizing, and stimulating innovation within several of its service providers.

Thus, Brazil has certain areas of excellence in terms of innovation. The service and agribusiness sectors, in spite of difficulties in assessing their innovative efforts and performance, are examples of virtuous cycles of learning, cooperation, and innovation within Brazilian economy. According to Bound (2008), Brazil's innovation system is in large part built upon its natural and environmental resources, endowments, and assets.

11.2.3 Heterogeneity of the Production Structure

The Brazilian productive and innovative structure is characterized by regional, institutional, and political asymmetries. The Brazilian production system is comprised by an expressive number of micro and small enterprises (MSEs), with very distinct competitive, technical, and institutional specificities. In view of the high number of MSEs, the formulation of new institutional designs and of policies that promote knowledge flows in these enterprises presents particular relevance for the Brazilian scenario.

MSEs face huge challenges in the short-term, not only for surviving and maintaining their activities, as also in terms of conceiving ways for enhancing their competitiveness and their chances of economic survival, through an ecologically and socially sustainable way. Large-sized enterprises have better possibilities for maintaining own laboratories of R&D, playing a relevant role in the governance of the Brazilian production and innovation system. Given the heavy investments required with long-term maturation, the insertion of small enterprises in these segments occurs only sporadically, generally as a result of localized efforts.

Another important asymmetric characteristic in the national production system and, particularly, among the MSEs, is the high and increasing informality that characterizes the Brazilian economy. In the mid 2000s, there were approximately 20 million informal small businesses, involving about 60 million people, operating in Brazil and which proliferate primarily as a result of economic recession and high unemployment of the last decades (Cassiolato and Lastres 2005). The high degree of informality prevents access to official financing sources, intensifying their financial limitations and, consequently, hindering the development of innovative activities. As pointed out by Arroio (2007), according to PINTEC 2003, less than 1000 small manufacturing enterprises were granted public support for promoting innovations in the period from 2001 to 2003. Pintec 2003 also shows a retraction in the number of enterprises that sought cooperation for innovating, from 2000 to 2003; this retraction, however, affected more intensively the MSEs.

Traditional data presented above should be very carefully analyzed, because it does not capture the high heterogeneity and specificities, especially the informality of existing cooperative relations among small enterprises. Cassiolato et al. (2005) claim that the informal practices of cooperation are part of the Brazilian economic and social fabric and that, therefore, they cannot be ignored. Thus, it is quite plausible that a significant contingent of micro and small enterprises (both formal and informal) do develop creative solutions in the face of problems and difficulties, although these solutions do not comprise the official statistics of Brazilian innovation.

Notwithstanding that official statistics do not represent adequately the reality of MSEs, and in spite of the deficiencies of the policies adopted in the last decades aiming to promote and support MSEs, such policies must become the focus of permanent actions by governments and new institutional designs must be created for promoting local productive arrangements and for supporting MSEs. Such actions might reduce the institutional and regional heterogeneity of the national innovation system, mitigating the limitations to the competitive insertion of MSEs.

11.3 Subsystem of Capacity Building, Research, and Technology Services

The process of learning and building capabilities, defined as the incorporation of new knowledge and the expansion of the ability to develop, produce, and commercialize goods and services, has been regarded as a key element in the innovation process (Cohen and Levinthal 1990). This section examines, from the standpoint of educational institutions and research institutes, investments by firms in both training programs and R&D to understand the characteristics of the innovation process.

11.3.1 Basic Education

The learning process is directly associated with knowledge accumulated and it defines the possible spectrum of generation and assimilation of new knowledge and technical advancement (Cohen e Levinthal 1990). In view of the cumulative nature of the learning process, basic education constitutes a major pillar in the process of capabilities building. In Brazil, the 2006 School Census reveals that 42.2 million, out of the 55.9 million Brazilians who are officially enrolled in the distinct modalities of basic education, attend elementary and secondary schools, the remaining being divided into preschool (7 million), special education (375,000), youth and adult (5.6 million) and vocational (775,000). In 2005, the basic education network was comprised of 203,900 schools, being 35,500 private; 206 federal; 33,300 state; and 134,900 municipal.

From the quantitative view, private education in Brazil seems to have a complementary role in comparison to public system. In its 35,500 establishments (17.4 % of the total), 7.3 million children and youth study (13 % of the whole students' population), and 527,500 teachers work (19.9 %). Qualitatively private schools are in general better than public ones—the only exception being for federal public schools (Dantas 2007).

However, the high costs of private education limits the access to these schools—only 10 % of students are enrolled in private schools at primary education and 12 % of them at secondary education (IBGE/PNAD 2006). Such duality in the quality of education (public *versus* private) incites social inequality in the country with consequences for access to higher education. The drop in the quality of public basic education in comparison to private education contrasts with the reality of the Brazilian education system of three decades ago, when public education was acknowledged for its high quality.

Brazil presents a relatively slow and constant process of expansion of its basic education system. In 2005, 97.2 % of children between 7 and 14 years old were enrolled in primary education (IBGE/PNAD 2006). However, these figures deserve critical analysis, once the relevant data for the enhancement of individuals' capabilities is not enrollment rates, but the rates of primary school completion, which has declined in Brazil since 2000. The high and increasing abandonment rate has significantly reduced the primary education completion rate. From all school age children who enrolled in the first grade, only 84 % complete the fourth grade; 57 % complete the primary education; and only 37 % complete the secondary level (Cassiolato 2010). Not surprisingly, it happens to the most detriment of poor children (Dantas 2007).

Brazil is among the countries with highest illiteracy rates in Latin America. In 2005, there were nearly 13,150,680 illiterate people aged 15 and over in the country, corresponding to 11 % of the population. In terms of functional illiteracy, this number grows to 23.5 % in 2005. It is possible to identify a great disparity between rural and urban illiteracy rates, with the first being 45.8 %, and the second 19.3 % in 2006. Also remarkable is the great regional disparity of the Brazilian basic education system. According to Sistema de Avaliação de Educação Básica (SAEB), the performance of students in regions north and northeast is inferior to the rest of the country. Indicators related to infrastructure of primary education schools network, collected by School Census of 2005, also reveal worrying regional disparities (Neri and Buchmann 2007).

These features of primary education end up affecting secondary education and a delay is perceived in youth entry to secondary school. According to data from PNAD 2005, the enrollment rate of students aged 15–17 was 81.7 % out of an estimated population of 10.6 million youth. However, only 44.4 % was attending secondary education in 2005, this figure dropping to 22 % in rural areas. It is possible to relate these data to unfavorable socioeconomic factors which constitute a serious hindrance to human capital accumulation. According to PNAD 2005, 67.8 % of youth between 15 and 17 years old come from families with a per capita income either equal to or lower than the minimum wage. Thus, the decision to stay in school is made difficult in face of the need of generating income to contribute to household income.

It is possible to identify several other obstacles to the access to secondary education, which is not compulsory in the country. According to data from the School Census of 2005, 140 municipalities do not offer full and regular secondary education. According to Neri and Buchmann (2007), the installed capacity for regular secondary education corresponds to 80.7 % of the population aged between 15 and 17. Therefore, the universalization of secondary education does not rely just on a law to determine it, but rather on the expansion of installed capacity in order to guarantee the access of these youth to secondary education.

It is recommended that efforts must be exerted concurrently on two challenges: to provide a structure so that the most vulnerable students do not need to work for surviving, be it by means of a sufficing subsidy or through full-day school programs, and, simultaneously, to invest in the improvement of educational inputs, such as the quality and remuneration of teachers, infrastructure, schools management and curriculum, among others (Neri and Buchmann 2007).

11.3.2 Higher Education and the Firms–University Relationship

Studies on innovation have systematically pointed to the importance of the higher education system for technological innovation. First, higher education institutions produce research outcomes that can be adopted by enterprises in their innovation process. This may occur as much directly through the solution of problems, as through the use of research instruments and techniques developed by universities like, for instance, computational models and laboratory protocols, for the design and testing of technological systems. In addition, universities prepare qualified professionals and researchers who, when incorporated by firms and by other sectors in society, bring with them not only up to date scientific knowledge, but also skills for solving complex problems and for developing research and new ideas. These qualified workers, besides holding tacit ability for acquiring and using knowledge through innovative forms, also carry what Velho (2007) calls "knowledge of knowledge," that is, they are able to identify what is the specialist in each matter, once they participate in academic and professional networks in the national and international scopes. Cassiolato et al. (2007a) emphasized that the way by which the university participates in the national system of innovation differs at a significant degree between countries, as well as within each of them and within each productive activity. According to the authors, the functions performed by universities in the NSI are usually directed to education and research. It is important to emphasize that the university–enterprise interaction is an important institutional subgroup of the broad system of knowledge exchange, being peculiar to each country and dependent on the national infrastructure of Science and Technology (S&T) (Cassiolato and Rapini 2004).

Brazil was the last country in Latin America to develop a higher education system[6]. Brazilian universities exist since less than 100 years. Higher education in Brazil started in middle nineteenth century. From 1964 on, during the military dictatorship (1964–1985) several legal acts were created aiming to provide a legal framework for the higher education system, modernize it and improve its quality by enhancing its flexibility and efficiency in training human resources for the development of the country.

The Brazilian higher education system is marked by the presence of strong heterogeneities. First, one may perceive some elitism regarding the access to higher education, enrollment corresponding to mere 10 % of population aged between 18 and 24. This can be deemed as an extension of social exclusion that occurs along primary and secondary education, where just small elite has access to quality education and, thus, get to guarantee access to higher education. Furthermore, the regional distribution of these institutions is strongly unequal: 49 % of universities and other higher education institutions are located in the southeastern region, while 18 % are in the northeast, 17 % in south, 10 % in center-west, and only 6 % in the north (Dantas 2007). Taking into account the population estimates, the disadvantage of northeast appears still greater, once this region, in 2005, responded for almost 30 % of the national population, but for only 18 % of higher education institutions (IBGE/DPE). In addition, Brazilian higher education system is also marked by a

[6] The first universities in Latin America were created in the sixteenth century, in México and Peru (1551), in the seventeenth, in Bolivia (1623) and in nineteenth century in Argentina and Chile. For further details, see Mello et al. (2008).

sharp racial inequality (Cassiolato et al. 2014). However, some important positive changes happened from 2005 to 2014. Eighteen new public universities (of a total of 63) were created with the idea of increasing integration inside Brazil (universities for regional and local development) and with Latin American countries. Also a quota system was introduced that provides for a minimum percentage of place in public universities for students coming from poorest families and from black origin.

11.3.3 Graduate Education System

In the mid-1960s, Brazil decided to invest in training researchers, counting on the public universities as the main institutional basis of this goal. According to Velho (2007), along the whole 1970s about 800 new Masters and Doctorate courses were created and, in the beginning of the 1990s, the number of courses reached a little more than 1000, comprising all knowledge areas. By the end of 2006, there were near 2880 *stricto sensu*[7] postgraduate courses, being 2228 masters' courses and 652 doctorates. These courses have graduated 29,761 masters and 9366 doctors in 2006 (Velho 2007).

The number of qualified doctors a year in Brazil is very significant, even in international terms, and continues to grow at high rates. CGEE, 2008 argues that the policy of postgraduate Brazilian can be considered a genuine policy of state because the fact it is being maintained over the past decades, regardless of changes of governments and regimes. According to the author, this policy has been very successful in achieving train masters and doctors in number, diversity and quality incomparably higher than in countries with levels of development similar to that of Brazil. In 2004, Brazil was among the ten countries that most doctors trained in all areas of knowledge in the world. However, if one makes an international comparison by the number of doctors per 100,000 inhabitants in 2004 or the latest year for which statistics were available, Brazil falls to 27th position, which is an indication that the Brazilian development in the area of postgraduation still has a very long way to go.

Then the employment of more than 84.23 % (that is, more than 4/5) of doctors in educational institutions and public administration, combined with the employment of only 1.24 % of the processing industry, is an indication the relatively low participation of the productive sector in the effort to R&D and innovation in the country in 2004.

Velho (2007) affirms that the nonabsorption of PhDs by the Brazilian enterprises probably inhibits those who, under different conditions of the labor market for researchers, could be interested in taking a doctoral education in engineering. Thus, in terms of participation of knowledge areas in the composition of the stock

[7] NT: "*Strict sensu*": term that refers the specific learning system that comprises regular and permanent studies and research, and which grants an academic degree of high scientific competence in a particular branch of knowledge; it is used in Brazil as distinctive of the "*lato sensu*" that refers to any graduate education course aimed at vocational or scientific specialization.

of new researchers, it is reasonable to claim that the dynamic processes of relations between the scientific and technological sectors have not been fully established in Brazil.

Evidence that this system is serving only for reproducing itself lies in the methods for evaluating graduate education, which in spite of using multiple criteria ascribe a greater weight to scientific publications produced by professors and students as compared to activities such as: students training; joint work with the research beneficiaries (be them a firm or any other social segment); the communication of outcomes by means of other less traditional means, including the involvement in projects, workshops, electronic publications, diffusion articles etc. (Velho 2007)[8].

The research performed by Veloso (2004), with data of 1990 decade, also corroborates the argument that the graduate education system in Brazil is weakly connected to the productive structure. The field research aimed at obtaining data on the professional insertion of masters and doctors in the productive system and the relevance of the post-graduate course they attended for the function they perform[9]. The research outcomes showed that the masters' and doctoral courses train researchers for the academic career and, in the opinion of the graduates, they do well; however, they do not prepare masters and doctors with knowledge suitable to work in other institutional contexts.

It is worth analyzing the causes for the low interaction of the graduate education system with the Brazilian productive structure. One of the possible causes is the late character of the creation of higher education institutions of the national system, associated to the historical process of Brazilian industrialization, which demands on the scientific infrastructure remained limited and scarcely challenging until at least the end 1980s and constituted hindrances to the consolidation of the NIS. According to Suzigan and Albuquerque (2008), the low demand of the industrial sector on the scientific infra-structure is related to exaggerated protectionism, the dominance of strategic industry by multinational enterprises, the discontinuity of public policies and the recurrent macroeconomic crises.

[8] The Graduate education Evaluation System was created in 1976 and—it is important to emphasize—in spite of being target of some criticism for relying excessively on criteria internal to the academic sphere, there is a broad acknowledgement that the implemented evaluation system has created attitudes and procedures that turned Brazilian graduate education into an acknowledged quality system, once the Evaluation System holds attributions of a certification or accreditation of graduate programs. This means that only accredited courses may confer valid graduate degrees. As a result, this confers to graduates coming from these courses certain quality stamp and improves their value in the labor market (Velho 2007).

[9] The original study interview 87,000 masters and doctors graduated in the 1990 decade, in 15 knowledge areas, coming from universities of the Northeast to the South of the country. Data were organized according to three categories of broad knowledge areas. Fundamental Areas: Agronomy, Biochemistry, Physics, Geosciences, Chemistry and Sociology; Technological Areas: Civil Engineering, Electric Engineering and Mechanical Engineering; Professional Areas: Management, Medical Clinic, Law, Economy, Odontology and Psychology. In the three groups, the Professional destination of masters is quite varied and, in a general manner, higher education teaching is not the major occupation; doctors, in their turn, are concentrated in academy (universities and research institutions).

Similarly, Cassiolato (2007) claims that, during the period of import substitution, the protected market did not require the development of innovations, and the most common collaboration activities of universities occurred with public companies which belonged to technologically advanced sectors, and with some private companies of the agro-exporter sector.[10]

The most significant contribution by universities consisted in the preparation of human resources and interactions, when existing, were limited to consultancy activities, routine services (measurement, quality tests and control), rather than high level research and experimental development. Such scenario is referred to an isolated role of universities in the process of knowledge production. Other recurrent problems pointed out by the author are those related to the determination of property rights. The absence of efficient mechanisms, either on the part of universities that must rely on internal bureaucratic efforts for protecting research outcomes or on the part of the intellectual protection system, backgrounds the recurrence of informal university–enterprise relationships as the best strategy for obtaining results.

Finally, Cassiolato (2007) enumerates other problems, namely communication difficulties, bureaucracy, inadequacy of research personnel, inadequate financing, socio-cultural factors and cultural differences between university and industry in terms of R&D activities related to long term *versus* short-term perspectives.

11.3.4 Research Institutes

In the introduction we showed that until the end of the nineteenth century, there were some scientific research activities on chemical mineralogy, natural sciences, agronomy, zoology, and studies of bacteriological and microbiological problems, being developed in a limited and sparse character within institutions like museums—particularly the Imperial Museum (1818), after National Museum, the Museum of Para (*Museu Paraense*) founded in 1866 under the designation of *Museu Arqueológico e Etnográfico da Sociedade Filomática do Pará* and after renamed *Museu Goeldi*), and the museum of São Paulo (*Museu Paulista*—1893)—and research institutes.

During the post-war period several key research institutes were set up. In 1949,the Brazilian Center of Research in Physics (*Centro Brasileiro de Pesquisas Físicas*—CBPF); in 1950, the Technological Institute of Aeronautics (*Instituto Tecnológico da Aeronáutica*—ITA) and, following, the Technological Center of Aeronautics (*Centro Tecnológico da Aeronáutica*—CTA), both key components of the successful aircraft innovation system in Brazil.

During the military dictatorship, important research centers were set up in the state enterprises, such as CENPES of Petrobras and CPqD of Telebras. Also during this period EMBRAPA—*Empresa Brasileira de Pesquisa Agropecuária* (1973) was set up with the objective of developing research and development activities and

[10] For details on research institutions in different sectors, see Cassiolato (2010).

for transferring technology to farmers. The agricultural production, an area where Brazil holds significant competitive advantages in the world market, experienced a revolution from the 1970s on, with the outcomes of the activities of EMBRAPA.

The current success of Brazilian mining and mineral ore processing industry in the international market is the valuable experience of interaction between the Department of Materials and Metallurgical Engineering of UFMG with enterprises of the sector. Similarly, the current position of Embraer—the Brazilian Enterprise of Aeronautics—as one of the greatest world manufactures of aircrafts is the result of a long historical period of efforts involving government, enterprise, and education and research institutions.

In brief, one may observe that, as in the process of development of universities, the late beginning of creation of research institutions is a major element for understanding the limits of the current NSI. By focusing on cases that are illustrative of the interaction between social and economic demands and the creation of institutions, it was sought arguing that the successful cases existing in the country have solid historical roots. In the last years, research institutes in Brazil experienced a number of changes, mainly characterized by the reduction of the public resources directed to them. As a result of such strategy, one may note that many research institutes in the country have lost their functionality, once they did not find in the private sector financial sources for sustaining their researches. Even so, the country still counts of excellence research centers with sophisticated innovative capabilities in diverse areas such as agro industry (with emphasis to EMBRAPA), aeronautics (highlighting Embraer, CTA, and National Institute for Spatial Researches (INPE)), and petroleum (remarking Petrobras Research Center—Cenpes),which are still funded by the public sector or by state companies. Brazil, therefore, has developed in some specific areas, by means of a long process of capabilities building and interaction of the research institute and the universities with the production structure, excellence centers. That is, innovative capabilities were developed through partnerships involving efforts, political will and a period of maturation.

11.3.5 Technological Parks

The discussion about tech parks started at the beginning of the 1960s. At that moment, parks represented a potential tool for supporting and promoting the integration between two worlds: academic (and its scientific and technological activities) and industry. Roughly speaking, parks aimed at facilitating the transfer of information, knowledge and even technology between these partners (university and industry); creating and strengthening new technology-based small- and medium-sized firms, and the firms' competitive gains; and generating new jobs positions.

The movement of tech parks in Brazil is quite young, having started its first projects in a more organized pattern at the beginning of this decade. Since 2002, tech parks have been considered in the formulation of scientific and technological as well as industrial policies. The federal government, through the Ministry of Science and Technology (MCT) and, particularly, the Brazilian Innovation Agency

(FINEP), have supported several initiatives spread all over the country, most of them still in an initial phase of development.

11.3.6 Vocational Education and Training

The growing contribution of scientific knowledge to the technological process refers us to the relevant role performed by vocational schools and training programs developed within companies. They constitute a prime source of knowledge generation and diffusion, especially in a country whose higher education is restricted to a small part of the population. Although presenting an increasing enrollment, the technical education system in Brazil is yet little developed and insufficient for meeting the industrial demand. In 2001, enrollments in vocational education totaled 462,258, and in 2004, this number raised to 676,093 learners according to data of School Census of 2004 developed by Inep. Despite the growth, this number still represents less than 7.5 % of the total students attending the secondary level in the country (9,169,357).

One of the main reasons of the scarcity of qualified workforce in Brazil is the disparity between current supply of technical courses and the demand by sectors that grow more intensively, as services and some industrial segments such us mining, sugarcane (sugar and alcohol).

Technical education, which is a vocational training that holds status of an undergraduate course, also faces problem regarding its expansion. In 2007, the Cefets (Federal Centers of Technological Education) gained autonomy for installing new courses and expand enrollments. However, once again, the obstacle is the lack of resources from the federal government to implement this action. Brazil has 34 Cefets, in 22 States. The federal vocational education network gathers, according to data of Inep, about 34,000 learners, more than a half of the 60,000 students who attend vocational education in the country. In the state ambit, remarkable institutions in the preparation of technologists are the Fatecs (Tecnology Colleges). Nevertheless, once more, the demand (an average of 32,000 candidates per year) is much higher than the supply (around 3000 places annually).

One way to increase the coverage of technical training is through partnerships, mainly some that meet the regional demands. In the state of Minas Gerais, where mining constitutes significant industrial activity, the courses should be created in partnership with companies operating in the mining sector. Technical education in Brazil is still carried out, most of the times, in a place distant from the workplace and without much experience with the company's reality. The partnerships, besides reducing costs for the public education system, also make the workers learning process to be closer to the routines of the enterprise. It, thus, benefits the learning process by incorporating the tacit knowledge which is acquired through the routines of the enterprise and exchanges with its workers.

The reunification of secondary and vocational education is a step forward in the perspective of expanding technical courses as students may do the secondary level along with the vocational disciplines[11]. Thus, instead of studying 3 years and have traditional education, the learner can study during a same period and get a technologist diploma.

In addition to the problem of scale shortage, vocational education is characterized by a strong regional concentration. In 2001, nearly 70 % of enrollments were concentrated in the southeastern region, 17 % in the south, 8.5 % in northeast and 2.5 % in the center-western and northern regions. In 2006, the regional heterogeneity was still strong: 58 % in southeast, 21 % in south, 12 % in northeast, and 3.9 % in center-west and north. However, the public system for technical training has been sharply transformed in a positive way. Since 2005 more than 280 new Federal Institutes of Education, Science and Technology were set up by the federal government. These institutions are based on a concept of professional and technological innovation without similar in other countries (Cassiolato et al. 2014). These institutions provide technical training integrated to terchnological secondary and undergraduation courses and offer also post-graduation and professional MSc and PhD courses aiming at applied research and technological innovation. These institutions are particularly important to Brazil insofar as they articulate technical training with local and regional specificities and productive vocations (Cassiolato et al. 2014).

The private vocational system is fundamentally comprised of the so called "S System," a group of 12 institutions which financial resources come from social obligations incident on the payroll of the enterprises in each category and are aimed at financing activities of vocational capabilities building and improve worker's quality of life. Currently, a 2.5 % contribution over the salaries of employees in industry and commerce nationwide is applied for maintaining the "S System." In fact, it is a public resource administered by the private sector, with the objective of meet the demands of the productive sector.

Although "S System" providing training courses with quality acknowledged as much by the society as by the productive sector, one of the most common criticisms is the excess of short length courses. To the "S System" lacks the understanding that learning is a permanent process and that, thus, longer length courses as well as the idea of continuity among the courses is crucial for creating capabilities

The advocates of a reform in the current "S System" criticize the lack of criteria in the provision of the services and the fact that they are not freely provided; moreover, they point to an increasing elitism regarding the target public, which is due to the high fees charged. The institutions of the "S System" defend themselves arguing that it would not be possible to maintain the quality of the courses if they were 100 % free and claim that most of the learners come from the public education network.

However, the lack of a consensus about the "S System" does not hide the deficiencies in the qualification of workforce in Brazil. Complaints on the part of the

[11] Before the law, if a student wanted to have a vocational training, they had to, for example, attend high school in the morning and a technical course in the afternoon or at night, often in different schools. Or, had to finish high school and get the diploma to then begin their vocational training.

enterprises about the deficit of technicians (particularly of the secondary level) for filling the supply of job posts are recurrent. Consequently, there is a low participation of workers holding technical competences in formal employment in Brazilian manufacturing industry. The national bottleneck of qualified workforce led some Brazilian companies articulated with the global market (as is the case of Vale do Rio Doce) to the point of recruiting foreign workforce. According to Instituto de Pesquisa Econômica Aplicada (Ipea), 9.1 million workers applied for jobs in 2007. Among them, only 1.7 million had a technical qualification.

Moreover, enterprises do not have a proactive attitude on issues related to training and capacity-building. That is, their efforts towards training and capabilities building in face of the shortage in technicians supply are very limited. Based on PINTEC (2005) data, one notes that the Brazilian innovative enterprises invested, in average, R$ 136,000 in 2005, in activities of capabilities building and training of human resources (HR), this being the lowest investment among all the innovative activities captured by the research.

Figure 11.5 presents a comparative analysis of companies that develop training activities and capacity building in Brazil and selected European countries in 2000 and 2005. It shows that Brazil reduced the number of companies that develop activities for training; the percentage was reduced from 35.77 to 28.35 % in the analyzed period. This is contrary to the tendency in other countries. Another point to be highlighted is that in the first year of analysis, the percentage of Brazilian companies that held training activities was similar to other countries reviewed. However, for the following period, it is possible to identify a strong reduction in the proportion of Brazilian firms with training activity. So, while there are demands of the productive sector for qualified human resources, it is not possible to say that there is an intensive effort for invest in training programs.

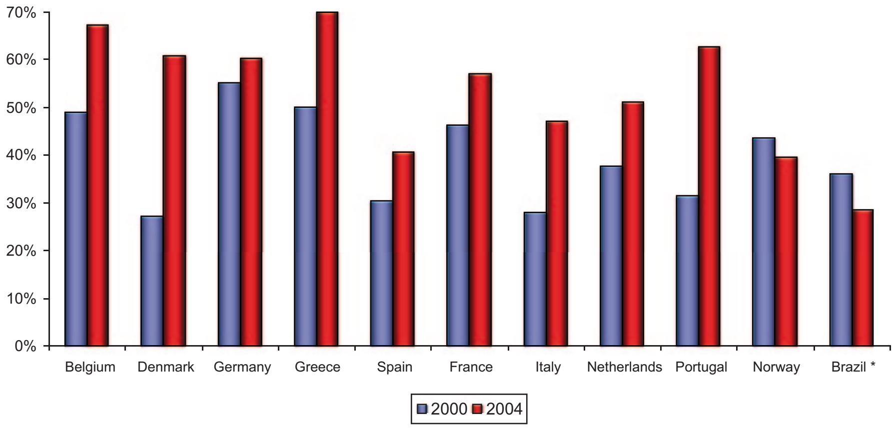

Fig. 11.5 Brazil and selected countries—Enterprises that developed training programs (%)—2000 and 2005. (Source: CIS 2000, 2004; PINTEC 2000, 2005)

11.4 Sub-system of Policies, Representation, and Financing

At least since the 1970s, there has been, in Latin America, a perception that decisions and strategies regarding industrial and technological investment are strongly influenced by both the macroeconomic context and by the policies that have an effect on it (Cassiolato and Lastres 2008). In developing or underdeveloped countries, the macroeconomic policy comprises an "implicit policy[12]" which, depending on its objectives and instruments, may hinder, and even cancel, explicit policies aimed at the industrial and innovative development of the country. Consequently, the impact of implicit policy on the NSI is often more significant than that of the explicit policies of industry and innovation (Cassiolato and Lastres 2005).

The key variables of the economy (interest rate, exchange rate, inflation rate, etc.) shape and determine microeconomic decisions insofar they affect capital costs and conditions the strategic options of private agents. Similarly, microeconomic decisions set patterns at various levels that affect and determine the very macroeconomic regime from which they derive. There is, therefore, a double and reinforced interaction between micro and macroeconomic levels (Coutinho 2005).

11.4.1 The Implicit Policy

Since its colonial period until the mid-twentieth century, as an economy specialized in some basic commodities such as coffee and sugarcane, the role of implicit policy was only of assuring this pattern of specialization. The policy did not create conditions for the country to reap the benefits of the second industrial revolution.

Since the end of the World War II, this changed significantly, when, like other developing countries, Brazil implemented an extensive program of import substitution. The program counted on various instruments of fiscal, credit, and foreign trade policies that allowed the country to, within 30 years, set up a wide, complex, and diversified extractive and manufacturing industry and stimulated improvement of technological capabilities within the productive structure.

Brazil has benefited from the high international liquidity which prevailed in the global economy in the period from the end of the sixties until 1973, when the first petroleum shock took place. However, from 1974 on, the government persisted in a strategy of economic growth based on a growing external debt as the recycling of petrodollars brought liquidity to the international market. This strategy was only changed in the mid-eighties when the external context (impacts of the second petroleum shock, Mexico's moratorium, growth of interest rates in the international financial market, etc.) obstructed its continuity. The deterioration of the external

[12] In addition to the macroeconomic policy, other policies have important impact on innovation as, for instance: industrial, tax, commercial, and education policies. The emphasis given here to the macroeconomic policy is due to the relevance of such policy in the period studied.

current account, the need to control public accounts and the declining in conditions of finances of state companies blocked Brazilian industrial development and broke off the trajectory observed in previous decades (Cassiolato 2010).

As a result, policy efforts during the 1980s were directed to the control of public accounts and inflation, sided with attempts to improve the trade balance through export growth. The chaotic inflation, the increasing budget deficits and the general instability implied the abandonment of any strategy. In a period when a new technological paradigm was unfolding in the world economy, Brazil went through a deep crisis which prevented the use of implicit policy instruments that would allow the entry of the country in the third industrial revolution. Apart from maintaining alive the S&T infrastructure the only exception in terms of support to industrial development during the 1980 decade was the creation of the National Policy for Information and Communication Technology, which sought to implement sectors of information technology in Brazil, based on incentives and protection to the domestic production of mini and microcomputers.

The 1990s decade was characterized by a radical change in terms of macroeconomic policy in Brazil (similarly to other countries in Latin America) with the adoption of the Washington Consensus. The central ideas of this policy regime were: promoting prices stability; liberalizing trade in order to “discipline” domestic producers and force them to obtain productivity gains; promoting privatization and attraction of direct foreign investment for reducing supply bottlenecks of industry and infrastructure; and promoting financial opening to attract foreign capital (Belluzzo and Carneiro 2003).

A major problem deriving from a macroeconomic policy based on overvalued exchange rates, which lasted almost throughout the 1990s, was the deterioration of the external current account. Consequently, the Central Bank of Brazil started operating in the exchange market to keep exchange rate within a range informally established, with the upper limit set as R$1 = R$1.

To do this, the Brazilian government had to keep interest rates at a considerably high level. This was how government guaranteed the entry of foreign capital, which came to Brazil due to the difference between interest rates in Brazil and the rest of the world, particularly the USA (Cassiolato and Lastres 2005). But the Brazilian economy became increasingly more dependant on capital inflows, leading to external vulnerability. The maintenance of high domestic interest rates also raised interest of the public debts, further aggravating the macroeconomic situation of the country.

In view of both the unsustainable external situation of the country and crises faced by the emerging countries in the second half of the 1990s (characterized by speculative attacks to local currencies), the Brazilian government was forced to change its exchange rate policy. Between April 1998 and January 1999, foreign reserves fell from US$ 74 billion to near US$ 30 billion (Silva 2002).Therefore, in January 1999, the government modified its exchange rate policy to a floating exchange rate regime.

Since the late 1990s, macroeconomic policy has been based on three pillars, namely, rigid inflationary goals that, in general, are guaranteed through high interest rates; restrictive fiscal policy linked to primary fiscal surplus; and flexible exchange rates regime (Gonçalves 2006).

The high real interest rate and an overvalued exchange rate have had a negative impact on the economy, discouraging productive investments in the real economy, and presenting a direct impact on its growth. GDP per capita between 1995 and 2002 grew at an insignificant 0.8 % per year. Such policy sustained a valuation of the real at the expense of real interest rates of 20 % a year, which yielded a rise of the net public debt/GDP, from 30 % in 1994 to 51 % in 2002. In the same period, there was also a significant accumulation of current account deficits reaching US$ 186 billion. The use of high interest rate as the only mechanism for fighting inflation has been quite polemical and highly criticized by several segments of the economy, particularly those related to production[13].

From 2003 on, pushed by the growth of the world economy headed by the Chinese economy, exports increased in average 22 % per year (2003–2007), a significant jump in comparison to the former period (3.7 % per year between 1995 and 2002), total external debt/exports decreased from 350 to 120 %, the reserves amount exceeded the external public debt and the growth rate of per capita GDP reaches 2.4 % per year.

Inspite of the improvement observed in several indicators, the country still relies upon the two instruments—overvaluation of the exchange rate and high interest rates—for anchoring all economic policy for fighting inflation.

11.4.2 Science, Technology, and Innovation Policy

11.4.2.1 Brief Background—From the 1950s to the 1980s

The Brazilian National System of Innovation has changed significantly between 1950 and 1970, when the country was converted from a traditional supplier of raw-materials into an economy based on manufacturing industry. Significant initiatives of S&T were adopted in the sphere of the federal government, aiming at organizing S&T. The late 1940s and the 1950s were a rich period regarding the provision of government institutions to coordinate and execute S&T policies. Important initiatives include the setting up of CNPq (National Council of Scientific and Technological Development) and Capes (Committee for Improvement of Tertiary Level (Post Grad) Personnel), both created for organizing and financing research and graduate studies (Cassiolato 2007).

[13] It is worth remarking the existence in Brazil of a long-term interest rates (TJLP), created in 1994, which is defined as the basic cost of financings granted by the National Bank of Social and Economic Development (BNDES), the main provider of investment funds in the Brazilian economy. This rate is currently of 6.25 % per year, which reflects a declining trajectory taking into account that in the middle 2003 it was at 12 % and, in the beginning of 2006, 9 %. However, this rate is influenced, as well, by the SELIC rate set out by the Central Bank. Thus, the maintenance of this latter at high levels, in order to fulfill inflationary goals, may affect the determination of TJLP, restrict the investment level and, consequently, restrict the effects of explicit policies directed to the development of the national system of innovation.

Also remarkable is the creation of some sectoral R&D institutions by the federal government in strategic areas. For the first time, institutions established were not restricted to biomedical and agricultural areas. Among those institutions stand out the CTA founded in 1954, and the INPE created in 1961. Other institutional models were adopted in various sectors, such as the oil sector with Petrobras (created as a public enterprise in 1953) and mining, iron, and steel were state-owned enterprises with internal R&D labs were set up.

From the point of view of S&T development, it was only in the late 1960s that Brazil started again to include the issue of scientific and technological development in its policy agenda, as part of a series of policy measures that transformed the Federal Government (such as the setting up of a Central Bank).

Brazil implemented a strategy that consisted primarily of providing a good S&T infrastructure. The first serious attempt to mobilize financial resources for scientific and technological development in Brazil was made at the National Development Bank (BNDE) in 1964 when FUNTEC (National Techno–Scientific Fund) was created with the aim of providing financial resources for upgrading of scientific–technological infrastructure.This was to be achieved primarily through the establishment of joint graduate courses and research programs (not exclusively, but almost entirely) in public universities and research institutes[14].

The second important institutional change in S&T in Brazil was the creation of FINEP (Agency for Financing Studies and Projects) in 1969 as a separate agency of the Ministry of Planning. FINEP, which could be roughly characterized as a development bank for S&T, started operating mainly in financing feasibility studies, but in 1971 had its functions greatly expanded. A new fund, FNDCT (National Fund for Scientific and Technological Development), was created using federal budget resources to foster scientific and technological capabilities.[15]

A mention should be made to the transformation of the old National Research Council (CNPq) into an institution responsible for the coordination of all scientific and technological activities at federal level in 1973.

Perhaps, the most significant institutional innovation of the period was the setting up in 1973 of the Brazilian Agricultural Research Corporation (EMBRAPA).

Thus, the abundance of budgetary resources (Brazil was growing at an average of 8.5 % per year in the late 1960s and early 1970s) that were channeled to the setting up of good postgraduate courses and research in practically all scientific areas totally changed the landscape.

From the point of view of technological development at firm level, policies did not show a remarkable success but the roots for successes in the agroindustry (especially thorough the work of EMBRAPA), airspace (Embraer, CTA, INPE,

[14] The bulk of FUNTEC's support for scientific and technological development in its earliest period (1964–1971) was directed toward the R&D infrastructure: 76 % of financial resources were addressed to human resources (postgraduate programs) and 19 % to the research projects of public research institutes.

[15] FINEP was nominated as the executive secretariat of FNDCT, with responsibility for channeling its financial resources. The fund was the main financial instrument of the newly established Basic Plan for Science and Technology.

etc.), oil (where Brazil is the world leader in technology for deep water extraction), telecommunications (which was later lost), and energy (including biomass) were established.

The external debt crisis, which emerged at the beginning of the decade of the 1980s and blossomed after the Mexican Moratorium of 1982, blocked Brazilian development and interrupted the brilliant growth pattern that had been observed in the previous decades. The prolonged foreign exchange hardship, combined with wide-ranging and clever mechanisms of indexation, pushed the economy toward an unprecedented regimen of superinflation.

The debt crisis impacted the entire private sector as well as the large state enterprises holding dollar-denominated debts in the offshore euro market. The Federal Government absorbed most of the impact by assuming the dollar obligations of the private sector through various mechanisms, and ended up compromising its fiscal health ,and undermining its ability to continue fostering the development process. Fiscal weakness and a severe shortage of foreign exchange, coupled with the assumption of private debt by the treasury led Brazil to rampant inflation. From the point of view of the productive structure and its degree of competitiveness, potential problems that would affect the Brazilian economy, insufficient technological development, low level of specialization and low degree of integration with the international economy, were already detected in the early 1980s (Cassiolato 1981; Serra 1982).

Obviously, this crisis period (and the consequent short-run stabilization measures) had a significant impact on government S&T expenditures. Total expenditures of FUNTEC (the most important S&T fund) fell from US$ 1.2 billion (1970–1979) to US$ 754.32 million (1980–1989). To counteract the budgetary crisis, in 1984 the Brazilian Government began the negotiation of a loan agreement with the World Bank (International Bank for Reconstruction and Development (IBRD)). As a result a Science and Technology Reform Support Project (PADCT) was signed. However, the World Bank loan was not sufficient to restore the funding at the level of the 1970s.

Another important institutional development was the setting-up of a new Ministry of Science and Technology as part of the new democratic government of 1985. The Ministry introduced, for the first time, the issue of innovation in the policy agenda, set up an important program for human resources in the new areas of information technology, biotechnology, and advanced material, and was able to restore funding to its 1970s levels. However, the deepening of the crisis in the late 1980s—when inflation reached three-digit levels—brought significant institutional instability (the Ministry was downgraded to the level of a Special Secretariat with less political clout and resources) and the end of the decade witnessed another crisis for the S&T area in Brazil.

11.4.2.2 Characterization of the Main Programs and Policies of S, T&I and Guidelines Officially Adopted in the 1990s and 2000s

Against the backdrop of the macroeconomic policy, two distinct periods of Innovation Policies stand out within the period of 1990 and 2006, in the ambit of the federal government. In the first one (1990–1998), the innovation policy was configured on the basis of the industrial policy, being characterized especially by the need to counteract measures adopted during the period of imports substitution and having as its main strategies, the opening to the international market, and restructuring of the productive sector. Innovation appears as a consequence of restructuring and of competitive pressures, with a vision based on strategies of modernization and technological capability building. In the second period (1999–2006), innovation policy is characterized by a discourse advocating innovation and the first movements toward recovering the capacity of the federal government to foster and finance innovation are perceived in the institutionalization of a legal framework and instruments, although the strategic role that the federal government should play in this policy is not recovered yet.

Period 1990–1998

The innovation policy of the 1990 decade is marked by a turning point in the industrial and technological policy direction by the federal government[16]. This inflection has been directed to the liberalization of the market and toward the incentive to foreign investment to dynamize Brazilian industry and technology, hence undertaking a "radical neoliberal policy agenda." From the perspective of the broader guidelines of the industrial and technological policy, it can be claimed that they privileged a supposedly more neutral character through the use of mechanisms said "horizontal," which would not discriminate against sectors and enterprises and would facilitate the operation of a market economy.

Instruments were created based on the idea that the process of trade liberalization would induce firms to pursue innovation, as part of a process to survive in the domestic market, at a first moment, and to improve their international competitiveness at a second stage. Thus, in general, the State intervention was guided by the "nonadoption" of measures or by the adoption of "discouraging" measures, in this period when the economic authorities stood unfavorable to the innovation policy.

In the beginning of the 1990s, the guidelines of the Industrial and Foreign Trade Policy (PICE) were approved. The document containing the main guidelines of PICE clearly reflects the standpoint of the federal government for the period between 1990 and 1994: "[t]he Industrial and Foreign Trade Policy has the objective of increasing the efficiency of production and commercialization of goods and services, by means of the modernization and restructuring of the industry, thus

[16] For an evaluation of the industrial policy implemented in the early 1990 decade, see Guimarães (1996); Erber and Cassiolato (1997).

contributing to improving the quality of life of Brazilian population" (Portaria MEFP nº 365, of 06.26.1990)

The innovation policy of that period defined by the industrial policy, which was based, besides other factors, on processes of modernization and technological capabilities improvements in the search for international standards of quality.

The strategies then adopted can be summed up within two groups: the first one characterized by the elimination/reduction of both tariff and nontariff protection mechanisms, including the elimination of incentives and subsidies, and by strengthening the mechanisms for defense of competitiveness. The second group aimed specifically to the modernization of the productive sector, providing for the establishment of mechanisms for coordination, support, and financing for restructuring the industry and technological infrastructure, for the incentive to specialization of production and *planned exposure of Brazilian industry to international competitiveness* (MEFP nº 365, of 06.26.1990), in addition to building the technological capabilities of the enterprises.

The first part of this strategy, related more specifically to the trade policy, was quickly implemented; it is the implementation of the second part, related to innovation policy, that has been restricted to two main pillars: the grant of fiscal incentives[17] and programs aimed at promoting quality, productivity, and modernization of firms.

Period 1999–2009

The second period from 1999 started with a huge crisis as the untenable foreign exchange position forced a devaluation of the real and a change in the foreign exchange regime from a fixed to a floating exchange rate regime that was supported by multilateral institutions, particularly the International Monetary Fund (IMF) and the World Bank. The adoption of the floating exchange rate aimed to prevent the persistent deficits in the balance of payments, which were to be counterbalanced by means of a positive trade balance. The IMF support for avoiding the deepening of Brazilian crisis had, as a counterpart, the requirement that the country should adopt strict fiscal and inflation goals through, again, high interest rates and the adoption of an inflation targeting regime.

Expectations regarding changes in economic policy subsided as the crisis unfolded. The only significant policy change was the adoption of a more aggressive foreign trade policy, which had positive impacts on the balance of payments as increasing surpluses in the balance of trade started to materialise.

[17] In addition to the established tax incentives, which basically benefited enterprises of greater size, in the ambit of BNDES Participations (BNDESPAR)—an agency of the BNDES system that provides resources for enterprises by means of transitory and minor corporate share—, a specific line of support to small and medium enterprises operating in the area of technology. The Program for Technology Enterprises Capitalization (Contec) was constituted in 1991 and converted into a program in 1995, although the volume of resources made available has not been significant.

It was basically against the same macroeconomic policy background that policies specifically directed toward innovation started to be designed in 1999; they followed more or less the same approach at least until 2006. The guidelines and objectives, however, followed a very similar framework to the one in place in the previous period (1995–1998), which advocated horizontal policies as the most appropriate approach for an innovation policy. The difference was that the Federal Government started to recognise the need for intervention to correct so-called "market failures," particularly to establish partnerships between scientific and technological institutions and firms.

The rationale was that the lack of interaction between scientific and technological institutions and firms was preventing the Brazilian scientific infrastructure from "producing" innovations. In addition, the characteristics of the innovative process, involving high risk, high costs, and long maturation times justified, so the argument ran, the action by the State. The policy was hallmarked by this view and was based on the creation of mechanisms and instruments aimed at encouraging interaction between the academic world and the production sector, as well as reducing both the costs and risks of inducing investments in innovative processes by the production sector. It has to be pointed out that this was nothing new in the Brazilian context as policies for fostering links between universities and businesses had been implemented since the mid-1970s (Cassiolato 1992).

Innovation policies remained restricted to the sphere of the Ministry of Science and Technology (MS&T). However, at the beginning of 1999, the Ministry of Development, Industry and Foreign Trade formulated a detailed plan for industrial, technological, and foreign trade which explicitly recognised that one of the main problems of the Brazilian productive structure was a relatively low level of innovativeness. In this plan, one of the main policy proposals was to step up the pace of technological innovation (Cassiolato and Lastres 2005).

In 2000, the Ministry of Development, Industry and Foreign Trade created the Competitiveness Forums, which consisted of committees coordinated by its Department of Production Development whose main objective was to establish a dialogue between the productive sector, the government, and the Parliament. The forums aimed to promote debate and search for consensus.

Unfortunately, not much progress was achieved with the forums, and the MS&T remained the sole body responsible for innovation policy. The Ministry was taken captive by the interests of the most vocal part of the Brazilian scientific community and shaped its strategy based on three main pillars: (1) incentives for technological development and innovation in firms; (2) incentives for the creation of new technological infrastructure; and (3) incentives for newly established technology firms (start-ups) (Cassiolato et al. 2014).

In order to enable such a policy to be implemented, the Ministry thought up an ingenious scheme to provide new funding. Funds for Scientific and Technological Development, the so-called sectoral funds, were set up (using new taxes) with the aim of rebuilding the capacity to grant incentives for financing R&D and innovation. Between 1999 and 2002, 12 sectoral funds were created, the first of them being the petroleum sectoral fund, as well as another two of a horizontal nature: the

Yellow-Green Fund and the CT-Infra, which aimed respectively to finance projects involving university and enterprise partnerships for fostering innovation, and to restore and expand the scientific and technological infrastructure of universities and other research institutions (Cassiolato et al. 2014).

The sectoral funds displayed two main novel features: the establishment of coordinating committees bringing together representatives of government, the production sector, and academia and responsible for setting up guidelines, selecting and monitoring projects to be financed; and the rule that the research projects to be financed had to include both enterprises and scientific and technological institutions. The logic behind the creation of such a mechanism was to allow for the participation of the private sector and academia in taking decisions about projects to be financed, and to encourage the setting-up of partnerships in research projects, considering that innovation does not happen in isolation.

The restructuring of the MS&T's financing capacity allowed implementation of the policy's three pillars to begin. For the purpose of fostering partnership links between universities and enterprises, some schemes were also established for placing young researchers in enterprises. Such schemes were implemented by the National S&T Council, CNPq, through scholarships granted under the programme Human Resources for Strategic Activities—Innovation (RHAE—Inovação), and the Programmes for Incentives to Retain Human Resources (PROSET).

The originality of the sectoral funds, which rested on increasing otherwise scarce resources for S&T, was unfortunately outweighed by the very rudimentary notion of innovation adopted, i.e., joint R&D projects conducted by universities and firms. Implementation of the sectoral funds was based on the launch of calls for proposals with a view to the nonreimbursable[18] funding of "projects for research, development, and innovation partnerships between scientific and technological institutions and enterprises." Eventually only R&D projects got under way.

To improve the technological infrastructure, the Ministry of Science and Technology launched, in December 2000, the programme Basic Industrial Technology and Technological Services for Innovation and Competitiveness (TIB Programme). This pursued the aim of adapting and expanding the technological services infrastructure in the areas of metrology, standardisation, technology management, support services for clean production, and support services for intellectual property and technological information.

The support for technology business enterprises was provided through the creation of the National Programme of Support for Business Incubators and Technology Parks (PNI) and the INOVAR programme for fostering seed and risk capital. These programmes were implemented by FINEP, the financing arm of the Ministry of S&T.

Several other programmes were created by the MS&T to support the technological development of micro-, small- and medium-sized industrial enterprises. They consisted of actions directed toward technological extension, technological support for exports, and technological services. The regional dimension was targeted by

[18] Nonreimbursable financing was granted to S&T institutions with firms paying their counterpart.

another programme, the Programme of Support for Innovation in Local Production and Innovation Arrangements, which was implemented in partnership between the Federal Government and State Governments.

The third pillar of the innovation policy—encouragement of technological development and innovation in firms—was implemented via the revitalisation of tax incentives, the use of mechanisms for reducing interest rates on traditional lines of finance, and the establishment of nonreimbursable financing mechanisms, i.e., grants. Although explicitly provided for in the policy, these new instruments were not implemented during the 1999–2002 government as no consensus was reached within government on how to put them into practice.

The S&T policy was maintained with hardly any significant changes and concentrated in promoting S&T development via the concession of scholarships for students and researchers. There was however a significant increase in the government budget for the MS&T with the novel resources of the Sectoral Funds and three new initiatives, inspired by international agencies were introduced.

The first was the launching of the Milenium Institutes program. This program aimed at consolidating high level research groups as it diverted some of the new budgetary resources to them. It did not represent any strategical change and rapidly lost its appeal, as it is only a way for members of the S&T community with a political clout to guarantee some resources. In 2008, a similar initiative was put into place, now with another name, National Institutes of Science and Technology.

The second was an attempt to restructure research institutes associated to the Ministry of S&T. The idea was to introduce best managerial practices through the setting up of "Management Contracts" between them and the M S&T. The management contracts aimed at setting performance targets to the research institutes as a counterpart of guaranteed yearly budgets to them The basic idea was to introduce a more professional management structure and to stimulate the institutes to get financial resources in the "market" through partnerships with the private sector. Such attempt was frustrated by two reasons: strong internal resistance and the enormous difficulty in finding private partners.

The third initiative, the setting up of thematic research networks, was the most successful. The plan was to link different universities and research institutes working in the same theme in mobilizing research projects. As priority areas were chosen strategic areas such as biotechnology, with networks for genetic sequencing, the Genome project, and nanotechnology, etc. The success of this policy stimulated the setting up of other important networks, for example, the Genome project, a thematic research network on environmental modeling of the Amazon region.

The new government of President Lula who held office in 2003–2006 launched the Industry, Technology and Foreign Trade Policy (PITCE),[19] one of the main

[19] The guidelines for Industry, Technology and Foreign Trade Policy (PITCE) were issued in November 2003 and officially announced by the Ministry of Development, Industry and Foreign Trade in March 2004. In line with the idea of spreading the pro-innovation discourse throughout the ministries, the guidelines were jointly formulated by several agencies of the Federal Government.

pillars for the encouragement and promotion of innovation in firms. In practice, the government maintained the same guidelines and objectives of the previous science, technology, and innovation policy.[20]

It is true, nevertheless, that the PITCE represented an advance in comparison to the National Science, Technology and Innovation Policy, as it took into account the need to identify strategic options, even though it limited such options to knowledge-intensive areas that were not even defined or specified in the policy documents.[21] However, for PITCE, unlike the National Science, Technology and Innovation Policy, there is no agency appointed to coordinate the policy.[22]

In spite of the explicit acknowledgement of the need for an innovation policy and the need to select strategic areas, the new government implemented policies based on the same ideas and mechanisms created in the former period. In particular, sectoral funds remained the main sources of resources and the model for policy implementation.

The main difference between the period 2003 and 2006 and the previous government was the creation of two new sectoral funds, adding to the 14 funds created in the period 1999–2002, and the establishment of the Coordinating Committee for the Sectoral Funds by the Ministry of Science and Technology. Perhaps the most important novelty was that some resources of the sectoral funds began to be used by the government to support policy actions that were not strictly sectoral as it earmarked 50 % of the resources to finance such actions. This measure was an attempt to remedy the prevailing lack of coherence between projects approved (and funded) by the Boards of the different sectoral funds and the strategic guidelines set by the Federal Government for the National Science, Technology and Innovation Policy and the Industry, Technology and Foreign Trade Policy.

In addition to the sectoral funds, these two policies were linked to two basic legal instruments that were introduced: the Innovation Law, enacted in 2004, and the

[20] The objectives were: consolidating, improving, and modernizing the National System of Science, Technology and Innovation, by expanding the national science and technology base; creating an environment favorable to innovation in the country, strengthening the industry, technology, and foreign trade policy, encouraging the business sector to invest in research, development, and innovation activities; integrating all regions in the national efforts to build capabilities in science, technology, and innovation; developing a broad basis of support and engagement within society with regard to the industry, technology, and foreign trade policy; transforming S, T&I into a strategic element within Brazilian policy for social and economic development (BRASIL 2006, p. 12).

[21] As explicitly stated in the official policy document: "the lines of action to be considered by the Federal Government for the implementation of the industry, technology, and foreign trade policy are … Technological innovation and development … Along with the above actions, it is necessary to concentrate efforts on some knowledge-intensive areas …- these are strategic choices in activities that: account for significant shares of international investments in research and development; … are directly related to innovation in processes, products and modes of use … (BRASIL 2003, p. 27).

[22] In order to solve this problem of coordination the Executive established the Brazilian Agency for Industrial Development (ABDI) almost one year after the launch of the PITCE guidelines. However, the solution to the problem of coordination proved unfeasible, since the ABDI is an autonomous social service which, therefore, does not have any legal power over bodies belonging to the public administration. See Suzigan and Furtado (2006).

"Law of Good,"[23] enacted in 2005, both aimed at promoting innovation by means of either tax incentives or nonreimbursable grants and interest rate subsidies.

The analysis of both guidelines and implementation of the innovation policy, be it through the National Industry, Technology and Foreign Trade Policy or through the National Science, Technology and Innovation Policy, reveals that in addition to problems of coordination and overlapping of objectives and actions, the support for research, technological development, and innovation basically consisted in actions by the Ministry of Science and Technology and its agencies (FINEP and CNPq).

Continuity can in fact be observed between the innovation policy of the period 2003–2006, when all the Ministry's efforts were directed to improving/overhauling and implementing the instruments, and the mechanisms conceived in the former period (1999–2002). The Innovation Law (which had already been drafted by the former government) and the "Law of Good" allowed for the availability of resources for interest rate subsidies and grants. Also the sectoral funds were reformulated slightly to bring them into line with the guidelines proposed by the government.

After 2006, an important change occurred in the sense that a new industrial policy (Policy for Production Development or PDP) was designed and was centered on the innovation issue. The implementation of the PDP began in May of 2008. Therefore, it is still soon for evaluating its results. Even so, it is possible to highlight some positive aspects, as well as some issues of concern. Among the positive aspects, we may cite the attention with the governance of the policy and with "sharing responsibilities" among the various institutions responsible for its implementation.

As for the issues of concern, two of them stand out: the first one regarding the high number of sectors and areas considered, moreover with the possibility of including new segments, as indicated by the policy statement itself. In terms of official documents, the policy proposal is based on a systemic vision of the production system, as clearly stated in the following guideline expressed in the PDP: *Systemic actions—with focus on factors that generate positive externalities for the whole production structure*.

The formulation of the policy took into account the dialogue with other proposals of policies available in ministries, as well as in some organizations of the civil society, as following: PAC, the Program for the Acceleration of Growth (*Programa de Aceleração do Crescimento*), promoted by the federal government with the objective of overcoming the "bottlenecks" of infrastructure; PACTI, the Action Plan for Science, Technology and Innovation launched by the Ministry of Science and Technology aiming at enabling the implementation of the National Policy of Science, Technology and Innovation, and that takes responsibility for coordinating some priority sectors and areas defined by the PDP; and policies of Ministries of Labor and Employment (Ministério do Trabalho a Emprego—MTE), the Ministry of Health (Ministério da Saúde—MS) and the Ministry of Education (Ministério da Educação—MEC); besides the attempt of liaising with the National Confederation of Industry (Confederação Nacional da Indústria—CNI), an institution of the civil society.

[23] In Portuguese, "Lei do Bem". This legislation provided several incentives and made changes to the legal framework in an attempt to foster private investment.

In spite of the discourse, the excess of priorities, besides bringing risks of failure in face of the difficulties for managing them, seems not ascribing much importance to the systemic character of the innovation process, which would imply the choice for segments and economic activities capable of generating changes in the productive and social structure of the country.

The second matter of concern regards to the mechanisms of the policy that are essentially the same created in former years. In this case, the worries refer both to inadequacies of the old instruments, and by the way by which they are being implemented.

The guidelines and strategies of the innovation policy implemented in the recent period were mainly aimed at creating an innovation-friendly environment by rebuilding the capacity for promoting/financing R&D and innovation and also by changing the legal framework, which was seen as hampering the innovation process in firms. These guidelines and strategies are explicitly anchored in the idea of correcting existing "market failures," being essentially a reformist liberal policy (Erber and Cassiolato 1997, p. 34).

The innovation policy devised and implemented since 1999 displays a supply-side orientation and still follows the linear approach to innovation. Although labeling the projects to be supported with the words "research, development, and innovation," policies supported basically R&D projects. The logic underlying both instruments and the implementation of innovation policy since the early 2000s up to 2014 lacked a systemic view of the innovative process,[24] failing to contemplate wider aspects of knowledge acquisition and learning that are essential parts of the innovation process (Cassiolato and Lastres 1999). Policy focused on scientific and technological institutions and on enterprises, considering, at best, the links and interaction between these two actors. Hence, other institutions that are vital to the innovation process continued to be ignored by this logic.[25]

11.4.2.3 Main Outcomes and Problems of Adopted Policies of Science, Technology and Innovation

Period 1990–1998

The outcomes of the policies of science, technology, and innovation were not satisfactory, even though the government has included the support to S&T as one of the main elements of this policy. Indeed, due to the fiscal crisis, the policy was virtually limited to the liberalization of international market.

[24] Bill No 1631/07, governing operation of the National Fund for Scientific and Technological Development (FNDCT), was sent to the National Congress in 2007 and was still under examination at the end of 2008.

[25] In reply to the lack of innovation policies in the sphere of the Federal Government, State Governments started to design their own policies, to a greater or lesser extent, depending on the relevance of the matter for policy makers. For a description of state initiative, see the original paper presented at (please give the title of the seminar)

The analysis of the period 1990–1994 indicates that the process of trade liberalization had unplanned effects on the firms, inducing modernization, and increasing productivity of some sectors; producing changes in the productive structure and affecting the microeconomic behavior of agents. However, these effects on the productive structure were not positive, for they include: change in the capital origin of innovative Brazilian companies (which were acquired by foreign companies); significant reduction in production of equipment and machinery in Brazil, with consequent raise in imports of capital goods; adoption of modernization strategies based on the substitution of equipment and machinery reducing the need for human resources without the adoption of innovation strategies; and reduction (elimination) of integration between multinational companies and supplier firms, due to the adoption of outsourcing strategies. Therefore, the policy outcome was the concentration in segments and sector of lesser value added.

It is worth noting that, in view of the highly unstable and weakened macroeconomic environment before the escalate inflation of years 1990–1994, all explicit policies aimed at industrial and technological development was jeopardized and had limited impact.

Period 1999–2009

The analysis of the innovation policy adopted in the period reveals a policy based on the existence of "market failures" which was to justify distinct intervention by the State. This assumption led to a mistaken diagnosis about Brazilian reality which, combined to the lack of planning, budget, and coordination between policies, and to the fact of policies being inspired on those designed and implemented by developed countries, resulted in the formulation of policies, programs, and actions insufficient and ineffective, which benefited a limited number of firms in spite of the discourse of "horizontality." However, it did not affect the strategic decision by firms, since firms which search for available mechanisms would possibly invest in R&D independently of the existence of this policy, given their need for maintaining a competitive position in the market.

Without clearly defined goals and with its main mechanisms being implemented by initiative of the beneficiary, the impact of the policy on the strategy of the agents seem not to be significant, especially regarding innovation. As shown by IBGE's survey on Technological Innovation, the innovation rates for manufacturing firms appear practically invariable since 2000 and even falling after the 2008 crisis (Cassiolato et al. 2014). Similarly, the adopted policy was unable to influence the investment rates in the period, which stayed low (between 15 and 16% of GDP, according to IBGE). Consequently, the productive structure did not present significant variations if compared to the former period, with the movements for acquisition of Brazilian companies by foreign companies aggravated by the privatization policy instituted by the federal government and mainly focused, in this period, on the services sector (nontradable).

The whole logic surrounding innovation policy instruments and implementation in the period of 2000–2014 disregarded the systemic vision of the innovative process. As noted by Cassiolato and Lastres (1999), the new policies for industrial and technological development must be considered with reference to the new knowledge on innovative process. The analysis of instruments and implementation of the innovation policy has always been focused on scientific and technological institutions and on the enterprises, at most, on the articulation and interaction between these two agents of the innovative process. Thus, other fundamental institutions for the innovative process have been excluded from this logic, and even the governmental institutions which take part in this policy were not considered. Furthermore, the required process of coordination and interaction that must be established between the institutions did not occur.

Finally, despite these evidences, in 2007 we can only observe the continuity of this policy, which is still based on the incentive to R&D within firms and stimulus to the establishment of partnerships between universities and enterprises, by means of concession of fiscal incentives and financing for projects of R&D. This policy is based on those instruments created in previous years: tax incentives, sectorial funds, economic subventions, and interest rates equalization.

The implicit macroeconomic policy which, in the period immediately following the adoption of Plano Real (from 1995 to 1999), kept interest rates at levels extremely high, besides keeping an overvalued exchange rate and jeopardized Brazilian industrial and technological development. After 1999, Central Bank set up a very high level of interest rates (in real terms) which deterred investment decisions by the business system. The new process of appreciation of the exchange rates, initiated in 2006 (due to both internal and external factors) has also conditioned decisions and actions by the microeconomic agents and influenced the potential impact of explicit policies.

11.4.2.4 Regulation of Intellectual Property

As analyzed by Freeman (1998), an interactive relation between the technical-economic paradigm and the institutional organization of the society is observed. For each historical period, there is a corresponding particular form of interaction, from which emerges a specific modality of appropriation of the gains resulting from technological innovation. The technological paradigm characteristic of the learning and knowledge economy, especially the development of technologies of information and communication and biotechnologies, has brought the consolidation of more restrictive and sophisticated mechanisms of appropriation, which institutionally had their bases defined by the Agreement on Intellectual Property (TRIPS) signed at the Uruguay Round of GATT, in 1995.

While the use of patents has hampered the formulation of appropriate legislations tailored to building the NIS,[26] TRIPS nevertheless left a certain margin of

[26] In the past, all countries that reached the technological frontier took advantage, at a greater or lesser extent, of more flexible regimes of appropriation. Currently, the barriers posed to strategies of catching up are much greater, due to the regime of appropriation defined by TRIPS and strengthened by bilateral treaties of trade (TRIPS PLUS). For further details, see CHANG

freedom for each country to define its understanding of the general requirements of the Agreement and to consolidate them into a national legislation. This opens some breaches for less developed countries to explore the “gray” areas of the agreement and include flexibilities in their national legislations[27].

In Brazil, intense debates have marked the issue of intellectual property during the nineties. The liberalizing view prevailed in that period and the option fell on the stream that offered less resistance, surrendering, thus, to the pressures by holders of intellectual property from developed countries and to threats of bilateral commercial retaliation. Therefore, the regulation of TRIPS, consolidated through the Law nº 9279/96, was made in haste and disregarded some mechanisms allowed by TRIPS that could bring benefits to the country’s technological development.

Hence, in spite of having until the year 2000 for adopting a national legislation in conformity with the agreement, and until 2005 for conceding patents for products that were not included in the system of intellectual property of the country (among which, medicines), the Brazilian law on intellectual property was approved as soon as in 1996. The country wasted, thus, the transition period of 10 years for adapting the productive sectors and those of science and technology to the new context[28]. In addition, Brazil has instituted instruments that exceeded requirements of TRIPS, such as the “pipeline” mechanism, and concurrently failed to include the mechanism of parallel imports allowed in the agreement.

The results of these changes in the Brazilian patent protection regime do not confirm expectations and arguments of their advocates[29]. The available national statistics on patents for the period 1995–2014 show a relatively low number of concessions of new patents to both residents and nonresidents (demonstrating decrease in dynamism in the innovation process), a significant raise of requests for privilege of invention by foreigners (and insignificant for residents), besides the low

(2001)—*Intellectual Property Rights and Economic Development Historical Lessons and Emerging Issues.*

[27] The agreement admits a country to not conceding patent to an invention if such decision aims at protecting the public order, morality, life, human, animal, and vegetal health or, still, for avoiding damages to environment. It was also allowed to countries to adopt measures for promoting the public interest in sectors that have vital importance for its socioeconomic and technological development, since such measures are to be compatible with provisions of TRIPS. Similarly, in any area of the technological sector, the countries may act in order to avoid that the patents holders exceed their rights.

[28] Conversely, India made use of the maximum term for domestically regulating the agreement, what allowed for a great advancement of pharmaceutical industry in the country, which started producing generic versions of medicines supplied by the large pharmaceutical companies in other countries, thus became the first source of generic medicines in the world.

[29] The advocates of the new regime of intellectual property believed that this would contribute, among other benefits, for: raising competitiveness; improving standards of quality of local industry; facility for exchanging owner technology with other countries; strong stimulus to requests for patents of inventions in the country, to investments in R&D by foreign companies established in the country and to foreign; raise in the flow of technology transfer and reduction of the technological gap; local capabilities building and training of human resources. For further details, see Cassiolato et al. (2007b).

increment of requests for patents and and inventions deposited abroad by Brazilian residents[30].

The evaluation conducted by Elias (2004) on the results of the use of intellectual property as a stimulus to technological development and to the innovative capability of Brazilian pharmaceutical industry[31] reveals outcomes equally unfavorable: in spite of the changes in the regime, the tendency of national enterprises to register patents remained low and the pattern of reduced technological development performed locally by subsidiaries of multinational companies also remained unchanged. As for the contracts for technology transfer, the study demonstrates that only the category of brand use (which does not imply knowledge acquisition) has been relevant.

Besides, the change in the regime of appropriation posed restrictions to the implementation of policies that are necessary for strengthening the national system of innovation. The system of innovation in health is a relevant case, where patents have hindered the development of the national pharmaceutical industry, with strong repercussions on public health.

Consequently, it is necessary to review the emphasis given to interests of the advanced countries by the government in the nineties, looking for constituting a system of patents that fit the specificities and needs of the Brazilian innovation system, and to aim at a new balance between incentive to endogenous innovation and the full use of new knowledge and innovations internationally available.

Albuquerque (2007) suggested three fundamental elements for pursuing this objective. First of all, the search for arrangements more favorable to the dissemination of technologies in the country and to the creation of incentives for protecting adaptations and incremental innovations, crucial elements for the process of catching up. Second, patent legislation must be compensated by a simultaneous development of an anti-trust legislation, able to restrict the power of monopoly assured by patents. Third, administrative structures and enforcement institutions must be organized so that to enable a qualified intervention in processes of international negotiations. With this latter objective, the author emphasizes the necessary articulation between state bodies responsible for the concession of patents; state bodies of regulation of economic activity and antitrust policies; and Brazilian negotiators at international forums.

These elements may help to compensate difficulties introduced by the pattern of protection to intellectual property prevailing in the international ambit. However, they must be complementary to the efforts for the constitution of internal capacity for technological absorption, the basis for building a national system of innovation, and also must be inserted in a strategy for development consistent with national specificities and priorities.

[30] See tables in the statistical annex (INPI 2007).

[31] Patents represent the main instrument of private appropriation of innovations in this industry.

11.5 Concluding Remarks

This paper presented some general characteristics of the Brazilian NSI and its evolution by portraying its different subsystems. We argue that the present configuration of the NSI is both the result of the historical evolution of a country that was a colony from its inception in 1500 till the beginning of the eighteenth century. Even after independence, Brazil's commerce elite prevented the setting up of key institutions of a NSI which were only introduced in the last 60 years.

With regard to the production structure, the industrialization process, beginning *de facto* in the 1950s, changed the country from an essentially agrarian economy into an industrialized economy in less than three decades. Nevertheless, already in this period, the adopted model of development presented signs of exhaustion. Thus, the State began to diversify its strategies and to adopt a number of cooperation agreements with foreign companies, aiming the incorporation of new technologies. National firms, however, adopted adjusting technological strategies, with low investments in R&D. Some exceptions were identified, for instance, Embraer and Petrobrás, both state-owned companies, comprising "isles" of technological development based on explicit strategies of the State. From the 1980 decade until the middle of 2000s, industrial GDP underwent a sharp decrease, with increase in participation of services. These changes were reflexes of the strong fiscal–financial crisis as of the 1980s, which affected the structure of production activities, including inducing a sharp growth of informality in the production system. In the beginning of this period, state concerns were directed to the threat of an exchange rates crisis, which strengthened protectionism and limited resources for both industrial financing and science and technology. The State, became unable to direct the industrialization process, whereas domestic private agents, involved in protectionist custom barriers, had no stimulus or were unable to keep the required investments for the industry, especially investments which could promote a virtuous cycle on innovations, thus promoting the industrial development. During the 1990s, institutional economic reforms were adopted, with markets deregulation, privatization and trade liberalization. These strategies did not mend the technological background created in the previous decade. The main proposition of this new model aimed, above all, reaching technological development by means of DFI. However, it was observed that foreign companies, when introducing innovations in Brazil, do it through their R&D laboratories located in their headquarters. This model corroborated the argument that offering incentives for attracting multinationals cannot be regarded as a solid strategy for overcoming the national technological backward. It was observed that the adopted model jeopardized the development of strategic sectors, as in the case of telecommunications. The latter decades strengthened the production specialization in commodities, especially in agrarian and extractive subsystems and in products with relatively low value added.

Surveys on innovation indicate a relatively low innovation rate in Brazilian industry. However, the average innovation rate neither takes into account the high heterogeneity of Brazilian industry since indicators refer to the average values of broad sets of activities and capture solely the innovative efforts of manufacturing industry, neglecting innovations introduced by the agrarian and service subsystems. Even with the late beginning of construction of research institutions, the country accounts on excellence centers with sophisticated innovative capabilities in several areas such as agro industry (where EMBRAPA stands out), aeronautics (highlighting Embraer, CTA and INPE) and petroleum (highlighting Centro de Pesquisas da Petrobrás—Cenpes), which are still funded by either the public sector or state companies. Therefore, Brazil has developed, in some particular areas, centers of excellence through a long process of capabilities building and interaction between the research institute and universities and the productive structure. These are often not captured by PINTEC data. This fact brings the need for developing more meticulous analyses, focusing specific cases which comprise the Brazilian specificities, as much in sectoral as in regional terms.

However, in the last years, research institutes experienced a number of changes, mainly characterized by reduction of public resources for their funding. As a result of this strategy, it is observed that many of these research institutes lost their functionality, once they did not find financial sources in the private sector for funding their research activities.

The institutions responsible for the creation of capabilities are not sufficient to fulfill the demand for qualification. The quality of education in the country, virtually in all its dimensions, is a problem, even if isles of excellence exist. In some cases, even those students that persist until completing basic education do not accumulate human capital enough and do not qualify [to the labor market]. The vast heterogeneity of the education system (basic and higher) both reflects and reproduces the vicious cycle of exclusion. The unequal regional distribution of institutions and the structural persistence of inequality strongly affect the processes of innovation and technological development.

The role of the State in the Brazilian Innovation System has been crucial for the formation of a scientific and technological infrastructure as well as for the industrialization of the country. In recent years, particularly from 1999 on, the federal government has assumed a pro-innovation stand by designing and implementing a specific policy for promoting innovation. The explicit innovation policy adopted in the period of 1999–2002 was restricted to the Ministry of Science and Technology, and was opposed to the macroeconomic policy then in force. Only after 2003 this policy is incorporated by other Ministries, particularly by the Ministry of Development, Industry and Foreign Trade.

Although this policy has targeted the enterprise, its evaluation suggests that the mechanisms and instruments created for promoting innovation within enterprises have some characteristics that hinder the advance of NSI. Among them, stand out:

1. a bias toward technological innovation, prioritizing the mechanisms for support to research and development, to the detriment of other important innovative activities—thus ignoring (or neglecting) the heterogeneity of the production structure, which entails distinct levels of capacity;

2. a focus on the relations of partnership between enterprises and scientific and technological institutions, what makes difficult the integration of the other agents participating in the innovation process.
3. implementing forms still based on a linear model of innovation.

More recently, new changes occur in the policy, modifying its governance structure, through new guidelines, and with the election of priority sectors and areas, although keeping the instruments and mechanisms, but proposing a connection between them. The establishment of goals for this new policy indicates a progress, once in the former policy there were practically no short term goals.

From the perspective of the implicit innovation policy, the conclusion is that the linear vision hinders the liaison between the explicit policy and the other policies. Particularly in the Brazilian case, three implicit policies are noteworthy: the macroeconomic, the educational, and that of social development. The analysis demonstrates that the need for integration surpasses the matter of "taking advantage of opportunities." Nonintegration became an obstacle to the explicit policy of innovation, preventing, or hindering the accomplishment of outcomes and hence the social and economic development of the country.

References

Albuquerque EM (2007) Inadequacy of technology and innovation systems at the periphery. Camb J Econ 31:669–690

Arroio ACM (2007) Development, innovation and public policy: the Brazilian experience in support of micro and small enterprise. Research Paper 03/07. Rio de Janeiro. http://brics.redesist.ie.ufrj.br/

Belluzzo LG, Carneiro R (2003) Globalização e Integração Perversa, Política Econômica em Foco, n 1–maio/ago

Bound K (2008) Brazil the natural knowledge economy. Demos, London

Brasil (1990) Ministério da Economia, Fazenda e Planejamento. Política industrial e de comércio exterior.

Cassiolato JE (1981) 'Notas sobre a evolução da idéia de planejamento e política científica e tecnológica na América Latina, Texto para Discussão Interna, No. 02/81, CET/CNPq, Brasilia

Cassiolato JE (1992) The role of user-producer relations in innovation and diffusion of new technologies: lessons from Brazil. Thesis submitted for the Degree of Philosophy Doctor. The University of Sussex. Science Policy Research Unit, England

Cassiolato JE (1999) A Economia do conhecimento e as novas políticas industriais e tecnológicas. In: Lastres HMM, Albagli S (org.) (eds) Informação e Globalização na Era do Conhecimento. Campus, Rio de Janeiro

Cassiolato JE (2007) The Brazilian System of Innovation: policy challenges. Position Paper prepared for the InterAmerican Development Bank. IDB, Washington, US

Cassiolato JE (2010) Evolution and Dynamics of the Brazilian National System of Innovation, Paper to be presented at the Research Dialogue on Emerging economies in the new world order: promises, pitfalls and priorities, Indian Council for Research on International Economic Relations – ICRIER, New Delhi 11-12/04/201

Cassiolato JE, Lastres HMM (1999) Inovação, globalização e as novas políticas de desenvolvimento industrial e tecnológico. In: Cassiolato J, Lastres H (eds) Globalização & Inovação Localizada Experiências de Sistemas Locais no Mercosul. IBICT/MCT, Brasília

Cassiolato JE, Lastres HMM (2005) Sistemas de Inovação e Desenvolvimento-as implicações de política. São Paulo Perspec 19:34–45
Cassiolato J, Lastres H (2008) Discussing innovation and development: converging points between the Latin American school and the innovation system perspective? GLOBELICS working paper series, n. 08–02
Cassiolato J, Rapini M (2004) University-Industry interactions in developing countries: an investigation based on Brazilian data. Paper presented at second Globelics Conference, Beijing, 16–20 October 2004
Cassiolato JE, Villaschi A, Campos RR (2003) Local productive and innovative systems in Brazil: a policy perspective. In: Cassiolato JE, Lastres HMM, Maciel ML (eds) Systems of innovation and development: evidence from Brazil. Edward Elgar, Northampton
Cassiolato JE, Britto JN, Vargas MA (2005) Arranjos Cooperativos e Inovação na Indústria Brasileira. Chap. 13, In: Inovações, Padrões Tecnológicos e Desempenho das Firmas Industriais Brasileiras. Instituto de Pesquisa Econômica Aplicada—IPEA, Ministério do Planejamento
Cassiolato J, Bittencourt P, Rapini M (2007a) A relação Universidade-Industria no Sistema Nacional de Inovação Brasileiro: uma Síntese do Debate e Perspectivas Recentes. Research Paper 11/07. http://brics.redesist.ie.ufrj.br/†
Cassiolato JE, Zucoloto G, Elias LA (2007b) Avaliação Econômica da Produção de Medicamentos Anti-Retrovirais no Brasil: Uma Abordagem Sistêmica,United Nations Development Programme, Brasília
Cassiolato J, Soares MC, Lastres HMM (2008) Innovation in unequal societies: how can it contribute to improve equality? Seminario Internacional Ciencia, Tecnología, Innovación e Inclusión Social, UNESCO, Montevideo, mayo 2008
Cassiolato JE, Lastres HMM, Soares MMC (2014) The Brazilian national system of innovation: challenges to sustainability and inclusive development. In: Dutrénit, G., Sutz, J (eds) National innovation systems, social inclusion and development: The Latin American experience, Edward Elgar, Cheltenham
Cgee (2008) Características do emprego formal no ano de 2004 das pessoas que obtiveram título de doutorado no Brasil no período 1996–2003. Centro de Gestão e Estudos Estratégicos, Brasília
Cohen W, Levinthal D (1990) Absorptive capacity: a new perspective on learning and innovation. Admin Sci Quart 35 (1)
Coutinho LG (2005) Regimes macroeconômicos e estratégias de negócio: uma política industrial alternativa para o Brasil no século XXI. In: Lastres HMM, Cassiolato JE, Arroio A (eds) Conhecimento, Sistemas de Inovação e Desenvolvimento. Editora UFRJ/Contraponto, Rio de Janeiro
Dantas M (2007) A tragédia da educação pública no Brasil. http://brics.redesist.ie.ufrj.br
Elias LA (2004) Transferência de tecnologia: indicadores recentes sobre a indústria farmacêutica. Apresentado em 10 Anos do Trips: DEMOCRATIZAÇÃO DO ACESSO À SAÚDE. São Paulo, March 2004
Erber FS, Cassiolato J (1997) Política industrial: teoria e prática no Brasil e na OCDE. Revista de Economia Política 17(2):66
Freeman C (1987) Technology policy and economic performance: lessons from Japan. Pinter, London
Freeman C (1998) Japan, a new system of innovation. In: Dosi G, Freeman C, Nelson R et al (eds) Technical change and economic theory. Pinter, London, pp 330–348
Gonçalves R (2006) Desestabilização macroeconômica e dominação do capital financeiro no Brasil. In. Basualdo, E, Arceo, E. Neoliberalismo y sectores dominantes. CLACSO, Buenos Aires
Guimarães E (1996) A Experiência Recente da Política Industrial no Brasil: Uma Avaliação. Textos para Discussão, n 409. IPEA, Brasília
IBGE—Instituto Brasileiro de Geografia e Estatística (2006) Pesquisa Industrial Anual. Rio de Janeiro RJ, Brasil [s.n.]

IBGE/PNAD (2006) Primeiras Análises, demografia, educação, trabalho, previdência, desigualdade de renda e pobreza, IPEA, Brasília, setembro (2007) Disponível em. http://www.ibge.gov.br/home/estatistica/populacao/trabalhoerendimento/pnad2006†
Lundvall B-A (ed) (1992) National systems of innovation: towards a theory of innovation and interactive learning. Pinter, London
Mello J, Maculan A, Renault T (2008) Brazilian Universities and their contribuition to innovation and development. Research Policy Institute, UniDev Discussion Paper Series Paper, n 6
Neri M, Buchmann G (2007) Monitoramento das metas educacionais de Dakar. Estudo de casa do Brasil (2000–2005) para o global monitoring da UNESCO
PINTEC (2003) Pesquisa Industrial de Inovação Tecnológica 1998–2000. Instituto Brasileiro de Geografia e Estatística—IBGE. Rio de Janeiro
PINTEC (2005) Pesquisa Industrial de Inovação Tecnológica 2001–2003. Instituto Brasileiro de Geografia e Estatística—IBGE. Rio de Janeiro
PINTEC (2007) Pesquisa Industrial de Inovação Tecnológica 2003–2005. Instituto Brasileiro de Geografia e Estatística—IBGE. Rio de Janeiro
Rapini SM (2004) Interação Universidade-indústria no Brasil: Uma Análise exploratória a partir do diretório dos Grupos de Pesquisas do CNPq. Dissertação de Mestrado. Instituto de Economia. UFRJ
Serra J (1982) Ciclos e mudanças estruturais na economia brasileira do após-guerra. Revista de Economia Política 2 (2):5–45
Silva F (1971) A evolução das funções do governo e a expansão do setor público brasileiro. Pesquisa e Planejamento Econômico, vol 1, n 2, pp 235–282
Suzigan W et al (1974) Crescimento industrial no Brasil: incentivos e desempenho recente. *Relatório de Pesquisa*, No. 26, Instituto de Pesquisa Econômica e Aplicada, Rio de Janeiro
Suzigan W, Albuquerque EM (2008) A interação entre universidades e empresas em perspectiva histórica no Brasil. Texto para discussão, n 329, março de 2008
Suzigan W, Furtado J (2006) Política Industrial e Desenvolvimento. In Revista de Economia Política, vol 26, n 2, abr.-jun
Velho L (2007) Formação de mestres e doutores e sistema de inovação, NT 27, BRICS Project, RedeSist, IE/UFRJ, Rio de Janeiro, Brazil
Velloso J (2004) Mestres e doutores no país: destinos profissionais e políticas de pós- graduação. Cadernos de Pesquisa 34:583–611
Zucoloto GF, Toneto R Jr (2005) Esforço tecnológico da indústria de transformação brasileira: uma comparação com países selecionados. Rev Econ Contemp Rio Jan 9(2):337–365

Chapter 12
An Evaluation of Indigenous Innovation Policy in China

Xielin Liu and Cheng Peng

12.1 Introduction

In most economies, the free market is regarded as the best system for allocating innovation resources. Any government action would distort natural market operations (Bremmer 2010), and private enterprises are the main actors in an innovation system. The government works only in areas where the market has failed. The most developed country, the USA, either does not trust the government or understates the role of the government in industry. The case of high-definition television (HDTV) in Europe and Japan provides a good example in this regard. The strong government intervention in HDTV resulted in long-term damaging effects (Pelkmans and Beuter 1987). However, several economists hold that the visible hands, that is, the nation or state, can play a very important role in the country's competitiveness (List 1928). This principle has been adapted in developing or catching-up countries, where champion companies are picked as the main actor to finish the national responsibility. The rise of Japan, Korea, Singapore and Taiwan, more or less, was all closely related to the intervention by the government in industry (Freeman 1987; Okimoto 1989).

In recent years, there has been a trend to see the science and technology (S&T) and innovation policy from the demand side, and public procurement policy thus has been revitalised. The trend can be seen from the European Barcelona Target for R&D/GDP to reach 3 % (European Commission 2003) and the Aho Report (European Commission 2006). Ahrens (2010) proposed that government procurement

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can contribute to innovation by focusing on market signaling, de-risking R&D, bridging the finance gap, and stimulating demand.

China is a unique country with a legacy of planned economy. The global financial crisis gave the Chinese government a reason to take a more aggressive role in supporting innovation. The national strategy of indigenous innovation was developed in 2006 as a result of the "National Programming 2006–2020 for the Development of Science and Technology in the Medium and Long Term" in 2006. The goal of the new national programme is to make China an innovative country by implementing an indigenous innovation strategy. Following this strategy, China has been continuously increasing R&D expenditure even in periods of financial crisis. In 2010, R&D/GDP reached the highest level in China by 1.76 %, while it was only 0.6 % in 1996. During the same period, some developed countries stagnated or cut their R&D and education investment following the financial crises. China is regarded as the next science and technology or innovation superpower in many papers and reports (for example, Chesbrough 2010; Sigurdson and Jiang 2005).

China is a mixed economy with the market as a basic force and the government as a supporting agency to lead innovation. The reasons for such strong government support are two: Chinese companies are weak in innovation capability in an open economy and the government has the power to mobilise nation-wide resources to develop key technology. Some even argue that it is necessary to use a nation-planned system (*juguotizhi*) to develop next-generation technology in China (Mei 2009), that is, let the state have overwhelming power to implement innovation. Thus, there is a tendency to go back to using a planned economic system as the basic institution for innovation in China after the national strategy of indigenous innovation.

The direct action of innovation policy in China is to use national S&T programmes to push government research organisations, universities and state-owned enterprises (SOEs) or private companies to innovate, the latest area being mega projects. The indirect actions are tax subsidies and policies to induce companies to innovate. However, the inputs and outputs of innovation at the business level are the result of multiple factors. Thus, it is not easy to evaluate the real effects of government policy from other factors. Since this ambitious programme has been going on for 5 years, it would be interesting to monitor its progress from an academic perspective.

There are several papers on national innovation systems (Nelson 1993) and reports on China's innovation system and innovation policy (Liu and White 2001; Lundvall et al. 2006; Motohashi and Yun 2007; OECD 2008). For example, OECD has just published a review of Chinese innovation policy; it suggests that China needs more bottom-up decision making, giving private sectors a more important role and ensuring greater co-ordination among agencies to promote innovation (OECD 2008).

This chapter will try to answer the following questions: Can the national strategy of indigenous innovation work in an effective way to enhance enterprises' capability of innovation? In particular, do SOEs or private enterprises benefit more from the new national strategy? Is a national innovation system with a strong government more efficient than one with a market-driven innovation system?

The chapter has five sections. After introduction, Sect. 2 gives the background on indigenous innovation. In the third section, analysis of how the government implements the policy is done. The fourth section sees how enterprises respond to the policy. The final section presents the discussion and conclusions.

12.2 Background of Indigenous Innovation in China

China is one of the fastest growing economies in the world. After 30 years of open market and reform, China has already established a unique economic and enterprise system. This system proves to be very effective for mobilising resources for economic performance. Before the implementation of the indigenous innovation policy, the Chinese economy had more than 20 years of high economic growth (Fig. 12.1). The GDP per capita reached a level of more than US$ 5420 in 2011 (Fig. 12.2).

However, it seems that innovation capability has not developed in parallel. For example, China's economic growth has been strongly dependent on foreign technology and foreign direct investment (FDI). Poor innovation capability at the industrial level results in a situation where China's economy is still cost-driven and limits profit margins, trapped by intellectual property rights (IPR) and high royalty fees for licensing technology. In particular, China relies heavily on foreign technology supply in key industries, such as chips, software, machine tools and engines. Thus, how the Chinese innovation system can be made more productive and integrative is a major challenge for the future of China.

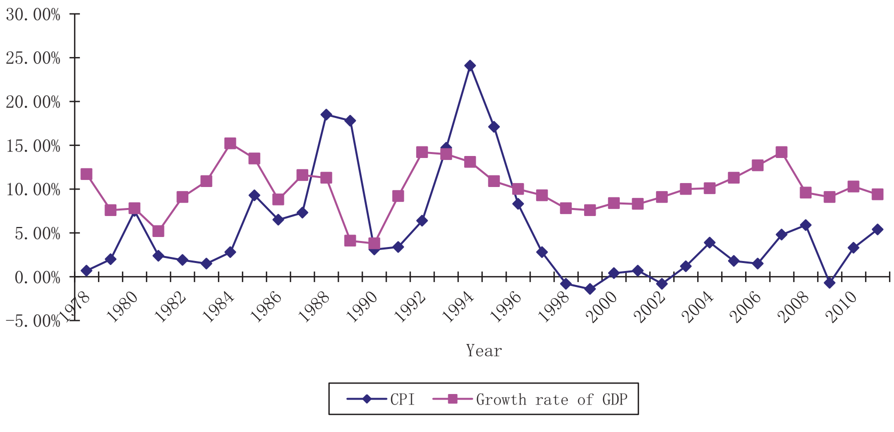

Fig. 12.1 GDP growth in China (1978–2011). (Source: Online database of Nation Bureau of Statistics of China. http://www.stats.gov.cn/). Note: *CPI* is consumer price index

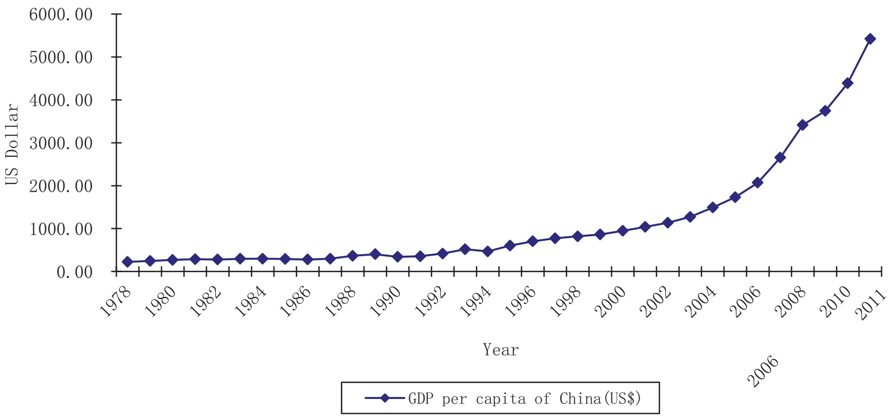

Fig. 12.2 GDP per capita of China (1978–2011). (Source: Online database of Nation Bureau of Statistics of China. http://www.stats.gov.cn/)

Against the background of the dilemmas of rapid economic growth but lack of innovation capability, opening up but lack of domestic innovation, targeting sustainable development but short of natural resources, the Chinese authorities launched a new movement called indigenous innovation at the beginning of the 21st century. The strategic goal of the indigenous innovation policy for 2020 is to solidly improve the capability of S&T to promote economic and social development, to master leading-edge industrial technology and decrease the reliance on foreign technology, to promote the enterprises from cost driven to innovation driven, and to make China one of the most innovative countries in the world (State Council of China 2006). The year of 2006 was a turning point for China as the government started to implement the long-range S&T development program.

However, there are many deep-rooted challenges ahead of China to become an innovative country. First, the economic growth of China has been strongly dependent on foreign technology and foreign-invested firms. Since 2000, foreign-invested enterprises accounted for more than 85 % of all hi-tech exports (NBS 2006a). In recent years, there has been increasing frustration among government officials and experts, because the 'market for technology' policy has not resulted in the immediate and automatic knowledge and technology spillovers from abroad to Chinese enterprises that policymakers had hoped for.

Second, driven by their cost advantage, Chinese companies made products for the world, but got a limited profit margin. At the same time, they are poor in innovation performance and have to pay high royalties as IPR to multinationals. Chinese companies have been granted a limited number of patents in the USA. In 2010, only 3303 patents were granted to China, whereas Korea had 12,508 patents (Table 12.1). Hence, innovations from domestic knowledge bases and IPR are badly needed in China.

Third, the high growth rate of the Chinese economy during the past 30 years will not be sustainable without a change in the development strategy. China needs,

Table 12.1 Patents granted in the USA. (Source: Online database of United States Patent and Trademark Office. http://www.uspto.gov)

Year	China	Japan	Korea	Taiwan
1997	66	24,191	1965	2597
1998	88	32,118	3362	3805
1999	99	32,514	3679	4526
2000	161	32,922	3472	5806
2001	265	34,890	3763	6545
2002	390	36,339	4009	6730
2003	424	37,248	4132	6676
2004	596	37,032	4671	7207
2005	565	31,834	4591	5993
2006	970	39,411	6509	7920
2007	1235	35,941	7264	7491
2008	1874	36,679	8730	7779
2009	2270	38,066	9566	7781
2010	3303	46,978	12,508	9635

for example, more energy-efficient and environment-friendly technologies, new management skills and new organisational practices to ensure sustainable growth in the near future.

The above concerns pushed the Chinese government to strengthen indigenous innovation. The strategy sends a strong message that the government should bounce back to lead the innovation process in China, and not trust that FDI can automatically give the Chinese industry technological progress as expected.

The specific goals are to increase R&D expenditure per GDP to a level of 2 % in 2010 and 2.5 % by 2020; to make S&T and innovation the most important enabling factor for GDP growth, contributing about 60 % of GDP growth; to decrease the dependence on foreign technology to less than 30 % (the ratio of expenditure from technology import to R&D expenditure was estimated at 56 % in 2004); and, finally, to be among the top five worldwide in terms of the number of domestic invention patents granted, and the number of international citations of scientific papers (State Council of China 2006).

There are generally four types of policy instruments for innovation: public procurement, regulation, research institutions/research universities and finally, public R&D subsidies (Aschhoff and Sofka 2009). Each has its advantages and limitations. In China, systematic policies are selected to fulfill the indigenous innovation strategy; the core is research consortia and public procurement.

First, since GDP growth is projected to increase at the same pace, increasing R&D expenditure as a share of GDP implies a huge increase in absolute terms. Second, fiscal policy to activate innovation capability at the company level is assumed to be the most important policy tool. Third, it will use standard setting and IPR as new policy tools to promote innovation. In fact, it was the indigenous innovation strategy that saved TD-SCDMA[1], the 3G standard for telecommunication, from uncertain conditions. Fourth, the Chinese government selected 16 mega S&T projects to promote the goal of national innovation. These projects are expected to help China master the core technology for strategic industries. It includes the general CPU, large airplanes, new broad wireless mobile telecommunications, nuclear stations, new drugs and moon landing. Here, leading SOEs have been given the main responsibility for the mega projects. Fifth, a new tax policy will make R&D expenditure 150 % tax deductible, thus effectively constituting a net subsidy, as well as accelerated depreciation for R&D equipment worth up to US$ 40,000. Last, the new policy has given public procurement of technology an important way to promote indigenous innovation in China. This policy is the result of learning from best practices in the USA and Korea. Public procurement in China today is significant, but the policy tool itself is relatively new to China. The original purpose of the practice of public procurement was to cut costs rather than promote indigenous innovation. Under the new policy, government agencies have to prioritise innovative Chinese companies by procuring their goods or services even if these are not as good or cheap as those of other companies (both Chinese and abroad). In this new policy, the government sets priority for indigenous innovative products in public procurement (State Council of China 2006).

Looking back on the system of indigenous innovation policy, it reflects a turning point for policy-making in China or for innovation systems in China. First, the policy packages have more ideas that are demand driven. Second, it intends to push innovation in a more systematic way, from R&D to product manufacturing, formation of supply chain and early market incubation. Third, the innovation policy has been upgraded to an economic policy that is higher than the traditional S&T policy. Fourth, the government used indigenous innovation to balance domestic demand and export orientation, domestic innovation capability and the acquisition of external technology. Finally, the government once again picked up SOEs to be the champions of innovation.

12.3 How did the Government Help Enterprises After 2006?

The role of SOEs and private companies in China is always a hot topic in China. To favour the role of SOEs in China has been the persistent effort of the government. The government strategy for SOEs is to merge them as far as possible. Thus, the number of SOEs in China is decreasing but their market power is increasing. Even in Schumpeter's era, he thought large enterprises would have more capability to innovate. As for monopoly and innovation, Schumpeter argued that an *ex-ante* oligopolistic market structure and the possession of *ex-ante* market power favoured

[1] Time division synchronous code division multiple access (TD-SCDMA) is an air interface found in UMTS mobile telecommunications networks in China.

innovation (Schumpeter 1942). However, the Chinese SOE is a unique company. Chinese SOEs are very large and very powerful in the market, but their motivation for innovation is quite low for three main reasons: the CEOs of the companies are most times treated as government officials, who can easily move from the SOE to a government agency, and so they do not care about the company's sustainability. Second, innovation is very risky, and they are unwilling to take risks. Third, they have many constraints on their operations; for example, they cannot give their senior scientists and engineers stock options as many private companies do (Mei 2009).

In the 1990s, China underwent the transition from a planned economy to a market economy. At that time, SOEs controlled 82.8 % of the economy. Although the output value of SOEs as a proportion of GDP is decreasing, their power is expanding. SOEs hold the dominant position in resource monopoly industries, and they are concentrated in the petrochemical, power, national defence, communications, transportation, mining, metallurgy and machinery industries. From our analysis, we found that though the market power of SOEs is increasing, they also control banks, oil, electricity, railroads, telecommunications, etc. For example, they control 55 % of the electricity supply, 89 % of the automobile industry and 70 % of electric generation equipment (Xinhuanet 2008a). Meanwhile, the expansion speed of foreign capital enterprise is rapid, especially in the manufacture of ICT, transport equipment and electrical machinery. The changing trends of different ownership enterprises also show that non-state-owned enterprises have a certain status in the competitive market, but are still weaker than SOEs and foreign enterprises. From Fig. 12.3, the average industrial output value of different ownership enterprises in China changed in 2010 compared to 2002, and the average output of SOEs reached US$ 232 million, ranking first. Over the past 8 years, the number of SOEs dropped, but the enterprise size expanded.

From Table 12.2, it is clear that though all companies in China have a low willingness to spend money on R&D, domestic companies are better than foreign

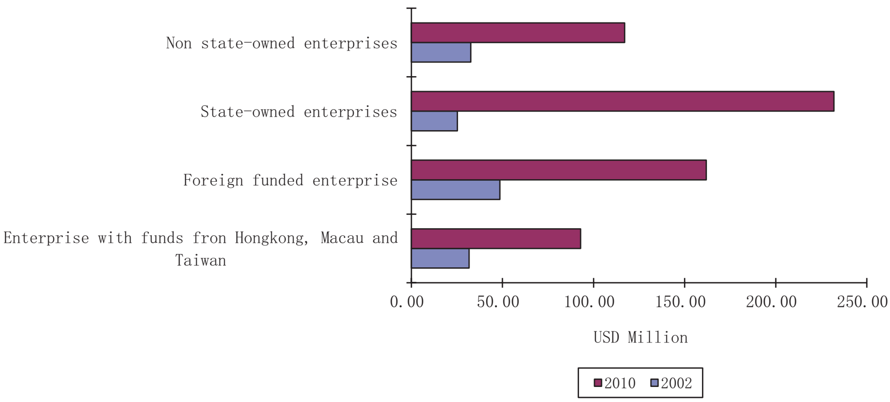

Fig. 12.3 Average industrial output value of different ownership enterprises in China (2002 and 2010). (Source: China S&T Statistical Yearbook 2003 and 2011)

Table 12.2 R&D/sales in different ownership of enterprises in 1998–2010 (%). (Source: Calculated from China S&T statistical yearbook)

	SOE	Companies based in Hong Kong, Macau and Taiwan	Foreign joint ventures	Wholly foreign-owned enterprises	Private enterprises
1998	0.6	0.1	0.4	–	0.4
2004	1.27	0.87	1.15	0.73	0.67
2010	0.71	0.78	0.81	0.60	0.66

companies, and SOEs are better than private companies. But the most innovative and competitive companies are those with private ownership, such as Lenovo, Huawei, Haier and ZTE. Though an increasing number of giant SOEs were entered in Fortune 500 in those years, their innovation capability is still low compared to similar companies in Fortune 500.

Compared with 2004, research and development (R&D) with various ownerships of enterprises in China declined in 2010, especially for foreign-invested enterprises. This phenomenon demonstrates that the growth rate of R&D investment is too slow to keep up with that of sales; apart from that, enterprises are reluctant to focus on R&D. However, the R&D strength of Chinese private enterprises in the past 5 years has not shrunk, reflecting that private enterprise R&D input is consistent with its growth rate for sales. The ability to conduct research and development is an enhancing symbol for private enterprises.

The indigenous innovation policy learned from history that enterprise plays a very important role in innovation. Without their involvement, by merely giving money to universities and research institutes, efficiency will be very low. Thus, the enterprise-led innovation system was proposed a long time ago, but in reality, as university and research institutes have stronger lobbying capabilities than enterprises, most national R&D projects go to them. In the new policy paradigm, most mega projects have used research consortia, in which enterprises played a more important role. For example, in the mega project 'High Performance of Digital Machine Tools', the co-ordinator is the Ministry of Industry and Information, while the main participants are Beijing First Machine Tool Group, Jinan Second Machine Tool Group, China Second Group of Heavy Machine, Xian Jiaotong University and China Academy of Machinery Science and Technology[2]. The role of enterprises in this research consortium is dominant.

From different sources of information, it seems that SOEs are the leading actors in most research consortia and mega projects. At the time, several private companies also joined the network and played a complementary role in the industry. This is typical for high-speed train projects. Thousands of SMEs join the project team as suppliers of parts. By this sub-contracting, private SMEs also made great technological progress.

[2] http://www.most.gov.cn/yw/201009/t20100928_82413.htm.

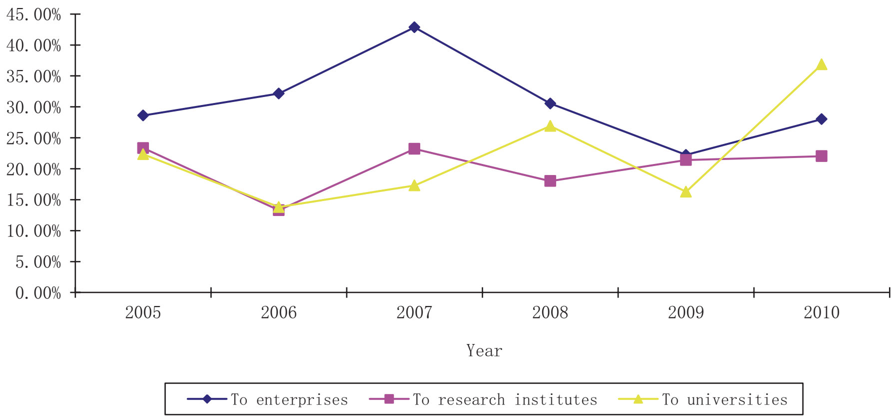

Fig. 12.4 Growth rate of government R&D investment to enterprises, research institutes and universities (2005–2010). (Source: China S&T Statistical Yearbook 2006–2011)

From 2005 to 2010, the government's R&D investment maintained a high growth rate (Fig. 12.4), but the growth rate for the government providing money to universities is higher than for government funding to research institutes and enterprises after 2009. In 2010, the growth rate of government R&D subsidies for universities was 38.86 %; but for government research institutes and enterprises it was 22.02 and 28.02 %, respectively. This means that after the indigenous innovation policy, enterprises got more direct subsidy from the government than in the past, which fits the policy goal of indigenous innovation: more support on industrial key technology. However, universities got more support from the government in nearly 2 years. One key question of this change is: can increasing government R&D expenditure promote enterprise investment in R&D and innovation?

Indigenous innovation has been implemented with packages of strategies and policies. The key policy tool is a government-led research consortia system around industry ecology.

The research consortia policy is not the invention of developing countries. It used to be an important innovation policy in Japan and the USA in the 1980s. By using the tool, the Ministry of International Trade and Industry of Japan (MITI) succeeded in forming effective research consortia (many leading companies, university and government research labs) to catch up with technology in the electronics industry (Okimoto 1989). But there were many failures in other sectors, such as in the computer industry. Thus, this kind of policy was stopped later.

In the USA, David (1991) used the terminology of "general purpose technology (GPT)". He argues that it can give rise to noticeably 'hot' areas for private research, if public policy planners can target some GPTs. In the IT industry in the 1980s, the federal government played the role of funding basic research and the defence sector purchased the products as a large user; these helped IT become a powerful industry around the world, but in other areas it failed.

12.4 How do Enterprises Respond to Indigenous Innovation?

Though the government aggressively promoted indigenous innovation by adding new policies and new resources, the most important criteria for testing the policy is how the enterprises respond to them. Here, invisible hands are effective. For general enterprises, innovation is an economic term rather than a political one. Innovation has to be related with economic benefits.

First, enterprises have to balance indigenous innovation and open innovation. The choice depends on which can give them the competiveness or benefits. However, as it is difficult to get a direct subsidy from the government and only a few companies can manage to do so, several companies still make their decision on R&D, which means that considerable Chinese enterprises directly purchase ready-made technology from abroad; for example, most Chinese car companies entrust car design to an Italian automobile design company. Some leading companies such as Huawei explicitly stated that they would choose open innovation rather than a full indigenous strategy (21st Economic Report Daily 2009).

Second, the data show that the Chinese now spend more money on R&D than on imported technology. This is an important indicator that Chinese companies now care to master the imported technology rather than to merely expand production capability based on technology importation. From Fig. 12.5, we can see that different kinds of enterprises have different ratios of expenditure on technological assimilation. The ratio of foreign-funded enterprises is higher than that of domestic enterprises; non-state-owned enterprises are higher than SOEs and SOEs are the lowest. The average level of this proportion of SOE was 0.15:1 in 2010. Foreign-invested enterprises account for 2.64:1, enterprises invested in by Hong Kong, Macau and Taiwan for 0.64:1 and non-state-owned enterprises for 0.62:1. This proportion of SOEs has been stable in recent years. In general, the ratio of SOEs is still low, while that of foreign-funded enterprises is rising rapidly.

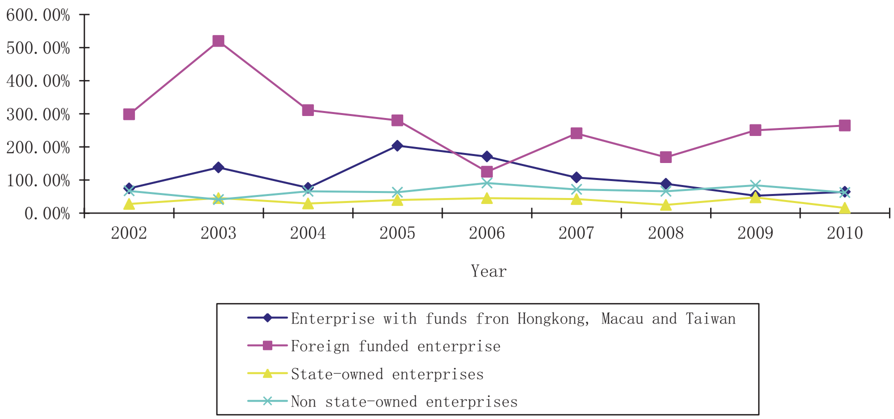

Fig. 12.5 Ratio of expenditure on assimilation to import of technology in different ownership enterprises. (Source: MOST and NBS, China S&T Statistical Yearbook 2003–2011)

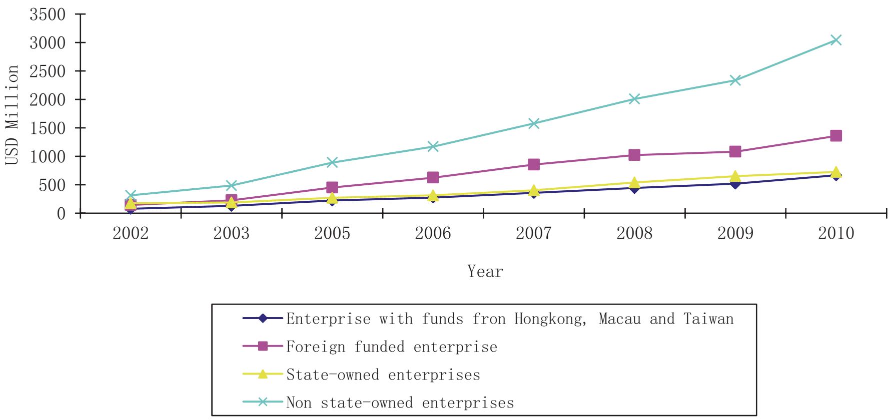

Fig. 12.6 Total industrial output value of different ownership enterprises (large and medium-sized) in China (2002–2010). (Source: China S&T Statistical Yearbook 2003–2011)

Third, private enterprises that operate in competitive markets have been leading in capability building in innovation. We will analyse the innovation inputs in different ownership of enterprises by number of scientists and engineers, R&D expenditure and the performance of their R&D labs. We focused on foreign, Hong Kong, Macau & Taiwan (HMT), state-owned and non-state-owned enterprises. It should be noted that SOEs include state-ownership holding enterprises, state joint ownership enterprises and state sole-funded corporations. The rest of the domestic enterprises are called non-SOE, including joint stock companies and private enterprises, etc.

From 2002 to 2010, the total industrial output value of different ownership enterprises changed in China. The non-SOEs not only firmly occupy the first position, but also their industrial output value (US$ 3042.19 billion in 2010) can be compared to foreign-invested enterprises (US$ 1359.07 billion in 2010). SOEs fell to third place in 2010, and their total output value was US$ 726.19 billion in 2010 (Fig. 12.6).

12.4.1 Human Resources in R&D

The scientists and engineers in a company are their main inventors, but high wages and good R&D infrastructure are required to retain them. Thus, whether a company is innovative, in some sense, depends on how many inventors work for them. Usually in China, only large SOEs can hold a high number of scientists and engineers. However, from Fig. 12.7, we can see that there is an obvious trend: the absolute number of scientists and engineers in SOEs is declining to the level in 2008. We found that the share of scientists and engineers in non-SOEs in total enterprises increased sharply from 49.5 % in 2002 to 62.7 % in 2008. The absolute number of scientists and engineers hired by non-SOEs with funds from Hong Kong, Macau, and Taiwan and by foreign-funded enterprises has increased.

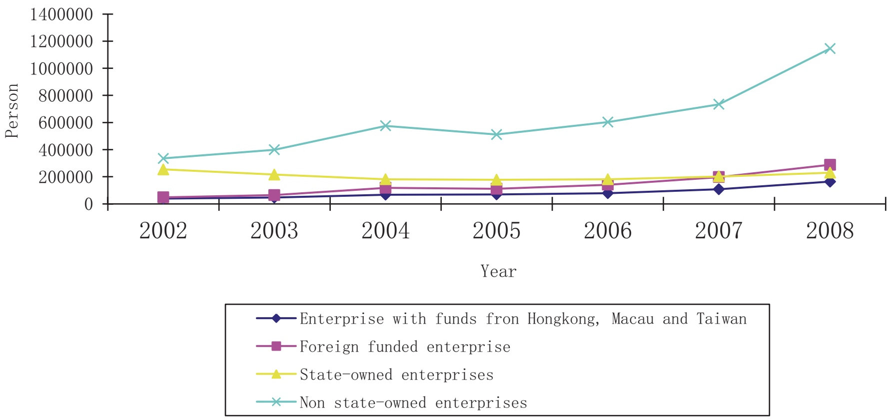

Fig. 12.7 Number of scientists and engineers in different ownership enterprises. (Source: China S&T Statistical Yearbook 2003–2009)

Thus, though SOEs have strong support from the government, their pool of R&D human resources seems to have been declining before 2005, while non–SOEs and foreign-related enterprises have steadily increased their R&D human resources. This trend shows us that: (a) a situation—the redistribution of innovation resources—has begun to emerge in China; and (b) the original policy suitable for SOE innovation is not entirely applicable to non-state-owned enterprises.

12.4.2 R&D Funding

R&D funding is a more direct indicator of enterprise efforts at innovation. From Fig. 12.8, after 2003, all forms of enterprises have been accelerating their R&D

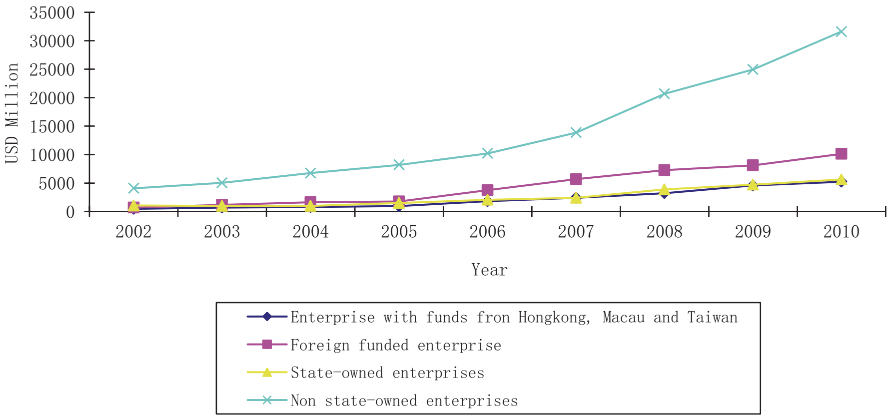

Fig. 12.8 Amount of R&D in different ownership enterprises. (Source: China S&T Statistical Yearbook 2003–2011)

expenditures. By 2010, SOEs accounted for 10.7 %, while non-SOEs accounted for 64.7 % in 2002 and 60.1 % in 2010.

12.4.3 R&D Labs

The number of R&D labs in enterprises is another important indicator of innovation capability. From Fig. 12.9, we can see that an increasing number of non-SOEs have set up their own R&D labs. The ratio of firms which have R&D labs in non-SOEs in 2010 reached 74.9 %, while the number of research institutes owned by SOEs continues to decrease, accounting for only 5.0 %. We can observe a parallel trend in private enterprises including foreign companies in China that have been continuously spending money on their R&D labs as shown in Fig. 12.10.

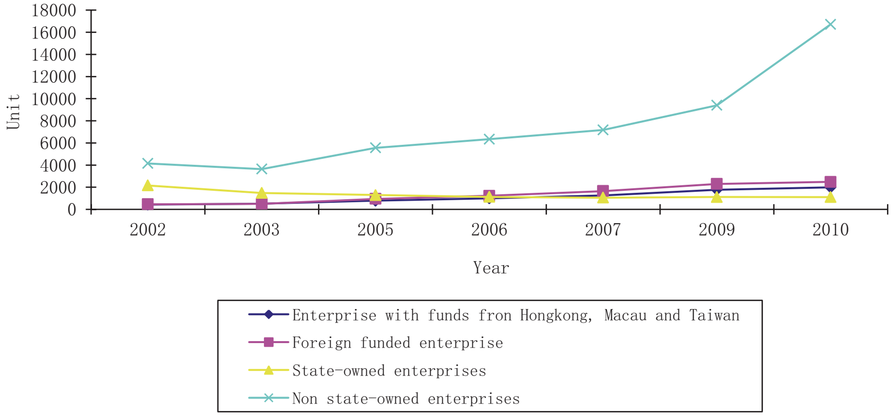

Fig. 12.9 Number of research institutions in different ownership enterprises. (Source: China S&T Statistical Yearbook 2003–2011)

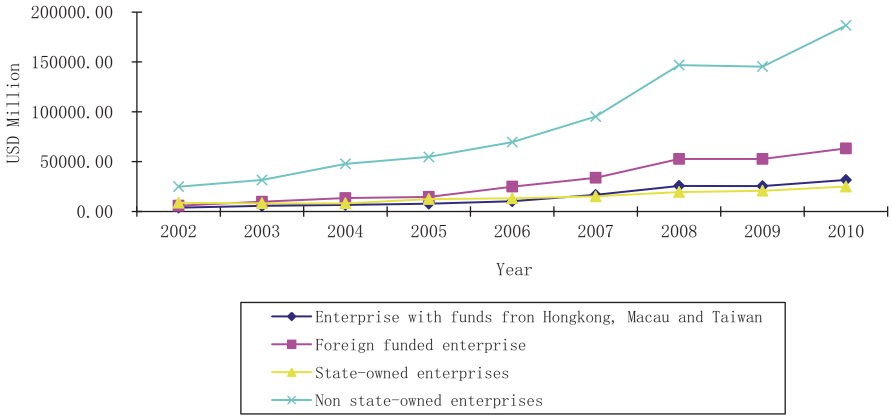

Fig. 12.10 Funding for R&D labs in different ownership enterprises. (Source: China S&T Statistical Yearbook 2003–2011)

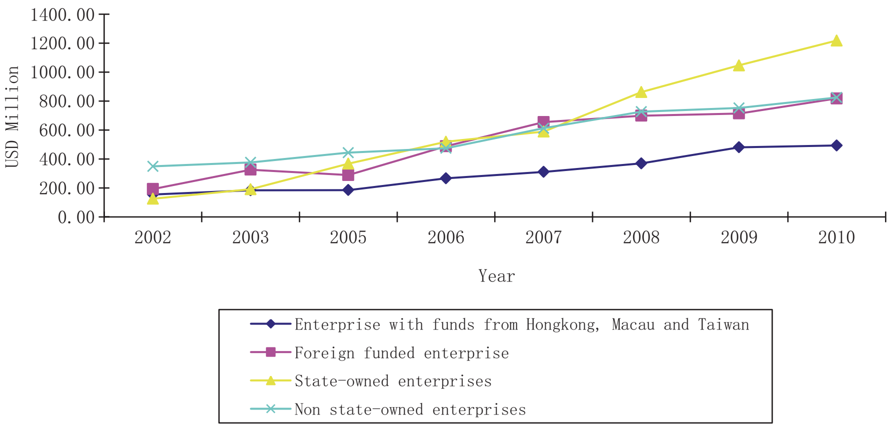

Fig. 12.11 Average amount of funding of every institution of different ownership enterprises. (Source: China S&T Statistical Yearbook 2003–2011)

Since 2002, the number of scientific research institutions of SOEs has continued to decline except in 2004. From Fig. 12.9, the growth curve of other ownership enterprises is similar; one possible reason is that other ownership enterprises have a similar perception of acquiring innovation resources. We think that the similar perception comes from the competitive market.

A phenomenon is that, although the number of labs in SOEs is declining, the funding for science and technology institutions has seen a growth (Fig. 12.10). In particular, the funding amount for R&D institutions of enterprises with funds from Hong Kong, Macau and Taiwan was at the same level as that for SOEs in 2010. The past view that Hong Kong-, Macau- and Taiwan-invested enterprises set up factories in China only to take advantage of China's cheap labour has changed. It is a prevalent trend that Hong Kong, Macau and Taiwan-invested enterprises have set up more R&D labs after 2007, and MNCs have set up 1160 R&D institutions in China (Xinhuanet 2008b).

From the above four aspects, in absolute value there has been a trend of large scientific and technological innovation resources flow to non-SOEs. SOEs have continued to decline in their proportion of innovative resources.

In the average amount of R&D expenditure of every institution of different ownership enterprises, SOEs rank first, followed by non-SOEs and foreign-invested enterprises. Hong Kong-, Macau- and Taiwan-invested enterprises stayed at the lowest level before 2010 as shown in Fig. 12.11.

12.4.4 Innovation Performance of Different Ownership of Business

We use the number of patent applications and the value of new product development as indicators of innovation performance. According to the number of patents granted in the USA, it is amazing to see that China increased rapidly after 2005 and narrowed the gap with Korea and Japan. It shows that the innovation capability of Chinese companies has been increasing after the implementation of the indigenous policy (Fig. 12.12).

The data shows that the number of non-SOE applications for patents is rapidly catching up. It really helps to improve innovation ability by increasing innovation resources for non-SOEs (Fig. 12.13).

According to the input-output analysis of technological innovation (Gross Value of New Products/Expenditures on New Product Development), the indigenous innovation of SOEs is inefficient. Their output dropped immediately, while spurting in 2009. Foreign-invested enterprises have more resources for innovation and innovation output will be more and efficient. Though private organisations had relatively

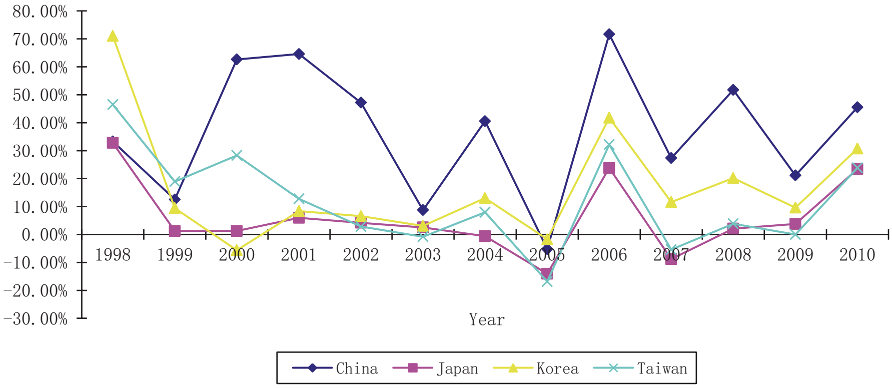

Fig. 12.12 Annual growth rate of patents granted in the USA to China, Japan, Korea and Taiwan. (Source: Online database of the United States patent and trademark office. http://www.patft.uspto.gov)

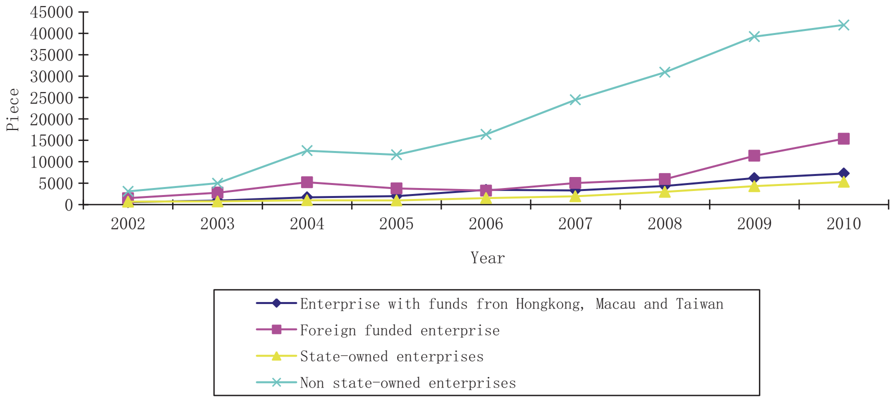

Fig. 12.13 Number of invention patent applications of different ownership enterprises. (Source: China S&T Statistical Yearbook 2003–2011)

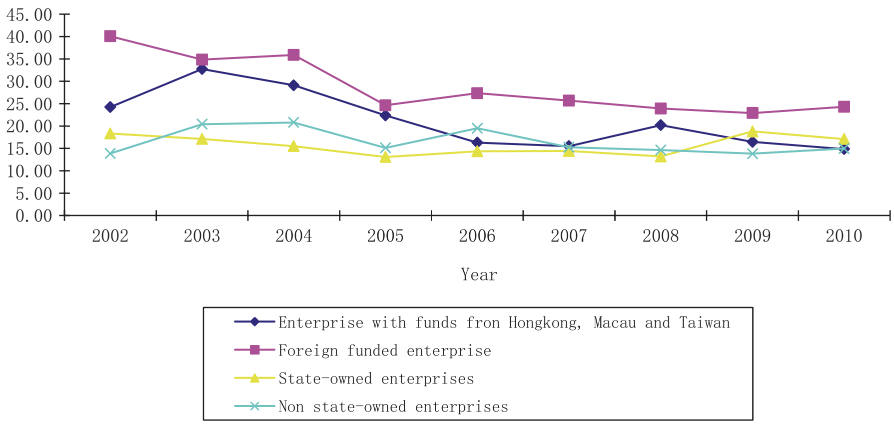

Fig. 12.14 Gross value of new products/expenditures on new product development. (Source: China S&T Statistical Yearbook 2003–2011)

fewer resources for innovation, simply from the number of invention patents and new product development it can be seen that their innovation output is higher than that of SOEs. It is obvious that their innovation efficiency is also higher than that of the SOEs (Fig. 12.14).

12.5 Discussion and Conclusion

After the indigenous innovation strategy, the government of China has used a more market demand-driven policy, and not just policies pushing technology. SOEs have been given a more important role in China, and have played a key role in several mega projects and research consortia.

It is true that after this kind of policy, leading SOEs are becoming more powerful in critical industries, but contrary to our expectations we find that, in China, private companies have accumulated more innovation capability than the SOEs in the past 5 years. Thus, though the Chinese government is very powerful, the real pushing power for innovation is the invisible hand.

We can say that in China, the basic mechanism for innovation is the market mechanism, but a new kind of innovation system in China is emerging. The old national innovation system has government, research institutes and university and SOEs as the major actors. This system failed in some ways, as the SOEs did not have any incentive for innovation, such as in the auto industry and the chip industry. The new one has different recipes for the system: central government, research institutes and universities, regional governments, SOEs, private enterprises and foreign-related enterprises. The key player is private companies. They are the final consumer of most of the R&D done in universities that are supported by the government. They are also the primary consumer of knowledge spill-overs from multinationals in China.

However, based on our findings, Chinese efforts for indigenous innovation must face the challenge of how to build a global innovation network. The challenge is: can a large domestic market alone ensure that indigenous innovation works in China? We found this to be true in some industries, such as the high-speed train sector. Here, the demand is clear. The money for the project is huge and the government-led consortia worked. The fastest bullet train has now been developed in China (Chen 2010). But in most competitive industries, this kind of strategy is very limited in its potential. The large airplane project is an example of this. The C919 aircraft is the product that Chinese companies are using to compete with Boeing and Airbus, but the orders are all from domestic SOEs. Though the domestic aircraft market is the largest in the world, can just the domestic market guarantee the critical mass necessary for final success? A government-led research consortia regime will reach its limit and open innovation is required to progress beyond those limits. Government protection that is too strong may trap companies in the domestic market.

In conclusion, the package of indigenous innovation policy is constructive and efficient for a catch-up economy with clear industry targets for innovation. For China to be an innovative country, it needs to give market competition more space to incubate and eventually yield radical innovation. At the same time, for the indigenous innovation policy to succeed, China should make its policies more open than they used to be. A completely inward-facing domestic market cannot give domestic companies the space they need to be globally innovative companies. Chinese enterprises cannot close themselves off from the global technology system. Only open innovation can give Chinese companies the possibility to win the next wave of innovation in the world and make China an innovative country.

References

21st Economic Report Daily (2009) Huawei will not innovate in a narrow indigenous sense. 12 May

Ahrens N (2010) Innovation and the visible hand. Carnegie Papers

Aschhoff B, Sofka W (2009) Innovation on demand: can public procurement drive market success of innovations? Res Policy 38:1235–1247

Bremmer I (2010) The end of the free market. Portfolio, Penguin Group, New York

Chen X (31 May 2010) The fastest train in the world being developed in China. China Quality Daily

Chesbrough H (2010) China, innovation superpower: how to deal with it. Forbes. http://www.forbes.com/2010/11/11/china-innovation-globalization-leadership-managing-strategy

David P (1991) Computer and dynamo: the modern productivity paradox in a not-too-distant mirror. In: OECD (ed) Technology and productivity: the challenge for economic policy. Organisation for Economic Co-operation and Development, Paris

European Commission (2003) Research investment action plan. European Commission, Brussels

European Commission (2006) Creating an innovative Europe, Expert group led by Mr. Aho. Brussels. European Commission, Brussels

Freeman C (1987) Technology policy and economic performance: lessons from Japan. Pinter, London

List F (1928) The national system of political economy (Translated by Sampson S. Lloyd). Longmans Green, London

Liu XL, White S (2001) Comparing innovation systems: a framework and application to China's transitional context. Res Policy 30:1091–1114

Lundvall B-A, Intarakumnerd P, Vang J (2006) Asia's innovation system in transition. Edward Elgar, Cheltenham

Mei Y (2009) Interview on nation-planned S&T system. The First Financing Journal (in Chinese), 7 Sept

Motohashi K, Yun X (2007) China's innovation system reform and growing industry and science linkages. Res Policy 36:1251–1260

Nelson R (ed) (1993) National innovation systems: a comparative analysis. Oxford University Press, Oxford

OECD (2008) OECD reviews innovation policy: China. OECD, Paris

Okimoto DI (1989) Between MITI and the market. Stanford University Press, Stanford

Pelkmans J, Beuter R (1987) Standardization and competitiveness, private and public strategies in the E.C. color TV industry. In: Gabel HL (ed) Product standardization and competitive strategy. North-Holland, Amsterdam, pp 29–46

Schumpeter JA (1942) Capitalism, socialism, and democracy. Harper, New York

Sigurdson J, Jiang J (2005) Technological superpower China. Edward Elgar, Cheltenham

State Council of China (2006) Some complementary policy for national long and middle–range S&T programming for 2006–2020. 27 Feb

Xinhuanet (2008a) More than 80 % of central SOEs in utility sector of China. http://news.xinhuanet.com/fortune/2008–08/25/content_9708312.htm

Xinhuanet (2008b) About 1160 R&D labs were set up by multinationals in China. http://news.xinhuanet.com/newscenter/2008–02/09/content_7583212.htm

Chapter 13
Technological and Institutional Change: India's Development Trajectory in an Innovation Systems Framework

Rajeswari S. Raina

> *... the linkages in industrialization in developing countries depend in fact less on technologically determined input-output relationships than on the characteristics of their economic systems which determine who takes the relevant investment and production decisions, how the incomes generated in the process are distributed, and what patterns of demand grow as a result.*
> *(Raj 1975, p. 113)*

13.1 Introduction

India faces a development paradox today. Service sector-led rapid economic growth co-exists with agrarian crisis and low industrial growth rates with limited employment opportunities. There is increasing policy attention on innovation for economic growth. Be it in the establishment of the National Innovation Council (NIC), or efforts to promote innovation in specific sectors like electronics, or the creation of innovation funds, or grassroots innovation promoted by the National Innovation Foundation (NIF), there is an active national effort to promote innovation. The expectation is that innovation will lead to economic growth and get the country out of the current impasse of jobless growth, rural poverty, and distress. With increasing investments in production and technology generation, the national innovation strategy seems to focus on technological change, mainly capital-intensive and export-oriented production technologies. How is this different from the past strategies for economic growth and technology choices made for the same? It is known that an

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obsession with innovation will entail a move from national systems of production to national systems of knowledge creation and learning (Lundvall and Maskell 2010). This chapter asks if India can make this transition to a national system of knowledge creation and learning to ensure rural employment, incomes, and reduction of inequality. It makes a case for institutional reform; new norms or institutions that govern innovation system components, that go way beyond planning and decision-making that merely enable incremental changes in existing production investments and technological capacities.

This chapter explores India's development trajectory, using the innovation systems framework as a lens. The innovation systems framework tells us that innovation—the generation, access to, and utilization of knowledge towards socially progressive and economically profitable ends—happens only when both technological and institutional changes occur, and when several actors with shared interests, competencies, and causal understanding are linked to work together. In particular, we ask how institutions, "the characteristics of economic systems" (see quote above), the overarching rules or norms that shape economic decisions and technological choices were considered in the past. The chapter presents the institutions that govern production investments and technological capacities in agriculture and industry. These are the two sectors that are critical to production and consumption opportunities for India's massive rural population; a structural reality that distinguishes the Indian economy and innovation therein from other developing countries.

There is no single rigid definition of the national innovation system (NIS). The plethora of definitions available allows each country to shape its own NIS, with its historical and cultural specificities, especially those specific to its intellectual and skill base (Niosi 2002). The NIS literature was built with reference to the innovation behavior of firms or clusters thereof, within a sector, a region, or a nation-state. Though the term NIS was first used by Freeman (1987), it was contributions from Nelson (1993) and Lundvall (1992) that established the two different (yet overlapping) innovation system discourses that we see today. The first (Nelson 1993) draws from the legacy of development economics where formal organized scientific knowledge is a major driver of innovation; it focuses on S&T-based, national empirical evidence of innovation. In the second (Lundvall 1992), the thematic discourse is about interactions and learning, cumulative knowledge, structural and functional capabilities in the national and global space. Though not drawing exclusively upon the social construction of technology or actor–network theories, this second broader definition of innovation systems seeks interdisciplinary explanations of innovation and gives due credence to institutions or the rules and norms that govern the actors. The narrow (S&T based) and broad (interaction and learning based) approaches to NIS have, however, not confronted each other. They enjoy a "peaceful co-existence" (Edquist and Hommen 2008) with few attempts to bridge or reconcile their differences. For India's NIS, a reconciliation between these two approaches is important given the overarching institutions or norms of development that govern both S&T actors and the development sectors (agriculture and industry) critical to rural poverty.

This chapter contextualizes and explores the S&T actors and other drivers of innovation in its major development sectors, focusing on the institutions or norms that

Table 13.1 Institutions, capital, and their mutual relationships in NIS. (Source: Adapted from Table 1.2 in Lundvall et al. 2009, p. 18)

	Easier to produce, Reproduce or use	Not easy to produce or reproduce
Tangible resources	Production capital	Natural capital
Intangible resources	Knowledge capital	Social capital

Lundvall et al. note that knowledge capital is not easy to reproduce; but it is easier to reproduce than social or natural capital. It becomes useful or effective only when combined with the other dimensions of capital, as indicated by the arrows here.

govern the technological capacities and the relationship between these capacities and the production activities.

Development sectors are endogenous to the NIS, being shaped by the interactions and learning processes that take place. In particular (Table 13.1), the nature of interactions or learning processes, the relationship between knowledge (formal organized S&T in the first narrow definition of NIS) and production, natural and social capital are governed by a set of norms or institutions. Being relatively easier to reproduce (compared to natural and social capital), knowledge and production capital have been the preferred dimensions of capital that the state (in developed and developing countries) has planned for and invested in. Though these are explicitly evident as production investments and technological capacities, the norms or institutions that govern them are often not explicit. Little attention is given to the ways in which the intangible drivers of knowledge and technology shape the production investments, social and natural capital (Table 13.1). These institutions that govern innovation—the relationship between production investments and technological capacities are the focus of this chapter.

In their analysis of the NIS in the USA, Mowery and Rosenberg (1993) refer to the antitrust laws or statutes and the military R&D investment and procurement as two overarching rules that shape the innovation system and performance of the actors. Similar institutionally determined linkages shaped Brazilian industrial growth and the contribution of innovation to this growth. A national strategy to attract investments in iron and steel predisposes the creation of a laid-back innovation system. "Industries producing homogenous products such as steel, non ferrous metals and other standard inputs for the industrial system do not rely on innovation of products to compete or generate market power…" (Raj 1975, p. 116, citing Furtado 1973). The rules or habits that govern how actors work and interact are the key drivers of a NIS; the emphasis is on the distinction between organizations or actors and the institutions that govern them and set the ground for their actions and interactions (Edquist 1997; Nelson and Winter 1982).

Institutions, recently re-discovered as "the 'deep' determinants of development," are the variables and processes that "shape the proximate determinants of growth: factor accumulation, technology adoption, and policy choices" (Adam and Dercon 2009, p. 174; Commission on Growth and Development 2008; Rodrik et al. 2004). An innovation system has several components: an enabling policy framework, appropriate knowledge and technology generation and flows, availability and access to a range of intermediary services, investment and capacities for production, and sustained demand and dynamic consumption. The institutions or norms that govern these key components, the major actors like the state, the S&T or research and teaching organizations like the university, the service actors like banks, traders, transport, or extension agencies, the production units of firms and farms, and the consumers or the demand actors, are central to understanding how these actors perform to enable innovation. Thereby innovation for economic development depends on these institutions or rules; on "how" production and technological capacities are created in the key sectors of the economy, and "how" people participate in and gain from these capacities. The overall institutional infrastructure plays a major role in the ways in which investment in production capacities are made, which in turn influences the ways in which technological capacities are generated and realized (Cimoli and Porcile 2009). There is no single prescribed causal relationship between these production investments and technological capacities. In fact, the relationship depends on the institutions that determine who takes the relevant investment and production decisions, how incomes generated and thus, are distributed, and the nature of demand that grows as a result; these are more crucial for industrialization or any production process than technology choice (Raj 1975).

This chapter begins with the current phenomenon of jobless economic growth in India (Sect. 2). Compared to other developing countries, the economy is growing rapidly. But there is still a massive section of the population in rural India that is excluded from mainstream economic growth, with limited employment opportunities in agriculture, industry, and even in the rural nonfarm sector. An overview of formal S&T (the knowledge capital enabled by the state) and the agricultural and industrial production decisions and investments made in the economy is provided in Sect. 3. Despite the employment rhetoric, policy frameworks and programs, production investments, and technological capacities have focused less on labour-intensive and more on export-oriented capital-intensive growth. Even within the S&T or formal technology generation component, the focus has been on high-tech capital intensive technologies. With production and technological capacities sidelining labour-intensive production and knowledge systems, the economy evidently has not been able to achieve the structural transformation achieved by many other emerging economies. Given the innovation systems discourse about interactions and learning, the co-evolution of technological and institutional change, we question the overarching institutions and norms that shape production and knowledge capital (Table 13.1 here), and their mutual relationships. In particular (Sect. 4), the norms or assumptions that govern agriculture in order to mobilize rural labour and capital surpluses (commodities) to feed into industrial growth, and the norms of techno-centric interindustry linkages based on developed country experiences contradict the institutional realities and structural features of the economy. They preclude the expected learning capacities of the NIS. Section 5 presents a summary and asks whether India will enable institutional understanding among its innovation system components and changes in its NIS, to ensure relevant production and consumption opportunities for the massive rural population. Most importantly, to confront the widening rift between the structural infirmities and technological capacities, and enable a national system of knowledge creation and learning that can evolve with the changing development demands, which are increasingly about sustainable and resilient production, distribution, and consumption systems.

13.2 Background—India's Development Paradox

For many developing countries, the mid-twentieth century was a period of major choices. They were all dependent on agriculture, both in terms of share of the sector in GDP and in employment. The development experiences of the west—though devastated by war, the resurgence of industrial growth in Japan and Germany, and the civilized industrial landscape of the USA, UK, and France—were evident and emulated with enthusiasm. The developing countries were then characterized by poverty, slow GDP growth rates (the Hindu rate of growth, as it was known in India), very high population growth rates, massive dependence on agriculture, low levels and pace of industrialization, high rates of unemployment, and inequality. Investments were made in modern agriculture and industrialization to ensure increased production, economic growth, and development outcomes.

Today, in the emerging economies (the then-developing countries), poverty, unemployment, and income inequality are still high. While the rate of population growth has stabilized (at least in some countries), the rates of GDP growth have been spectacular (especially in China, India, Brazil, and South Africa), and the pace of industrialization has picked up. With the least value added per worker in agriculture, India, China, and Thailand continue to host massive sections of their populations in the sector and maintain a relatively low capitalization of agriculture compared to the other countries (Table 13.2). By the end of the 1970s or early

Table 13.2 India is rural and agrarian among emerging economies. (Source: World Bank (WDI) various years)

Emerging economies	Share of agriculture in GDP (%)		Agriculture- value added per worker (constant US$ 2000)		Share of industry in GDP (%)		Rural population in total population (%)	
	1980	2010	1980	2009	1980	2010	1980	2010
Argentina	6	10	6615	9987	41	31	17	8
Brazil	11	6	1179	3760	44	27	33	14
China	30	10	191	525	48	47	80	55
Egypt	18	14	1366	3024	37	38	56	57
India	36	19	313	468	25	26	77	70
Malaysia	23	11	2791	6544	41	44	58	28
Mexico	9	4	2247	3231	34	34	34	22
South Africa	6	3	2012	3641	48	31	52	38
Thailand	23	12	399	725	29	45	73	66

1980s, many of the developing countries (including China, Egypt, and Mexico) had begun to garner a third or more of their GDP from industry; this did not happen in India. By 2010, the Asian economies did increase the share of their industrial sector in GDP (Latin America faced a decline). But India lags far behind Malaysia, China, and Thailand in the size and pace of industrialization. Among all the emerging economies, India is evidently rural in its economic and demographic profile. Today all the other emerging economies have achieved the rural transformation they planned for in the 1950s.

By the turn of the century, over 60 % of India's workforce was employed in agriculture (less than 2 % in developed countries, 44 % in China, and 21 % in Brazil) and the country was home to the largest number of undernourished people and malnourished children anywhere in the world (FAO 2006; UNICEF 2008). Though poverty had declined overall (Dev and Ravi 2007), the rates of decline in poverty were the lowest during the 1990s than ever before, with an increase in economic inequality in all its dimensions (Sen and Himanshu 2007). There was conclusive evidence that the percentage of India's population counted as below the poverty line (BPL) has decreased (Gangopadhyay et al. 2010). But the majority in rural India still lived in poverty, and interstate as well as intrastate inequality had increased (Dev and Ravi 2007; Gangopadhyay et al. 2010).

The theoretically expected shrinking of the primary sector in the economy has happened—down from 50 % of GDP in 1950–1951 to 15 % in 2009–2010. But the decline in the share of agriculture in national GDP and in employment (about −50 and −12 %) has not been commensurate (Fig. 13.1). In the context of (i) the nature of and relative increase in share of national income and employment in the sec-

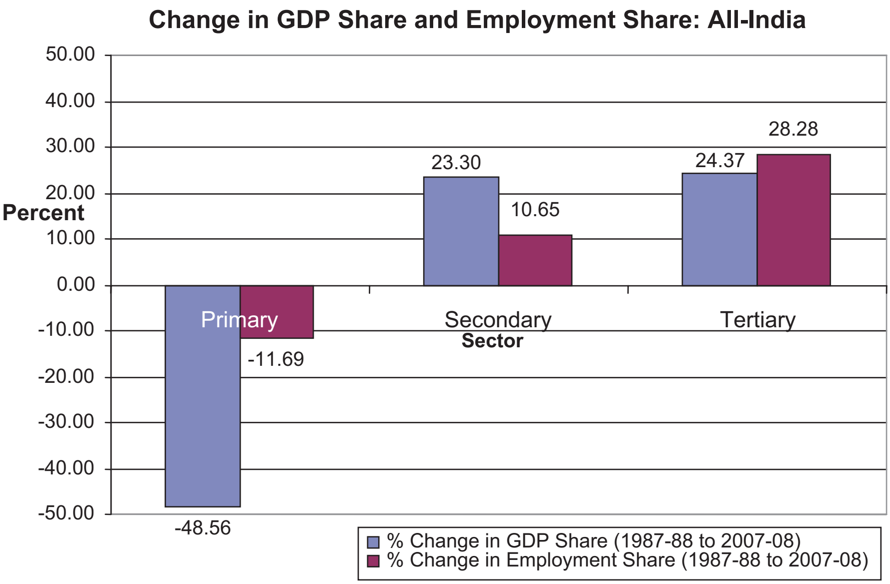

Fig. 13.1 Patterns of change in employment and incomes. (Source: Estimated from Ministry of Finance 2011 and CSO data)

ondary and tertiary sectors, and (ii) the increasing number of (young) unemployed people in rural areas, especially the increasingly marginal and small operational holdings (84 % of all operational holdings) in agriculture that often survive on family labour on and off-farm, the structural change and rural employment questions are rather intimidating. The tertiary sector seems to have done better in employment growth rates and share in the national GDP. Industrial growth seems to have added little to employment.

The disconnect between industrial growth and the overall employment scenario draws specific attention to the rural context, the location of 70 % of India's population and almost the same proportion of India's poor, who are mostly un- and under-employed (Dev and Evenson 2003; Lanjouw and Murgai 2009).[1] By virtue of its sheer magnitude and in its diverse roles as production, demand and intermediary components of the NIS, the rural population and livelihoods are critical to break the prevalent structural constraints. In the context of rapid economic growth and increasing inequality, many recommendations have been made to enable investment in and capacities for production and technological change in agriculture and rural industry.

13.3 Investing in Innovation for Development

The limits imposed by the structural features would ideally have been factored into the investment and design of formal knowledge (S&T) capacities and in sector-specific production capacities in agriculture and industry. In this section, we find that both aggregate demand and labour-intensive industrialization have been constrained and severely impeded by the nature of production investments and technological capacities that the state has enabled.

13.3.1 Investing in Knowledge for Innovation

In contemporary economic history, India's successful green revolution and the not-so-successful industrial growth have both received attention in terms of the technological capacities generated and used. The state has played a major role in enabling innovation through formally organized knowledge/technology generation, technology development, incubation and transfer initiatives (extension), and through a range of schemes or programs designed to incentivize or support technology

[1] There are recommendations to use the advantage that India has already built in the IT sector to enable higher productivity in agriculture and the rural non-farm sector (Singh, 2008), to invest in rural industrialisation or rural non-farm sector employment (Das 2010; Nayyar and Sharma 2005), and to enhance public support for agricultural growth as the key driver of economic growth in the country (Balakrishnan 2010). But few question the reasons for the disconnect between industrial and agricultural-rural growth, or the nature and content of technology-based investment decisions made. Solutions that alter or modify existing technological–institutional arrangements are seldom discussed.

adoption or market-oriented production. Though domestic private and global public and private sector investment in Indian S&T are increasing, the state and its public sector research organizations play a major role in setting the direction and pace of technology generation.

The formal S&T system in India has seven major components: (i) central government S&T departments (numbering nine)[2], (ii) other central government ministries (socio-economic sectors), (iii) state government departments or councils, (iv) private corporate R&D organisations, (v) central and state universities and centres of excellence, (vi) independent research institutes, and (vii) non-government organisations or community-based organisations. Though these organisations have grown in number and personnel, the R&D intensity in the country (measured as Gross Expenditure on R&D to total GDP) remains 0.8 %, way below the levels evident in developed countries (3.3 % in Japan, 2.6 % in the USA, and 1.9 % in the EU) and China, at 1.42 % (Mani 2010; Mathieu and van Pottelsbergh 2008; World Bank 2011). The promise to increase the R&D intensity to 2 % by the end of the Tenth Five-Year Plan (2006) remains a dream.

Among the nine components of public S&T, the Central S&T agencies (i) and (ii) above account for almost all of public sector S&T expenditure in the country (Table 13.3). Together, the research expenditure on defense, atomic energy, and space consistently account for over 60 % of the total central government S&T expenditure. While this reveals a certain priority in the S&T establishment and the government, the fact that public sector R&D has contributed little to civilian use or development ends in general, and that little of the state-supported S&T and university research outputs are taken up by industry is a matter of concern (Mani 2010). Overall, the S&T capacities have been centralized (including the modes of planning for and organizing S&T) with central agencies receiving much of the funding and support (Table 13.3). The National S&T Management Information Systems (NSTMIS) survey estimates that the Central S&T agencies account for 62 % share of the total national S&T, with the state governments, higher education and public sector units accounting for 8.5, 4.2 and 5 %, respectively, and the rest, about 20 %, coming from private and civil society organizations (DST 2009). While S&T investments by State Governments and UTs has picked up since the VI Five Year Plan (Table 13.3), their share in the national S&T expenditure remains miniscule.

Much of the recent innovation investment as well as new organizations and institutional arrangements (be it patenting, insurance, or legal guarantees) have gone into high-tech industries (specifically in IT, biotechnology, chemical, and electronics), and some have come with specific foreign investment in production and R&D. It is important to see that, among developing or emerging economies, the relative share of high-tech exports in total industrial exports was more or less the same across the

[2] The nine organizations, the Departments of Science and Technology (DST), Atomic Energy (DAE), Space (DoS), Biotechnology (DBT), the Defence Research and Development Organisation (DRDO), the Department of Scientific and Industrial Research, the Ministry of Earth Sciences (with its own R&D institutes) and the two Councils for Medical Research (ICMR) and Agricultural Research (ICAR) under their respective ministries, account for roughly 60 % of the national S&T expenditure.

Table 13.3 S&T Expenditure in India: a profile (Rs. crore and %). (Source: Estimated from Planning Commission, various years)

S. No.	Dept./Agency	Fifth plan	Sixth plan	Seventh plan	Eighth plan	Ninth plan	Tenth plan	Eleventh plan
		1974–1979	1980–1985	1985–1990	1992–1997	1997–2002	2002–2007	2007–2012
		Exp.	Exp.	Exp.	Exp.	Exp.	Exp.	Outlay
1	Central S&T Agencies/Deptts	384.51	990.16	2589.14	6125.64	12067.88	23641.26	66580.08
2	S&T in Socio-economic Sectors	308.65	989.66	2408.14	8275.49	9742.39	N.A.	N.A.
3	S&T in the States/UTs and NEC	0.00	36.39	89.25	158.70	483.82	1543.60	1886.92
4	Total S&T	693.16	2016.21	5086.53	14559.83	22294.09	25184.68	68467.00
5	*Total Public Sector*	*39426.20*	*109291.70*	*221850.20*	*485457.30*	*813997.80*	*1255783.77*	*3644718.0*
6	Total S&T as % of Total Public Sector	1.76	1.84	2.29	3.00	2.74	2.01	1.88
7	Central S&T Agencies as % of Total Public Sector	0.98	0.91	1.17	1.26	1.48	1.88	1.83
8	S&T in Socio-economic Sectors as % of Total Public Sector	0.78	0.91	1.09	1.70	1.20	N.A.	N.A.
9	S&T in States as % of Total Public Sector	–	0.03	0.04	0.03	0.06	0.12	0.05
10	*Total Central Sector*	*18755.00*	*57825.20*	*130394.82*	*288930.00*	*457583.30*	*638327.00*	*2156571.0*
11	Central S&T Agencies as % of Total Central Sector	2.05	1.71	1.99	2.12	2.64	3.70	3.09
12	S&T in Socio-economic Sectors as % of Total Central Sector	1.65	1.71	1.85	2.86	2.13	N.A.	N.A.
13	*Total State Sector*	*20671.00*	*51466.50*	*91455.38*	*196527.20*	*356414.50*	*450446.77*	*1488147.0*
14	S&T in States as % of Total State Sector	–	0.07	0.10	0.08	0.14	0.34	0.13

Table 13.4 India's S&T strengths among emerging economies: evidence in the economy. (Source: World Bank, WDI, various years)

Emerging economies	R&D expenditure as % of GDP 2007	High-tech exports as % of total manufacturing exports		Exports of goods and services as % of GDP	
		1992	2010	1990	2010
Argentina	0.5	8.0	7.5	10	22
Brazil	1.1	4.9	11.2	8	11
China	1.4	6.4	27.5	16	30
Egypt	0.2	0.4[b]	0.9	20	21
India	0.8	4.0	7.2	7	22
Malaysia	0.6[a]	38.9	44.5	75	97
Mexico	0.4	11.2	16.9	19	30
South Africa	0.9	7.0	4.3	24	26
Thailand	0.2	22.0	24.0	34	71

[a] data for 2006; [b] data for 1994

board (Malaysia and Thailand with their early-bird IT catches being the only exceptions) about two decades ago (Table 13.4). The massive increase in high-tech shares to total industrial exports made by some countries (nearly 28 % in China compared to 7 % in India) also reflects a relative increase of high-tech or knowledge-intensive production in total domestic production and relative structural transformation (See Table 13.2). Integration of these economies and their production capacities with the global economy is much higher today than it was two decades ago. While the Malaysian and Thai economies seem to survive almost entirely on exports of goods and services (as high as 97 and 75 %, respectively, of the total GDP), India figures with China, Mexico, South Africa, Argentina, and Egypt as economies showing a significant increase in exports (Table 13.4). All these countries witnessed massive increases in domestic and foreign investment in S&T in manufacturing and service sectors since the 1990s. Structural change in these countries—even in China—ensured that these technological investments and corresponding institutional changes led to increased employment in industrial and service sectors. Common to all, however, is the increasing inequality in their domestic economy, with skilled labour gaining significantly more than unskilled rural labour from all the technological capacities developed in or transferred to these economies.

13.4 Investing in Agricultural Production and Technology

In this section, we explore how the state invested in modern agriculture, in particular, the ways in which irrigation, chemicals, and high-yielding varieties of major cereals ushered in a new relationship between production investments and technological capacities.

All the public and private sector components established since the mid/late 1960s, mandated to produce more cereals to ensure food security, continue to exist and receive state patronage.[3] The components of the modern agricultural innovation system (AIS) include a massive public policy and administrative component, a highly diverse production or enterprise component ranging from 410 million individuals (cultivators, main and marginal workers in agriculture), industrial and service sector organizations (fertilizers/chemicals, agri-machinery, banking, transport, etc.), a diverse and complex network of intermediary actors (extension workers in line departments, market agents and co-operatives), a strong public sector (and some private sector) research and technology generation component, and a large population of consumers (mainly rural and unskilled) constituting the demand component.

An overarching state directive for production investments has been the key feature of India's AIS, right from the early postindependence phase (Balakrishnan 2010). India's planners had indeed given specific attention to agriculture in their capital goods investments, with massive investments in irrigation and fertiliser industry (see Mahalanobis 1958; Sivaraman 1991). It was however, in the 1960s, the green revolution period, that output price policy, disbursement of modern inputs and capital formation became integral to state intervention. With technological options shaping production investments, it was irrigation that accounted for almost all the public sector capital formation (Fan et al. 2000; Vaidyanathan 2007). Rice and wheat gained the most from these forms of policy and administrative support (Barker and Herdt 1985; Rao and Gulati 1994), the unique convergence of technological and production capacities.

In the mid-1960s, the state decided that a central line of authority and control was necessary to generate technologies for the green revolution (Raina 2011). Technological capacities have grown steadily since. The recent lament of the state that the research system focuses on irrigation-chemical-based technologies with little concern for environmental impacts (Planning Commission 2008), and the evident technology fatigue (Ministry of Finance 2010; Swaminathan 2005) attracted policy attention, and with it increasing accusations of weak agricultural extension. During 1990–2009, the formal knowledge generation (agricultural research) component received less than 0.4 % of agricultural GDP (Fig. 13.2 above), while the subsidy for inputs ranged from 8–11 % of agricultural GDP (RBI and CAG, various years). Even with the gross input subsidy accounting for 88 % of the total plan outlay for agriculture, irrigation, and rural development put together in 2006–2007 (Vaidyanathan,

[3] The agricultural innovation system, as designed and put in place during this period—1950s to 1970s—must be seen in the context of the national concern for food security. The Central Government enabled institutional innovations with various levels of physical and financial capital investments in new public sector organizations like Food Corporation of India, and the National Seeds Corporation. Land reform, wage parity, and agricultural employment were the demands of rural India that were left to the state governments to plan, enact, and implement. Minimum Support Price, subsidies, credit (including loan waivers every now and then), irrigation and electricity costs/subsidies, and procurement prices and processes (especially for rice and wheat) became key issues addressed by the central government and large farmer lobbies (Raina 2011).

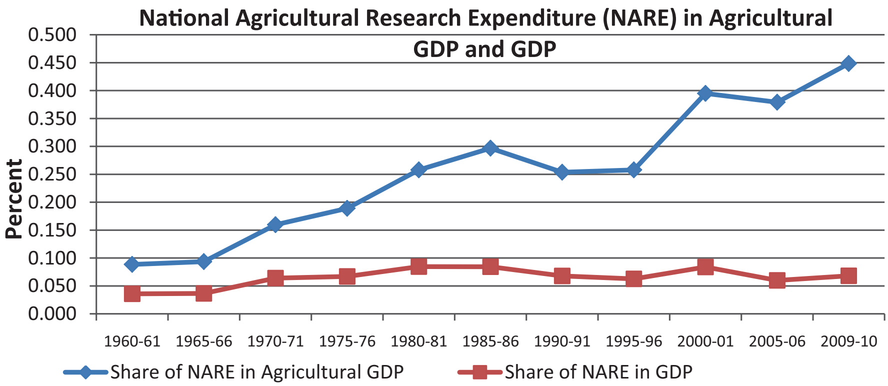

Fig. 13.2 Limited investment in agricultural research. (Source: Estimated from CAG and CSO (various years), based on share of research in total agricultural research and education expenditure. (From Rajeswari 1995 and Raina 2012))

2010), there is significant stagnation in production growth rates in the irrigated rice-wheat systems—the main users of these subsidized inputs thus far (Bhalla and Singh 2010; Government of India 2008). Having invested in a particular kind of production capacity, the state does not seem to want new technological capacities to transform or sustain this production capacity. Technology generation seems to have become subservient to the production investments, instead of technology frontiers pushing new production capital. Today, the two key domestic policy planks of output price support and input subsidies (Ray 2007) are a stranglehold on agricultural S&T (Raina 2011; Raina and Vijay Shankar 2011).

Within the production component of the AIS, agricultural labour has not figured in any of the strategic documents or policies for technology development and production support. By the turn of the century, it was evident that with the low and declining employment elasticity of the sector, agriculture would not be able to generate enough jobs for the rapidly growing rural populations (Bhalla 2005; Palanivel 2006). Throughout the period 1951–2010 (except during the decade 1961–1971), the number of agricultural workers and agricultural labour within the rural workforce kept increasing. Since the 1990s, there is an increasing number and share of agricultural labour in the agricultural workforce (a 44 % increase in the one decade 1991–2001; Labour Bureau 2009). This is partly a consequence of limited nonfarm rural employment and increasing proportion of marginal and small-farm holdings (accounting for 84 % of the total operational holdings and 48 % of the total area operated)—the latter being laborers as well as cultivators.

Small farmers gained little from public investment compared to the large landholders. Overall, the share of gross capital formation (GCF) in agriculture in total GCF fell from 20 % in 1980–1981 to 10 % in 1999–2000 and 6 % in 2007–2008, rising marginally to 10 % in 2009–2010 (Ministry of Finance 2009, 2011). The evident increase in the share of private capital in GCF since the mid-1980s (Fig. 13.3), roughly corresponding with the latter phase of the green revolution (Bhalla and

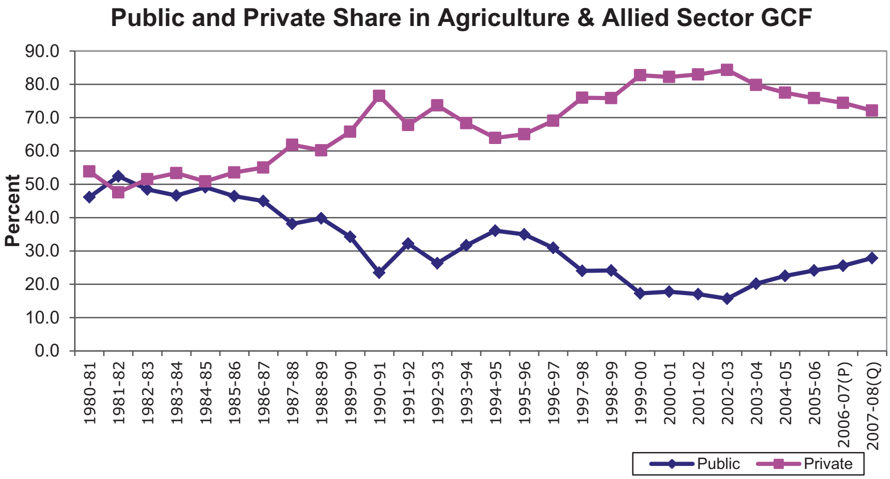

Fig. 13.3 Capital formation in agriculture and allied sectors. (Source: CSO, various years)

Singh 2010), was mainly in irrigation—groundwater extraction, though private investment on accessing more water in the tube-well irrigated production systems did not beget a commensurate productivity response (Vaidyanathan 2010). Yet, public capital formation that supports private capital formation (with a steady increase in the share of the former in current account expenditure) was maintained by the farm lobby—mainly the politically conscious and interest-seeking middle and large farmers (Mishra and Chand 1995). While public financing of private capital in the green revolution period was 35 %, it went up to 60 % in the postgreen revolution period (1980s; *ibid*, p. A-78). The National Food Security Mission (NFSM) launched in 2007–2008, maintained the subsidized input supply favoring those who owned or could access private capital.

There is a strong case for enabling a higher rate of growth of public GCF *for* agriculture through investments in rural infrastructure (roads, power, warehouses, etc.), industrial (local input production units, processing units), and service (location-specific research, data and information, markets, credit, transport) sectors, compared to the current emphasis on GCF *in* agriculture (Mishra and Chand 1995; Ministry of Agriculture 2003). This demands decentralized research and administrative reforms at least down to the block-level in the sector (Planning Commission 2011). But the existing production capacities and interest groups (established by the state, vested with middle and large peasants in irrigated chemical intensive cereal producing tracts and input industry) militate against these institutional changes; especially the potential new technologies and decentralized innovation capacities that a different public policy will usher in.

The agricultural workforce in rural India faces a double truss: limited technological capacities and an unrelenting state with limited learning capacities. Despite the investments in production capacities and massive subsidies, the state (i) taxes the sector by ultimately ensuring that all the gains are transferred to other sectors (industry and service sectors to supply the inputs and technologies) and consumers (through lower food prices) (Ray 2007) and (ii) denies much needed public investment for marginal and small farmers to be gainfully employed within agriculture and related rural industries. Ultimately, there is no AIS in India. There is an agricultural production system run by an instrumental state, increasingly controlled in turn by select farm lobbies and input industry that stand to gain directly from a narrow, highly subsidized and much fatigued technology-based production investment.

13.4.1 Investing in Industrial Growth

The national planning efforts, based on the assumption that modern agricultural development would lead to increasing absorption of redundant rural labour into the industrial labour force, did ensure increasing investment in and incentives for industrial development. Here we explore how the massive un- and under-employed rural populations participated in and gained from the investments made for industrialisation.

Industrial growth is broadly grouped into three phases: the immediate postindependence period (1950–1964), the green revolution or agriculture-linked industrial growth era (mid-1960s to late 1970s), and the de-regulation and liberalization era (beginning in the 1980s) (Chandrasekhar 2011). Policy support for industrial investments and technological change began with specific subsectors like textiles (which was the leading industry and export earner during the first phase). The import-substitution era (second phase) was driven by technology and saw public sector capital formation go into a phase of deceleration in the 1970s, leading to a market-led expansion of private industrial investment (largely middle- and upper-income markets). The consequent shift in the industrial commodity basket, from agro-based products to chemical or metal-based goods (synthetic textiles, cars, TV sets, electrical goods, etc.), marks "industry's relative degree of independence" from the pace and content of agricultural growth (Chandrasekhar 2011, p. 215). By the mid-1970s, Indian industry "had run up against a demand constraint" (ibid, p. 215). But an indirectly taxed and subsidy-driven agricultural production could never attain the breakthrough in real incomes to generate the required aggregate demand.

Capital formation in industry went through a major change in the 1980s, with a major fiscal stimulus, the liberalization of imports of capital goods and components, and the abundant assurance that the state had given up on "the implicit *compact* that had bound capital and labour together in the previous four decades" (Nagaraj 2003, p. 3708). Industrial performance kept pace in states like Gujarat, Maharashtra, Tamil Nadu, and Karnataka, while some of the least industrialized states like Orissa, small states like Himachal Pradesh, and Union Territories like Puducherry caught up since the 1980s (Papola et al. 2011). A key characteristic was the capital-intensive production investments, especially in leading industries like chemicals and basic metals. Though the falling real price of capital goods (fixed investments) enabled these capital investments (Nagaraj 2003), it is the consequent increase in the share of machinery in gross fixed capital, the relatively slower growth of labour-intensive subsectors and the disconnect between industrial and agricultural growth patterns that stand out (ibid).

Since the 1980s, with deregulation and proactive industrial investment (including reduced tariffs, import permits, etc.), the IT-led service sector growth did not add commensurate employment, neither did industrial growth (Nagaraj 2011). Even after reforms in public sector industrial research in the 1990s [mainly reforms in the Council for Scientific and Industrial Research (CSIR)], the capacity of Indian industry to move on to a technology-driven enhancement of employment and productivity is limited. Compared to other developed and emerging economies, especially China, India's GERD to GDP ratio is still the least (Mani 2010). The postliberalization imports of technology and equipment added to the legacy of low innovation demand (a capital goods industry under no pressure to innovate with new products, cut costs, or maintain environmental compliance). There was limited investment in the (intermediate) machine tools industry and in manufacture of household/essential goods, with the luxury goods—automobile sector leading the manufacturing industry in growth rate, innovation, and new products (Nagaraj 2011). Skill-augmenting production investments with new rules or institutions to govern skilled labour markets were strengthened by the imports and domestic development of technology (in the IT and pharmaceutical sectors).

Industrial investment and production decisions were cognizant of the employment and income potential of small-scale and rural industries. The Industrial Policy Resolution (IPR), 1956, aimed to ensure that the decentralized (cottage and small-scale) sector is integrated with the vitality and development of large-scale industry. The state decided to concentrate on measures to improve the competitive strength of the small producer (Das 2010), and in the process became a supplier of technologies—which may or may not be accepted by the small producers. The Industrial Policy Statement of 1977 opted for decentralized industrialization along with a close and symbiotic relation between the large and micro and small manufacturing enterprises (MSMEs). The expectation was that large enterprises would pave the way for technological change in MSMEs, large capital goods industries would meet their machinery requirements, and basic goods industries would help address the infrastructure as well as other development needs of MSMEs. None of this happened. In fact the luxury goods industry grew rapidly and "the machine tools industry… has barely grown with imports to consumption ratio nearly doubling in the 1990s" (Nagaraj 2003, p. 3714). The Industrial Policy Statement, 1980, which was in spirit no different from the IPR, 1956, and the micro, small and medium enterprise development (MSMED) Act of 2006 made a strong case for external orientation of small firms and enhancing firm competitiveness (Das 2010). The local institutional features of demand assessment, production decisions, resource mobilization, and market development that characterize MSMEs in rural India have a place in these policy statements. But the main program focus is on technology upgrading, competitiveness, global market linkages, and export facilitation, along with a minor concern in these policies to ensure access to credit (the most debilitating and dire need of most MSMEs) and market development.

That the capital goods industry did grow and that the production capacity so created remains unutilized because of lack of demand (back in the 1970s) does not seem to have altered the trajectory of deregulation and industrial reform initiated in the 1980s and the liberalization phase post-1991. Public investment is still largely in the capital-intensive infrastructure subsector (rising from 33.3 % in 1973–1974 to 53.5 % in 2001–2002 and 55 % in 2009–2010). And the share of manufacturing in industrial investments has fallen steadily over the past two decades, adding little employment in industry (Nagaraj 2011), and leaving a major middle layer of the machine tools industry and other enabling or feeder subsectors untouched.

Going back to our discussion (Sect. 13.3.1) on the centralized S&T system with weak state-government commitment to rural manufacturing, knowledge capital continues to be invested in routine (defence, atomic energy, and other high-tech) areas. Even in agriculture (a state subject according to the Constitution of India), there is almost complete centralization of knowledge capital (Raina 2011). The SAUs in India receive limited and rather lukewarm support from the state governments, compared to the proactive shaping and support by provincial governments and universities in China, Brazil, Malaysia, or Thailand. The modern technology-based production investments in agriculture are now a burden; a heavily subsidized "low equilibrium trap" (to reverse the famous Schultzian adage about the resource poor farmer) legitimized by the state for ensuring food security, though there is little evidence that production enabled by the irrigation-chemical intensive technologies leads to food security, or the much needed aggregate demand pull for rural nonfarm employment and incomes. In industry, the capital-intensive export-oriented production decisions are reinforced, despite much policy rhetoric about labour using development initiatives and programs. In agriculture, the first National Agriculture Policy in 2000 ensures maintenance of the same relationships between production investments and technological capacities, with no mention of agricultural or rural labour.

While enabling production investments and building technological capacities, the state paid little attention to the social capital (health and education of the workforce) necessary for innovation and development outcomes. Even where technological capacities were enabled, little investment of knowledge capital went into understanding the production regimes, resources, and relationships that the rural manufacturers were involved in. Given this limited understanding, the investments and technological support offered for rural industries or craft-based production, added little value to the production systems involving unskilled workers, women and caste-based craft-workers, who fall outside the high-skilled employment being enabled in the service sector. Rural India has gained little from the production investments and technological capacities. The aggregate demand constraints imposed on the economy by a weak rural sector and the massive loss of potential domestic market and knowledge base are not factored into current innovation plans.

13.5 Missing Institutions: Economic Theory and the Locus of Innovation

The rural population and their diverse livelihoods constitute in varying magnitudes the production and natural capital (the tangible resource base) and the knowledge and social capital (the intangible resources) in the NIS. Analyses of the Indian economy and industrial performance (high-tech sectors like IT, chemical or the pharmaceutical industry) in particular, have drawn attention to the institutional features that drive and shape the economic activities within industry (Kapp 1977; Nagaraj 2006, 2011; Raj 1975). This section analyses the institutions that govern investments in particular kinds of production and knowledge capital—the ones that are relatively easier to reproduce and control (Table 13.1 here).

While an elite capture of public investments for private gain has been noticed in both agricultural and industrial sectors, it is assumed that in a vibrant democracy like India, the technological and production demands of the majority of rural India will definitely be addressed through authentic democratic processes[4]. If it is merely elite capture that biased state-enabled technological and production capacities against the rural poor, then surely that can be corrected through democratic processes. But deep-seated norms or the institutions that shape production investments and technological capacities prevail; they are difficult to reform. In agriculture for instance, it would be equally unacceptable for the liberal, right-wing and socialist or left-front political parties to do away with the current centralized subsidy driven production capacities, and establish decentralized location-specific innovation capacities through administrative and technological changes. There are theoretically expected development outcomes that emanate from two (related but not entirely dependent) themes in development economics, about rural mobilization and industrial growth and patterns of linkages. They provide the overarching institutional framework that governs production investments and technological capacities.

Policies and programs for rural development have always been informed by the theoretical norm that labour and surpluses from rural areas have to be mobilized for deployment in industry (Johnston and Mellor 1961; Raj 1990). This is the first immutable institutional driver of production investments. In India, as in much of the developing world, this norm of rural transformation is enabled by investing in rapid agricultural growth through technological advances (Mellor 1976; Schultz 1964). That this technology-driven growth has to be accompanied by a consolidation of holdings to medium or large farms that allow mechanization is a logical fall-out. Theoretically, the "reduction in farm labour force is a necessary condition" for this secular transformation of the economy (Johnston and Mellor 1961, p. 590). If the movement of labour out of agriculture is not sufficient, then the consequences are extremely small farms and serious underemployment of labour that is directly reflected in increasing rural poverty; which is the reality today in India.

The second overarching norm is one of the expected linkages. The economic models (Leontief's input-output model) that indicated the nature and patterns of linkages did shape investment decisions in Indian industry. The assumption was that the commodity composition of the under-developed country's output would bear a resemblance to that of the country on whose input-output statistics the model or experiment was performed (Raj 1975). Partly related to this is the assumption that these linkages are essentially determined by technology—and "since there was thought to be hardly any choices here, institutional factors could make little difference

[4] Only franchise – one among the three democratic values of franchise, voice and authenticity, is exercised by the majority of the Indian population.

to industrial structures" (Raj 1975, p. 109). That industrial growth did not add jobs is not surprising; the fact that the institutional features evident in technology choices, investment decisions, and intrasectoral linkages between different industries were ignored is surprising (Nagaraj 2003, 2011).[5] To reiterate, the institutions or rules that frame India's NIS draw upon theories based on developed country industrialization and growth experiences.

The need for agricultural and rural incomes to maintain the aggregate demand for industrial goods, investments in labour-intensive industrial production, and the technological capacities needed to create dynamic linkages have been discussed over decades now (Chakravarty 1984; Nagaraj 2011; Raj 1986). The persistence of the overarching institutional frameworks is not for want of recommendations: to invest substantive public sector resources in agriculture and rural infrastructure (Mishra and Chand 1995), to invest in the education and skill base of rural populations, to ensure changes in local technological and production systems (say, advances in the machine tools sub-sector), and to create aggregate demand in the domestic market (Balakrishnan 2010; Nagaraj 2011). The massive rural population still surviving on a thinning share of the economic pie, battling a heavy burden of negative state support, and constituting the largest demand component of the NIS, remains the weakest.

13.6 Toward Policy Learning and Innovation for Development in India

While recognizing that agriculture is critical to economic growth, the processes of mobilizing knowledge, natural resources, labour, and capital to achieve this growth are crucial. Any strategy for agricultural development "can exist only as an integral component of a larger rural policy frame" (Lewis 1962, p. 166). The view that a "broad-based" development strategy (much like the Japanese case) that will lead to increasing productivity and employment among a large and growing number of small farms is necessary for "countries with abundant rural labour" —CARL (Raj 1990; Tomich et al. 1995) is yet to gain acceptance within the state, though the policy processes that favor large farms and industrialization of agriculture were critiqued and strategies for a different engagement of the state recommended early on in India (Rudra 1978; Sen 1981). In India, the share of rural nonfarm incomes in rural livelihoods has been increasing steadily, with some parts diversifying into rural nonfarm opportunities partly driven by consistently low agricultural productivity (Lanjouw and Murgai 2009) and other parts of the country using agriculture as a means to access and exploit wider urban and international markets (Bhalla 2005; Ghosh 2005; Nayyar and Sharma 2005). But these essentially rural production systems

[5] Raj (1975) refers to Hirschmann's work, which pointed out very early that the linkages in the input-output matrix matter not so much as the cause of industrialisation but as the result or consequence of industrialisation. Therefore, potential linkages are likely to be "realised in practice only if certain conditions are satisfied" (Raj 1975, p. 107).

are not linked to the formal sector—industrial technologies, employment, and growth. They have gained little from the national S&T policy or industrial policy.

Production investments in agriculture have been entirely techno-centric—dictated by the formal knowledge capital (given the production capacities and programs to promote green revolution technologies). It has been more nuanced in industry (featuring industrial policy resolutions, technology policy statements, etc.). The relative neglect of agricultural policy in the national imagination is evident in the fact that the country had only some piecemeal strategies and legislations, and the National Agricultural Policy was formulated by the Department of Agriculture and Co-operation only in 2000. Industrial policy, on the other hand, has received attention since the days of the Bombay Plan (1945), the Industrial Policy Resolution (1956), the Industrial Policy Statements (1977 and 1980), and several revisions or amendments to these. The policy component of the NIS seems to have let down the normative expectations that the state would play a protecting, regulating, and facilitating role in the industrialization of modern India (as spelt out in the Bombay Plan); policy learning and correction is hampered by entrenched production capacities and associated actors.

As discussed earlier in this text, the extreme centralization (Table 13.2) and massive S&T investments for export-oriented high-tech production capacities in countries that otherwise invest low or minimal resources in S&T (Table 13.3, column 2) are part of a larger institutional framework. First, the developmental state and the directions it gives to the science it patronizes is the "ultimate command" for national highly centralized scientific and technological capacities. Second, the Schumpeterian expectation that such enhanced production capacities and investment will build substantial technological competencies, which in turn will add to further economic growth. Third, and stemming from the massive agrarian population in developing countries like India, is the spin-off effect of expected employment and livelihoods gains from knowledge-intensive manufacturing using labour released by agricultural modernization. The Science & Technology Policy (DST 2003) in India, on building scientific capabilities through increased investments in education, credit, infrastructure, etc., has been oriented to global integration through high-tech goods production. Neither this policy statement nor the earlier ones—the Scientific Policy Resolution (1958) and the Technology Policy Statement (1983) address the economic context and structural infirmities in which this centralized high-tech S&T is expected to work. When some emerging economies (like China and South Africa) seem to have addressed this economic and technological wherewithal (to get labour and capital that has been released from agriculture and absorbed by modern industrial sub-sectors), India seems to confront a widening rift between its economic structure and technological capacities. India's rural population and livelihoods, and their potential roles as three major components: production, demand, and intermediary components of the NIS have been ignored.

Indian S&T and innovation capacities in space science, information technology, biotechnology, and high-end medicine receive accolades the world over. We have argued in this chapter that the Indian state made capital-intensive techno-centric production investments for agriculture, and a luxury goods-led industrialization strategy that failed to exploit the capital goods advantage generated in the immediate post-independence period. Not only was this divorced from location-specific institutional features of labour and resources in the country, but it also significantly reduced the mutual dependence between location-specific industrial and agricultural activities. Based on an institutional expectation that rural labour and capital could then be mobilized for industrial investment and economic growth, the modern technology-driven productivity approach to agricultural growth did not only not generate surpluses, but also substantively weakened the economic opportunities for small farms and agricultural labour, and undermined innovation potential in the sector. Industrial growth focused on luxury goods and export markets did not add jobs as expected. The institutional features that were critical to technology choices, investment decisions, intrasectoral linkages between different industries continue to be ignored, weakening the innovation potential within the sector.

Though it is too much to hope for, the state will perhaps make it imperative that all its research councils or sector-specific research organizations expend some of their energies on understanding the institutions governing the natural and social capital within their development sectors and their own knowledge capital (natural and social sciences, technologies and dissemination efforts). An understanding of these institutions, "… the characteristics of their economic systems which determine investment and production decisions" (Raj 1975, p. 113), is important for a reconciliation between the S&T-based approach to innovation and the broader interaction and learning-based approach to innovation. India's centralized and technocratic decision-makers may find this reconciliation unpalatable. But several emerging economies have acknowledged, confronted, and changed the stranglehold of certain decision-makers and lobbies over their national knowledge, natural, and social capital resources. Though the political contexts and processes were different, Malaysia, Egypt, Brazil, China, and South Africa offer examples of institutional reform for innovation that addresses their own structural realities. Will India be able to do this to foster innovation? A broad-based regionally differentiated set of employment-generating production investments in agriculture and industry would be the first step to address the innovation and economic development opportunities for India's massive agricultural and rural population. Massive public investments with simultaneous decentralized administration and design of the production investments as well as technological capacities are necessary. India has to design its own NIS; one that includes and caters to its domestic markets and rural population.

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References

Acemoglu D (2002) Technical change, inequality and the labour market. J Econ Lit 40(1):7–72
Adam C, Dercon S (2009) The political economy of development: an assessment. Oxf Rev Econ Policy 25(2):173–189

Balakrishnan P (2010) Economic growth in India: history and prospect. Oxford University Press, New Delhi
Barker R, Herdt RW (1985) The rice economy of Asia. Resources for the Future, Washington, DC
Bhalla S (2005) Recent developments in the unorganized rural non-farm sector. Working Paper No. 05/2005, Institute for Human Development, New Delhi
Bhalla GS, Singh G (2010) Final report on planning commission project growth of Indian agriculture a district level study, CSRD. Jawaharlal Nehru University, New Delhi
CAG (various years) Combined finance and revenue accounts of the union and state governments in India. Office of the Comptroller & Auditor General of India (CAG), New Delhi
Chakravarty S (1984) Aspects of India's development strategy for the 1980s, in Chakravarty's selected economic writings. Oxford University Press, New Delhi.
Chandrasekhar CP (2011) Six decades of industrial development: growth of the manufacturing sector in India from the 1940s. In: Narayana D, Mahadevan R (eds) Shaping India—economic change in historical perspective. Routledge, New Delhi, pp 206–231
Cimoli M, Porcile G (2009) Sources of learning paths and technological capabilities: an introductory roadmap of development processes. Econ Innov New Technol 18(7):675–694
Commission on Growth and Development (2008) The growth report—strategies for sustained growth and inclusive development. The World Bank, Washington, DC
CSO (various years) National Accounts Statistics, Central Statistical Organization, New Delhi
Das K (2010) Indian rural clusters and innovation: challenges for inclusion. SIID Working Paper No. 9, Centre for Policy Research, New Delhi
Dev M, Evenson R (2003) Rural development in India: rural, non-farm and migration. Working Paper No. 187, Stanford Centre for International Development, Stanford
Dev SM, Ravi C (2007) Poverty and inequality: all-India and states, 1983–2005. Econ Polit Wkly 42(6):509–521
DST (2003) Science and Technology Policy 2003. Department of Science and Technology, Government of India: New Delhi
DST (2009) Research and development statistics 2007-08, NSTMIS, DST: New Delhi
Edquist C (1997) Systems of innovation: technologies, institutions, and organizations. Pinter, London
Fan S, Hazell P, Haque M (2000) Targetting public investments by agro-ecological zone to achieve growth and poverty alleviation goals in rural India. Food Policy 25:411–428
FAO (2006) State of food and agriculture. FAO, Rome
Gangopadhyay S, Lanjouw P, Vishwanath T, Yoshida N (2010) Identifying pockets of poverty: insights from poverty mapping experiments in Andhra Pradesh, Orissa and West Bengal. Indian J Hum Dev 4(1):5–28
Ghosh J (2005) Trade liberalization and agriculture: an examination of impact and policy strategies with special reference to India, HDR Off. Occasional paper 2005/12, UNDP, New York
Johnston B, Mellor JW (1961) The role of agriculture in economic development. Am Econ Rev 51(4):566–593
Kapp WK (1977) The nature and significance of institutional economics. Kyklos 29(2):209–232
Labour Bureau (2009) Indian labour yearbook 2007. Ministry of Labour and Employment, Labour Bureau, New Delhi
Lanjouw P, Murgai R (2009) Poverty decline, agricultural wages, and non-farm employment in India: 1983–2004. World Bank policy research Working Paper 4858, World Bank, Washington, DC
Lewis JP (1962) Quiet crisis in India –economic development and american policy. The Brookings Institution, Washington, DC
Lundvall B-A, Maskell P (2010) Nation states and economic development: from national systems of production to national systems of knowledge creation and learning. In: Clark G, Feldman M, Gertler M (eds) The Oxford handbook of economic geography. Oxford University Press, Oxford
Mahalanobis PC (1958) Science and natural planning. Anniversary address at the National Institute of Sciences of India, January 1958
Mani S (2010) India. In: UNESCO science report, UNESCO, Paris

Mathieu A, van Pottelsbergh B (2008) A note on the drivers of R&D intensity, CEPR Discussion Paper No. 6684, CEPR
Mellor J (1976) The new economics of growth: a strategy for India and the developing world. Cornell University Press, Ithaca
Ministry of Agriculture (2003) Report of the committee on capital formation in agriculture. Directorate of Economics and Statistics, Ministry of Agriculture, Government of India: New Delhi
Ministry of Finance (2009) Economic survey. Ministry of Finance, Government of India, New Delhi
Ministry of Finance (2010) Economic survey. Ministry of Finance, Government of India, New Delhi
Ministry of Finance (2011) Economic survey. Ministry of Finance, Government of India, New Delhi
Mishra SN, Chand R (1995) Public and private capital formation in Indian agriculture- comments on complimentarity hypothesis and others. Econ Polit Wkly 30(25):1365–1369
Mowery D, Rosenberg N (1993) The US national innovation system. In: Nelson RR (ed) National innovation systems. Oxford University Press, New York, pp 29–75
Nagaraj R (2003) Industrial policy and performance since 1980. Which way now? Econ Polit Wkly 38(35):3707–3715
Nagaraj R (2006) Aspects of India's economic growth and reforms. Academic Foundation, New Delhi
Nagaraj R (2011) Industrial performance 1991–2008—a review. Industrial Development Report, UNIDO, Vienna
Nayyar R, Sharma A (2005) Rural transformation in India: the role of non-farm sector. Institute for Human Development, New Delhi
Nelson R (ed) (1993) National innovation systems. Oxford University Press, New York
Nelson R, Winter S (1982) An evolutionary theory of economic change. Harvard University Press, Harvard
Niosi JE (2002) National systems of innovation are "x-efficient" (and x-effective): why some are slow learners. Res Policy 31(2):291–302
Palanivel S (2006) Technical report on linkages between international trade and employment growth in Asia and the Pacific. UNDP, Colombo
Papola TS, Maurya N, Jena N (2011). Inter– regional disparities in industrial growth and structure. ISID, New Delhi
Planning Commission (2008) Eleventh Five Year Plan (2007-2012) agriculture, rural development, industry, services and physical infrastructure—Vol. III. Planning Commission, Government of India: Oxford University Press: New Delhi
Planning Commission (2011) Report of the XII Plan working group on natural resources management and rainfed farming. Planning Commission, Government of India, New Delhi
Planning Commission (various years) S and T Plan Outlays, (www.planningcommission.nic.in/sectors/science.php?sectors=sci)
Raina RS (2011) Institutional strangleholds: agricultural science and the state in India. In: Narayana D, Mahadevan R (eds) Shaping India—economic change in historical perspective. Routledge, New Delhi, pp 99–123
Raina RS (2012) Institutional immunity: limiting the scope and space for innovation and development in India, Presented at the Conference on India's Economy- A longer and broader view, organized by CDS and NMML, Nehru Memorial Museum and Library: New Delhi, 14–15 December 2012
Raina RS, Vijay Shankar PS (2011) Rainfed agriculture: enabling new rules of the game. *SIID Policy Options, No.1*, *December 2011*, Centre for Policy Research, New Delhi
Raj KN (1975) Linkages in industrialization and development strategy: some basic issues. J Dev Plan 8(1):105–120
Raj KN (1986) Growth and stagnation in Indian industrial development. Econ Polit Wkly 11(5–7):223–236

Raj KN (1990) Idle rural labour and its investment potential: a re-appraisal (reprinted- the second for three lectures on employment aspects of planning in underdeveloped economies, 1956, delivered at the national bank of Egypt). In: Raj KN (ed) Organizational issues in Indian agriculture. Oxford University Press, Delhi
Rajeswari S (1995) Agricultural research effort: conceptual clarity and measurement. World Dev 23(4):617–635
Rao CH, Gulati A (1994) Indian agriculture: emerging perspective and policy issues. Econ Polit Wkly 29(55):A58–69
Ray S (ed) 2007 Handbook of agriculture in India. Oxford University Press, New Delhi
RBI (various years) Handbook of statistics on Indian economy. Reserve Bank of India, Mumbai
Rodrik D, Subramanian A, Trebbi F (2004) Institutions rule: the primacy of institutions over geography and integration in economic development. J Econ Growth 9:131–165
Rudra A (1978) Organization of agriculture for rural development: the Indian case. Camb J Econ 2(4):381–406
Schultz TW (1964) Transforming traditional agriculture. New Haven: Yale University Press, Reprint, New York: Arno Press
Sen A (1981) Market failure and control of labour power: towards an explanation of 'structure' and change in Indian agriculture. Camb J Econ 5(4):327–350
Sen A, Himanshu (2007) Some aspects of poverty in India. Paper presented at the international conference on revisiting the poverty issue: measurement, identification and eradication, Patna, 20–22 July 2007
Singh A (2008) The past, present and future of industrial policy in India: adapting to the changing domestic and international environment. Working Paper No. 3, Centre for Business Research, University of Cambridge, UK
Sivaraman B (1991). Bitter-sweet: governance of India in transition. Ashish Publishing House, New Delhi
Swaminathan MS (2005) Science and Shaping our Agricultural Future, K. R. Narayanan Oration, 27 September 2005, South Asia Research Centre, Research School of Pacific and Asian Studies. The Australian National University, Canberra
Tomich TP, Kilby P, Johnston B (1995) Transforming agrarian economies: opportunities seized, opportunities missed. Cornell university Press, Ithaca
UNICEF (2008) Status of the world's children- child survival. UNICEF, Paris
Vaidyanathan A (2007) Water policy in India: a brief overview, Occasional paper, No. 6, IIM, Indian Institute of Management, Bangalore
Vaidyanathan A (2010) Agricultural growth in India: the role of technology, incentives and institutions. Oxford University Press, New Delhi
World Bank (2011) Science & Technology. World Development Indicators. (www.data.worldbank.org/topic/science-and-technology)
World Bank (Various years) World development indicators. World Bank, Washington, DC

Chapter 14
The Role of the Diaspora in Supporting Innovation Systems: The Experience of India, Malaysia and Taiwan

Rajah Rasiah, Yeo Lin and Anandakrishnan Muniratha

14.1 Introduction

The importance of embodied knowledge flows in the growth of firms was explained in detail by Marshall (1890) who emphasised the systemic nature of knowledge—that they are embodied in the system rather than the individual. However, such knowledge synergies were confined to small firms that were not engaged in high-tech operations involving considerable acquisition of knowledge from research and development (R&D) operations and links with universities. Rasiah (1994) and Saxenian (1994) discussed the movement of experienced human capital from older firms to support new firms in Penang (Malaysia) and Silicon Valley and Route 128 (USA). Whereas firms in Penang were little linked to the ecology of universities and R&D centres, there were considerable linkages between them in Silicon Valley and Route 128 in Massachusetts. Saxenian (2006) went on to discuss the new Argonauts (Saxenian's mythic term for global commuters employed in the high-tech sector) who returned to stimulate the entrepreneurial activities in a number of countries. The role of foreign human capital in providing technical and professional labour in economic growth is well known in developed countries, such as the USA, UK, Canada and Australia that benefitted enormously from the process. Only Singapore and Israel, both of which were developing countries in the 1970s, are known to have benefited explicitly from such policies.

Not only does the effective appropriation of knowledge from abroad quicken the development of particular capabilities but there are also elements of path

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dependence and networking synergies that require integration in such knowledge pools. Hence, even large countries such as the USA, Germany and China have benefited from such flows of knowledge to strengthen their regional and national innovation systems (NIS).

A profound understanding of how knowledge embodied in human capital circulates—from mere pre-employment qualifications to its enrichment with tacit and experiential knowledge as well as subsequently to connecting with and evolving in the marketplace—will help governments organise strategies that can enhance their development policies. India, Malaysia and Taiwan offer an excellent laboratory to analyse how different economic structures, levels and types of government policy have evolved from a fairly passive one in India, to a proactive one in Taiwan and an eclectic one in Malaysia to produce wide-ranging ramifications for their respective NIS. What appeared to arouse national concerns in the 1950s that triggered wide discussions among scholars and policymakers about brain drain eventually translated into brain gain and brain circulation to transform Taiwan as national human capital from abroad began to participate significantly in the country's technological catch up (Glaser 1978). From the Indian Institute of Technology (IIT) framework that was started in the early 1960s, India has benefited considerably from the returning Argonauts, especially since the 1990s.

This chapter examines the role of the flows of national human capital in enhancing NIS in three countries: India, Malaysia and Taiwan. Government policy to develop national capabilities will be discussed because of the importance of national institutions and meso-organisations in producing the bulk of the high-tech workforce as well as absorbing the experiential knowledge gained from abroad. We will evaluate the initiatives taken and the specific sectors to which human capital returned and their economic consequences. Given the difficulty associated with capturing human capital flows, the chapter will focus on the information technology industry to compare the experiences.

14.2 Theoretical Guide

The importance of innovation and technology has long been recognised as the driver of long-run economic development (Hirschman 1958; Marx 1956; Rosenberg 1982; Schumpeter 1934). Whereas governments have placed extensive emphasis on educating their labour force, particularly pre-employment education, for several decades initiatives to attract talented human capital were undertaken on a large scale mainly by developed countries such as the USA, Canada and Australia that had already benefited considerably from human capital immigration. Whereas, developed countries targeted qualifications irrespective of national origin, fast-developing countries such as Korea, Taiwan, China and India sought to attract back their own diaspora. Lacking a critical mass of nationals, Singapore and Ireland began to offer citizenship status to non-national human capital.

Most movements of human capital have been from developing to developed sites, but since the 1970s there have been dramatic changes as economic progress at host sites along with government initiatives that have attracted the return of a significant amount of human capital to countries such as Korea, Taiwan and China. However, most countries experiencing such beneficial reversals have strong government policies to attract back their talent. Diasporas have in particular been targeted by home governments to return and support national technology development initiatives (see also Lowell and Gerova 2004; Rasiah and Lin 2005; Sequin et al. 2006). As pointed out by Meyer and Brown (1999), 30–50 % of the developing world's trained science and technology experts still lived in the developed world in the late 1990s, which can be targeted by developing countries to support their technology development plans.

While the emigration of talent represents a loss to governments investing in education (Bhagwati and Hamada 1974; Kapur and McHale 2005), some countries have managed to turn such losses into benefits. Significant numbers of scientists and engineers graduating in the developed countries gained employment in flagship multinationals such as IBM, Intel, Motorola and Texas Instruments where they built their experiential capabilities before returning home to play a productive role in transforming their countries' technological base (see Rasiah and Lin 2005; Saxenian and Hsu 2001; Tung 2008). The relative success of Ireland, Israel, Korea and Taiwan in fostering return migration has been attributed to economic expansion as well as policies that foster domestic investments in innovation and R&D.[1]

The talent attraction strategies of the USA, the UK, Canada, Australia, New Zealand, Singapore and Ireland often included advertisements seeking skills and professionals with particular qualifications. Some countries, such as Korea and Taiwan, have identified in an ad hoc and informal way skilled and professional human capital from information supplied by those returning home. Those registering their skills and experiential records with the Ministry of Education and the National Youth Council are the ones largely kept in Taiwan.

Whether directed through purposive policies or otherwise, the human resource promotion initiatives of countries such as China, Ireland, Israel and Korea show that it is possible to attract back human capital to drive technological catch-up. Korea launched deliberate policies to attract back human capital and to solicit advisory support from their emigrants to gain innovation synergies and market access. Such initiatives have actually become global in that targeted centres, regions and multinationals of excellence have provided the human capital sought to achieve technological catch-up in developing home countries. This chapter seeks to discuss the experience of Taiwan, India and Malaysia in connecting and co-ordinating the spillover of such globally evolved knowledge in their human capital. Figure 14.1 shows the framework for analysing the outward movement, enrichment and inward return of human capital against policy-driven government and related organisations in Taiwan, India and Malaysia.

[1] See OECD (2002).

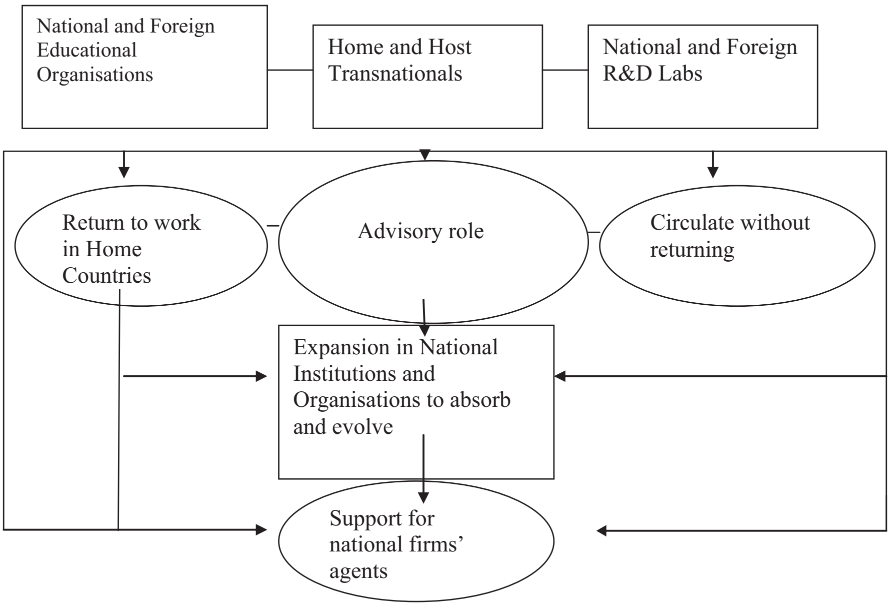

Fig. 14.1 Global human capital synergies and innovation systems, 2010

14.3 Catch-Up Drives Involving the Diaspora

Interestingly, the general picture of trade regimes painted by economists obscures the reality of how the diaspora has driven the industrialisation initiatives of Taiwan, India and Malaysia. As documented by Belassa (1982) and the World Bank (1993), India is arguably the most protected and closed economy of the three countries with import and export intensities accounting for a fraction of GDP value added. Malaysia and Taiwan are typically the most open economies with export-orientation dominating GDP growth. However, India has been the most liberal on policies to attract back its diaspora whereas Taiwan and Malaysia have been interventionist in attracting them back to support economic development.

Flows of western sources of knowledge became pronounced when Indians and Malaysians started studying in British universities during colonial rule, with enrolment in those universities rising exponentially after independence as the elite and the middle class preferred to support their children's education in Britain. Through both scholarships from home and host countries, student enrolment remained strong for many decades. With support from its ally, the USA, Taiwanese enrolment in US universities increased manifold from the 1950s. The nascent regimes, however, saw only privileged students studying abroad with some returning home. Among the notable returnees who played critical roles in both the independence and early development of their countries were Mahatma Gandhi and Jawaharlal Nehru from India, Tunku Abdul Abdul Rahman and Tun Razak, the first two Prime Ministers of Malaysia, and Lee Kuan Yew who was originally from British Malaya but became the first Prime Minister of independent Singapore in 1965. What marks out the foreign sources of knowledge embodied in nationals is their role in strengthening the innovation system in their home countries.

The three countries are not only diverse in their physical and demographic size and structure but their governments have also intervened differently to attract the diaspora. This section uses examples to examine the different approaches that characterised the role of foreign trained human capital in economic development.

14.3.1 Taiwan: Strategy-Based Interventions

Although there was a broad-based promotional policy to attract Taiwanese human capital, the government also had a specific approach to support industries classified as strategic. The government launched a comprehensive policy to develop strategic industries, which, *inter alia*, included R&D in the Industrial Technical Research Institute (ITRI) labs, acquisition of key firms to access knowledge and markets and organising human capital with tacit knowledge to spearhead growth. The semiconductor industry was one such major industry that the government developed successfully through this route and hence is discussed in detail here.

The government encouraged those studying abroad by offering incentives to return to Taiwan in the 1950s, which included, *inter alia*, providing them with accommodation and living expenses before they assumed their new jobs. This approach was not very successful despite further incentives offered in the 1960s. In the 1960s, a major source of foreign industrial knowledge came through MNCs. The western semiconductor firms of General Instruments, Philips, Texas Instruments and Radio Company of America (RCA) relocated low-end operations to Kaoshiung in 1966 (Lin 2009). These MNCs acted as training grounds producing experiential knowledge embodied in the local managers, engineers and technicians, a number of whom moved to work in local firms.

Recognising the need to build domestic capacities, the Taiwan government obtained a United Nations grant of US$ 300,000 to install equipment for microwave and laser experiments at the National Jao-Tung University and to establish the Far East Training Center for Electronics and Telecommunications in 1960. The National Jao-Tung University developed solid state technology with silicon surface and established a semiconductor laboratory in 1964, which produced Taiwan's first doctorate in semiconductor technology (Zhang et al. 2001).

The number of students studying abroad soared fivefold in the 1960s to 21,248 from just 4515 in the 1950s, most of whom enrolled in the fields of science and engineering. The first 'big' wave of 2177 diaspora returned to work in Taiwan in 1968–1973 (Lin 2009), which was a big jump from the 505 who returned in 1964–1967. The majority of the returnees joined universities or government organisations because the private sector in Taiwan was still emerging.

The government recognised in the late 1960s that rapid economic growth required a structural shift to higher value added activities. The mission of searching for the 'right' industry was left to the Technology Advisory Committee (TAC), whose major responsibilities were to provide the Taiwan government with information on technology and market trends. The TAC members were from overseas and had gained experiential knowledge working in MNCs in the USA.

The TAC was instrumental in convincing the government to launch the ITRI in 1974 and to develop the integrated circuits (IC) industry. It was the TAC that recommended RCA to be the anchor from where technology transfer should originate (Hong 2003), but it also recommended that indigenous IC technology would have to evolve from there with their own development. The TAC estimated that it would take 4 years and US$ 10 million investment to develop indigenous capability in semiconductor manufacturing. Interestingly, the chief executive officer of United Microelectronics Company (UMC) felt that nationally grown experts should spearhead the IC revolution. However, once Morris Chang had demonstrated the superiority of foreign experiential knowledge links with his leadership of the Taiwan Semiconductor Manufacturing Corporation (TSMC) into the world's largest contract manufacturer of fabricated wafers, the TAC became an unquestioned part of government decision making.

The government established the ITRI to upgrade Taiwan's technological capability after recognising that domestic firms were too small to participate in R&D activities. The Electronics Research and Service Organisation (ERSO) was launched as one of the ITRI labs in 1974, which started through the transfer of semiconductor technology from RCA. Stage 1 of the project for transferring technology from RCA was to establish the integrated circuit (IC) Pilot Plant in 1975–1979. In April 1976, ERSO sent the first batch of 19 engineers to RCA for technical training.[2] The RCA project had the following two profound impacts on the development of ICs and other high-tech industries in Taiwan. The first saw the acquisition by ERSO of manufacturing technology and knowledge of how to operate the IC business.[3] The second saw the application of design and R&D to ERSO's engineers. It is from the acquisition of RCA that high-tech firms in Taiwan began to understand the applicative meaning as well as the value of design and R&D.

To ensure that the domestic environment was conducive to technology absorption and catch-up, the government stepped up the production of R&D scientists and engineers and other professionals in technical fields as well as increased expenditure on R&D activities, which included grants. As a consequence, the number of researchers per million persons and R&D expenditure in GDP rose from 3326 and 1.9 %, respectively, in 1996 to 4159 and 2.6 %, respectively, in 2006 (see UNESCO 2010, Tables 19 and 26). Recognising the need to support R&D expenditure, the government took the lead by dominating its funding initially. As firms started acquiring the knowledge and moving up to higher value added activities, the private share of R&D expenditure grew to overtake the government share (see Rasiah and Lin 2005).

Through ERSO the government initiated three more large-scale projects to advance IC technology and deepened the technology capability of Taiwanese firms.

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[2] RCA offered a total of 353 man-months training to 53 Taiwanese personnel.

[3] ERSO also got someone to transfer the accounting framework used by RCA.

They were the Stage II Project of 1979–1983, the VLSI project of 1983–1987 and the sub-micron Project of 1990–1994. The diaspora was very much targeted to effect this transition, which led to the introduction of a formal policy to recruit science and technology talent in 1983. In 1983, the Executive Yuan launched the Programme of Strengthening the Development and Recruitment of High-Tech Talents (see Lin 2009) to promote the development of domestic talent, which it emphasised as equally important as recruiting diaspora from overseas.

The government also initiated other large-scale projects in computer and peripheral production, e.g., Computer Project I (1979–1983), Computer Project II (1983–1987) and Computer and Telecommunication Project I (1987–1991), which laid the foundation for the development of the computer industry in Taiwan (Huang 1995). Of the four concurrently implemented IC projects, ITRI spun off United Microelectronics Corporation (UMC) in 1980, Taiwan Semiconductor Manufacturing Corporation (TSMC) and Taiwan Mask in 1987 and Vanguard International in 1994 (Lin 2009).

TSMC built technological capability through ITRI's VLSI Project with technology shared from joint-venture-ship with Phillips. Its Chairman, Morris Chang, used his experience from working abroad to innovate a new business model, leading to the creation of the world's largest contract manufacturer of semiconductor devices. TSMC specialises in IC chip fabrication based on customer designs. Although large foreign customers continue to impose conditions on their orders, local technopreneurs have increasingly accounted for many of the designs used by TSMC. The horizontal specialisation of TSMC only in the anchor activity of wafer fabrication generated large demand for independent IC design companies. Because investment in IC design is not lumpy, several Taiwanese returned from the USA to open design houses.

Government investment in building the high-tech infrastructure was a major development in transforming Taiwan into a high-tech hub. The Taiwan government promoted high-tech industrialisation more aggressively when the Hsinchu Science Industrial Park (HSIP) was opened in 1980. Firms locating in HSIP were provided with generous incentives and grants, such as tax holidays, tax reductions and subsidised land.

The early returnees, such as Morris Chang, played a pivotal role in attracting technopreneurs back to Taiwan by not just interacting with them but also offering the opportunity to start businesses in Taiwan. The majority of the IC design houses are located in the HSIP, which accounted for 45.4% of all its companies (Lin 2009, Table 2). ICs, computers and peripherals, telecommunications and electro-opticals together accounted for 87.6% of the firms in HSIP, with a whopping 97.4% of its employment in 2008 (Lin 2009). Figure 14.2 shows the number of returnees working at HSIP. Taiwan also benefited from the 1999 to 2000 recession in the US economy caused by the collapse of the IT bubble, which drove several engineers to relocate to HSIP. Hence, the numbers jumped steeply over the period 1999–2001.

Knowledge flows through brain circulation have also been important in strengthening the innovation system of Taiwan. Technical and market information began to flow to narrow the knowledge gap between the USA and Taiwan (Xu 2000).

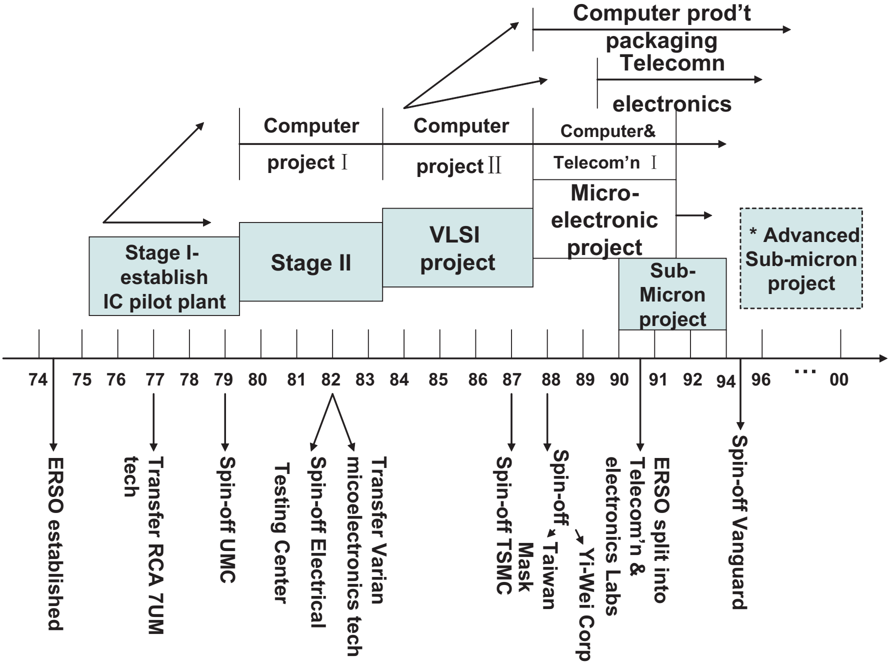

Fig. 14.2 Diaspora employed at Hsinchu science industrial park, 1982–2003. (Source: plotted from Lin 2009)

For example, an engineer facing technical problems in HSIP would often call up a friend in Silicon Valley for help (Mathews and Cho 2000).

Industrial upgrading programmes in Taiwan also benefited considerably from government efforts to expand the supply of technical personnel from 1983. Universities in Taiwan actively set up new graduate programmes and expanded the original ones. The number of masters and doctorates trained by Taiwanese universities significantly increased after 1984 (see Lin 2009), so that universities in Taiwan trained a total of 24,684 masters and doctorates in 1985–1989, which was more than double the number trained in 1970–1980. Over 100,000 obtained graduate degrees from universities in Taiwan in 1990–1998. Saxenian (2006) reported that the number of doctorates trained by Taiwanese universities for the first time exceeded the number of doctorates granted by universities in the US in 1999. The expansion in domestic graduates was critical in raising the absorptive capacity of the domestic economy for technological upgrading. Engineering education, in particular, has had a considerable influence on Taiwan’s national innovation system (Vogel 1991).

Given the significance of hands-on skills and technical knowledge, the government also stimulated the opening of training centres in Taiwan. Among them the Institute for Industrial Information (III) has been the most significant. From 1980 to 1996, III trained 175,000 people (Saxenian 2006). By the turn of the millennium the contribution of the domestically trained human capital towards innovation in Taiwan rose so much that the take-up of patents compared favourably with those who had returned from abroad.

14.3.2 India: Liberal Within State Regulation

The collapse of the Soviet Union from 1989 and the end of the Cold War changed India's fortunes dramatically. Export-orientation, foreign ownership and private interests began to rise in importance in the country, with active support from the Indian government.

India does not have an explicit brain gain policy (Malhotra 2009). Rapid development and rising demand for high-tech activities have started to attract both a complete return as well as brain circulation from the Indian diaspora. The Indian diaspora mainly studied in India before continuing their education abroad.

Following independence in 1947 the government of India introduced a planned economic regime focusing on the heavy industries of steel, electrical power, construction equipment, fixed telephone lines, defence equipment and dams. The talents and skills required for their establishment and operation had to be acquired initially by exposing Indians to then-friendly countries with the relevant capabilities, such as the Soviet Union, Yugoslavia, Czechoslovakia and Germany. At the same time the government set up a large number of R&D laboratories, such as the Council of Scientific and Industrial Research (CSIR) and Defence Research Laboratories, which employed researchers trained not only in India, but also in the UK, the USA and France.

The turnaround of the food crisis in India in the mid-1960s benefited from the contribution of Indian agricultural scientists collaborating with renowned agricultural universities and research bodies abroad. The foundation for India's space technology was laid by Vikram Sarabai, who had studied at the Massachusetts Institute of Technology, and was propelled by the participation of expatriate Indian scientists working in Bangalore, Sriharikotta, Hyderabad and Ahmedabad. India's nuclear programme was started by Cambridge-trained Homi J. Bhabha, who succeeded in attracting Indian scientists and technologists from India and abroad to lead nuclear missions. The telecommunication revolution in the 1980s was led by Sam Pitroda (Anandakrishnan 2009). The Indian education system and industrial system were motivated to keep pace with advances in telecommunication technology by keeping close watch on developments in the USA, UK, France, Japan and Sweden.

The number of Indians studying and working in the USA increased exponentially from 1965 when US immigration laws were changed in favour of qualified persons. Many highly qualified Indian scientists and technologists migrated to the USA, causing serious concerns about the brain drain.

It is estimated that at any one time nearly 1.5 million students are studying outside their home countries (Anandakrishnan 2009). Large numbers of college graduates and scientists go abroad for research, teaching and other academic activities. The global marketplace for education will expand substantially as academic systems become more similar, academic degrees more widely accepted internationally, immigration rules are tailored to people with high skill levels, and universities become more open to hiring the best talent worldwide.

Indians have been drawn to the Gulf as well as to Southeast Asia because of the higher wages offered for high-tech qualifications. Singapore and Hong Kong attract, *inter alia*, Indian academics and software engineers. Indians are also spread across Sub-Saharan Africa.

The most significant 'pull' factors for Indian students and scholars are better salaries, performance incentives and working conditions, and the opportunity to be at the centres of world science and scholarship.[4] In most developing countries academics cannot aspire to a middle-class lifestyle or expect to have access to the necessary tools of research and scholarship—including the ability to obtain the most current knowledge and to connect with the international community of scholars. The 'push' factors include limited academic freedom in many developing countries as academics are sometimes subject to restrictions and even punitive actions if they do not follow official policies. Favouritism and corruption in academic appointments, promotions and other areas further erode the academic environment of the university. In some ways, these conditions stem from the scarcity of resources, the pressure of increased student numbers on overburdened academic institutions and the growing number of self-financing private players who tend to economise on faculty costs. The 'pull' factors at the centres cannot be altered much, but the 'push' factors can be moderated. Overall, however, the migration of academic talent will continue in the current globalised environment.

At one time, the migration of talent was perceived as a brain drain because those who left were considered to be permanently lost, retaining negligible or no academic links with their home countries. This situation has changed. Many academics who have migrated maintain scientific and academic relationships with colleagues and institutions in India. Several have returned following improved economic conditions in India. The global melt-down of 2008–2009 that adversely affected the developed countries hastened this process, as several entrepreneurs and academics have returned to work in India. Interviews with the Directors of the Indian Institute of Technology, Kanpur, Indian Institutes of Management in Ahmedabad and Bangalore, Indian Institute of Science (Bangalore), the Rector of the University of Hyderabad and the Vice-Chancellor of Madras University showed that even prolific academics are returning to participate in India's technological progress.[5] Indian academics also circulate to lecture or consult, collaborate on research with colleagues in India, or accept visiting professorships without relocating back permanently. Facilitated by the Internet, these links are increasingly accepted as appropriate and useful.

Despite their establishment in the 1960s, it was only from the 1980s that graduates from the Indian Institutes of Technology (IITs) became known. The IITs were set up in the post-independence era consciously patterned on the Massachusetts Institute of Technology in the USA, and received substantial overseas help from the outset. With support from donor nations, the IITs benefited from visiting faculty from abroad, invitations for training abroad and the supply of modern laboratory

[4] The reasons are the same for most developing country human capital seeking to relocate abroad.

[5] Conducted by Rajah Rasiah from 3 to 15 March 2010 in India.

equipment and facilities from abroad. Similar international links were established by the Indian Institutes of Management (IIMs). For example, IIM Ahmedabad still maintains strong connections with the Harvard Business School. A recent development in Indian higher education is the opening of open universities, which drew heavily on the United Kingdom experience to support distance education.

The liberalisation of the Indian economy from 1991 increased the number of Indian students going abroad for education. Indian students have accounted for the largest foreign contingent studying in the USA since 2001. There were 83,833 students studying in the USA in 2006–2007 and 103,262 in 2008–2009 (Rajghatta 2009). India surpassed China in 2000–2001 to become the largest sender of students to the USA, from when the numbers grew strongly before a dip in 2005–2006 (Fig. 14.3). The number of returnees to India started rising strongly from 2002 to 2003. More than 70 % of Indian students in the USA are in graduate programmes, while only 22 % are undergraduate students. More than 75 % of all Indian students in the USA are in the disciplines of business management, engineering, mathematics and computer science (Anandakrishnan 2009).

A wide range of distance education programmes facilitated knowledge flows from abroad and from major Indian cities to large sections of the Indian population. Organisations such as the Institution of Electrical and Electronic Engineering (IEEE), USA, Nanyang Technological University (NTU), Singapore, EUROPACE and EUROSTEP in Europe and EDUSAT in India are available for distance education.

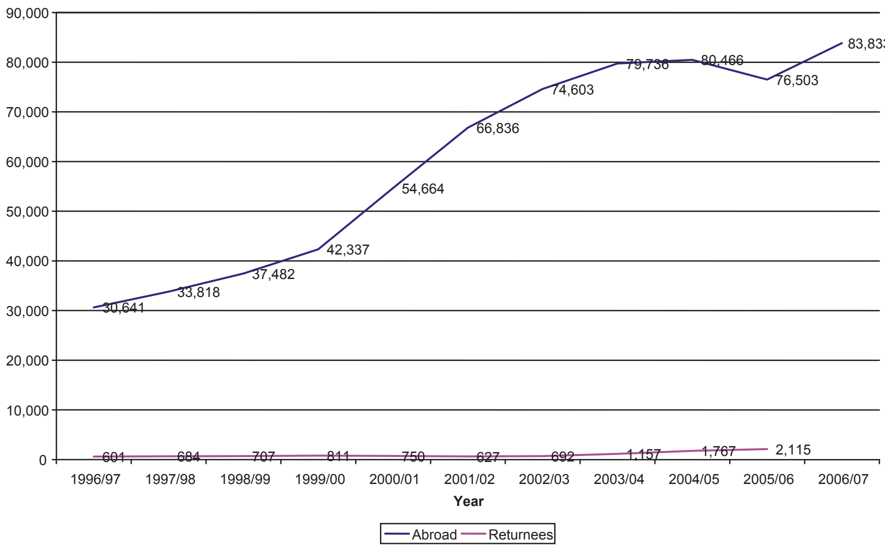

Fig. 14.3 Indians studying abroad and returnees from the USA, 1996–2007. (Source: Anandakrishnan 2009, p. 10)

Several Indian companies provide online tutoring for US schools and colleges, using personal computers and broadband support. For example, *Tutorvista.com* employs 900 teachers spread across 93 locations in India to reach more than 10,000 students across the world. Similarly, US-based *globalscholar.com* offers online tutoring from India for global students.

There are many learning universities, such as the Open Course Ware (OCW) of MIT. The OCW is a large-scale, web-based publication of educational materials from virtually all MIT faculties. This initiative enables the open sharing of MIT teaching materials with educators, enrolled students and self-learners around the world. It provides open access to the syllabi, lecture notes, course calendars, problem sets and solutions, examinations, reading lists and selected video lectures of MIT courses in 33 disciplines and all five of MIT's schools. In 2008, the initiative included materials relating to 1800 courses.

The Indian National Project on Technology Enhanced Learning (NPTEL) is a joint venture by the seven IITs and the Indian Institute of Science, funded by the Union Ministry for Human Resource Development. It has created material for 239 courses in core science disciplines as well as mechanical, civil, computer science, electrical and electronics and communications engineering that are available in web and video format. While 129 courses are available on the NPTEL in HTML and PDF formats, 110 video courses are regularly broadcast on the national television channel, DD Eklavya. NPTEL has placed the video courses on YouTube, creating a large repository of technical courses in the streaming video format. All the web courses are available to engineering colleges, which has been an important route for circulating Indian human capital from abroad back to India.

The trend towards R&D investment in emerging economies from the 1980s has extended to India following the development of human resource capabilities in science and technology. Although India's large market is attractive, a major reason for the off-shoring of R&D activities by Motorola, Microsoft, Intel, AMD and IBM is to access the large reservoir of software engineers. While domestic human capital has been the driver, the Indian diaspora has also returned to work in these MNCs.

India began investing in science and engineering research through research organisations such as the CSIR, Department of Scientific and Industrial Research (DSIR) and higher research, which included the founding and expansion of the IITs. The IITs have led to the development of a software industry since the 1970s that initially focused on the domestic market. International efforts by the Indian software industry began with Tata Consultancy Services, which provided programmers work at customer sites in the USA. As this activity increased during the 1980s, the Indian government adopted policies to stimulate its growth (e.g., exempting export revenue from taxation) that encouraged growth and kept the industry focused on the international market.

India became a major destination for the off-shoring of software work by US MNCs. Indian-born engineers who had studied and worked in the USA became critical players in the expansion of the software industry. Over a quarter of US engineering and technology firms in Silicon Valley launched between 1995 and 2005 were opened by Indians (Saxenian 2006). Indian expatriates actively contributed to the development of new Indian-based companies and the operations of US-based IT companies in India. As a result, the Indian government adopted policies to support the software industry, such as improving the physical infrastructure and opening the economy to global trade. Indian expatriates have increasingly focused on developing entrepreneurial ventures that combine US-based financing and market acumen with India-based engineering expertise.

Technological developments were also important in off-shoring IT-related work to India. The widespread adoption by the computer industry of the Unix workstation standard and the C programming language in the 1980s enabled the modularisation of programming, which helped independent software vendors to use standardised tools to develop programs for a wide range of operating systems and applications. During the 1990s, PCs with X-86 microprocessors and Windows operating systems replaced RISC/Unix workstations in programming, and the Internet provided a platform for the networked development of software and software installation, hosting and maintenance. The availability of word processing, spreadsheets, computer-aided design and drafting software combined with the Internet enabled remote, dispersed approaches to technical work, which facilitated a wide range of IT-related work in dispersed locations (Dossani and Kenney 2008).

Business factors, which have led to the development of new business models in global service industries, also contributed to the off-shoring of engineering and other services work to India. For example, Indian companies and the Indian affiliates of MNCs were well positioned to undertake much of the software coding and maintenance work in response to the Y2K crisis in the late 1990s and with that the expansion of the IT-related business-process off-shoring.

It is important to note that the Indian IT industry considers ‘engineering-services outsourcing’ as an area of significant growth. In addition to the offshoring of services, a great deal of overseas work involves the engineering of manufactured components incorporated into goods sold by US-based companies and even entire products. The number of workers employed in software development in India is increasing by 30–40 % a year, from about 2 % of US employment in 1995 to almost 20 % in 2005.

Initially the off-shoring of software development by US firms to India had one common characteristic—the work being off-shored was modular and did not require regular contact with customers. Several US companies began by contracting with a vendor to perform this non-integral work. After some time, they decided to set up Indian subsidiaries to perform more integral work. At first, although costs were lower in India, it was more difficult to hire an equivalent team there than in Silicon Valley. Nevertheless, as these companies gained experience in managing off-shoring relationships, the barriers began to come down. For example, *Broadcom*, a software-intensive semiconductor company, reports that its team in Bangalore is now as productive as its teams in San Jose and Irvine, with costs in India running about one-third of those in the USA (Dossani and Kenney 2008; Saxenian 2006).

The off-shoring of software engineering that started in the 1980s has expanded sharply since the 1990s, so that the revenue of Indian firms from software production rose from US$ 81 million in 1985–1986 to US$ 39 billion in 2006–2007, while exports as a share of revenue rose from 2% in 1994–1995 to 25% in 2006–2007 (Parthasarathy 2010). This has been due in large part to new communications technologies and the emergence of India as an offshore location. Higher value-added work based on talent will be an increasing component of off-shored software.

There are two trends emerging in the software industry. First, much routine programming is now automated. This has both reduced the programmers' share of work in software creation and increased the average sophistication of the work. Second, the growth of online collaboration via the Internet and higher capacities at lower costs offshore have increased the number of programming tasks. This may be seen from the fact that India is now the largest exporter of software after the USA, accounting for 60% of non-US software exports. Programming accounts for 60% of Indian software exports, down from 90% in 1995. Programming is, of course, not a stand-alone function. The work done by the Indian software industry is part of a supply chain, with most of the components still being fulfilled in the developed world.

Indian software employment has grown by 35% per annum over the past decade. Software-export firms located in India employed 706,000 people in 2006, up from 513,000 in 2005. In 1995, the comparable numbers for the Indian and US software industry were 27,500 and 1.5 million (which is 1.3% of the US workforce of 118 million). Two-third of India's software exports are to the USA, a share that has remained nearly steady over the past decade. Although product software is designed to meet a wide range of customer requirements, it can incorporate only a limited number of variations. Beyond this limit, software must be written to a customer's specifications. Industries such as banking, in which customer requirements vary significantly, need custom software. In general, the more varied the needs of different end-users, the more likely software is to be customised. And, because needs vary most at the applications stage, most customised software is application software.

Interestingly the founders of the top-ten software exporting firms in India were mostly educated and trained in Indian educational institutions but were able to establish strong relationships and connections with Indians abroad who provided the business acumen and knowledge of technology trends in software markets.

14.3.3 Malaysia: Entangled in Ethnic Policies

The human capital deficiency identified by several reports resulted in the government launching the Brain Gain programme in 2001 (see Malaysia 1995, 2008). A parallel programme to attract foreigners via the Malaysia as Second Home programme was implemented in the late 1990s, but it was originally only targeted at bringing to Malaysia elderly foreigners who had money to spend but were not allowed to work. A fairly substantial number of highly skilled Malaysians, estimated at around 780,000, was reported by the government to be working abroad especially in the developed economies (Mazlan 2009).[6] Recognising the role played by the diaspora in

[6] Mazlan Khamis presented his data at the Brain Gain Workshop on June 18, 2009 in Putra Jaya.

the successful upgrading experience of Korea and Taiwan, the government adopted measures to attract back talented Malaysians to the country, and hence three programmes have been introduced, with the first made operational in 1994, the second in 2001 and the third in 2006. The Returning Scientists programme (handled by the Ministry of Human Resources) and the Returning Malaysian Experts programme (handled by the Ministry of Science, Technology and Innovation) were aimed at attracting qualified Malaysians to return and participate in quickening technological upgrading.

The government approved the first scheme to attract Malaysian and foreign scientists from abroad to work in 1994. The Public Services Department issued a service circular in 1995 to set the guidelines to entice Malaysian and foreign scientists from abroad to work in Malaysia[7] in areas identified as a priority under the Intensification of Research in Priority Areas Programme (IRPA).[8] This programme was suspended in 1998 when the Malaysian economy faced a severe downturn following the Asian financial crisis. Around 93 scientists were hired under this scheme, of which 23 were Malaysians and 70 were foreigners (Thiruchelvam and Kamarul 2009).

Among the specific activities carried out under the initial brain gain programme was the hiring of an expert, Low Kwong Meng, who was instrumental in the government acquiring VLSI Technologies to start wafer fabrication operations in Malaysia. Located at the Malaysian Institute of Microelectronics Systems (MIMOS), he led a programme to transfer and root wafer fabrication. It can be argued that Silterra and first Silicon were very much the start-ups that began from such an initiative. Pointing to the expansion of wafer fabrication in Korea, Taiwan, Singapore and China, Low Kwong Meng argued that unless Malaysia made the move to wafer fabrication it would remain a low-end assembly and test site until its labour lost competitiveness.[9] With wafer fabrication as the anchor, initiatives could be taken to attract the high-end activities of design and R&D to Malaysia. However, Low Kwong Meng did not have the autonomy to carry through his plan. Two managing directors of US semiconductor firms felt that his Chinese ethnicity in a political state where Malays dominated denied him the drivers' role to implement such an expensive but necessary plan.[10]

The government then through the 2001 Budget launched the second initiative to attract Malaysian human capital back. A range of incentives were offered, which included:[11]

- Income remitted within 2 years from the date of arrival will be exempt from income tax;

[7] The government drew up guidelines to attract qualified Malaysians and foreigners to join their strategic technology initiatives.

[8] Established in 1988, IRPA was the main public funding mechanism of R&D carried out in public research institutions and universities in Malaysia.

[9] Interview by Rasiah on November 19, 1998 in Kuala Lumpur.

[10] Interview by Rasiah on March 27, 1999 in Putra Jaya.

[11] See http://www.mohr.gov.my/mygoveg/bi/gpexpert.htm for further information.

- All personal effects brought into Malaysia will be exempt from tax. Two motorcars registered in the applicant's country of residence for at least 6 months in the name of the husband/wife/child will be exempt from import duty and sales tax; and
- The spouse and children of the applicant who are not Malaysian citizens will be given permanent resident status within 6 months from the date of their arrival in Malaysia.

Since January 2001, 752 Malaysians were awarded the incentives from a total of 1340 applicants (Thiruchelvam and Kamarul 2009), while the Ministry of Science, Technology and Innovation (MOSTI) reported that until March 15, 2010 it had attracted only 650 experts to Malaysia.[12] Interviews with three returnees suggest that implementation problems and the lack of nationalist passion connecting the experts to productive roles were also major reasons why several of them left. Table 14.1 provides a summary of the key differences between the programmes administered by MOSTI and the Ministry of Human Resources (MOHR).

Whereas the focused brain gain approach of Taiwan has been successful, Malaysia's brain gain programme has proven to be less successful than even the liberal approach adopted by India, where the ethnic and religious turmoil has often erupted into costly explosions from time to time, but India's official policy has been both secular and directed towards performance and efficiency while at the same time giving preference to the disadvantaged. Official policy in Malaysia is coloured by ethnic considerations (Jesudason 1989; Rasiah and Ishak 2001). Indeed, the greatest limitation on the pursuit of technological catch-up is the perpetuation of such an ethnic-based policy.

A number of reasons can be advanced for the poor showing of the brain gain programmes.

Table 14.1 Schemes operated by MOSTI and MOHR. (Source: Thiruchelvam et al. 2003)

Aspect	Scheme under MOSTI	Scheme under MOHR
Target group	Skilled Malaysians residing abroad and foreign scientists	Skilled Malaysians residing abroad
Fields of expertise	Selected R&D fields	Wider range of fields of expertise including science and technology
Incentives given	Attractive remuneration package including education for children	All personal belongings, including two cars are given import duty exemption; and Spouse of Malaysians and children who are not Malaysians will be given permanent resident status within 6 months
Employment	Employment for those identified by receiving organisation	Government not responsible for finding employment for applicants under this scheme

[12] Informal communication with an official from MOSTI on March 23, 2010.

Although all the 33 organisations surveyed reported being aware of the circular on employment of Returning Malaysian Scientists and Foreign Scientists administered by MOSTI, only one reported employing foreign scientists through this circular. The organisations reported reluctance to implement it owing to a number of reasons. Some believe that the incentives were not attractive enough to approach top talent from abroad. Others noted the opposite by arguing that the circular would burden finances. Some organisations felt that the programme would create elements of unequal treatment among staff.

Thiruchelvam and Kamarul (2009) reported that the circular (3/1995) governing the returning Malaysian scientists and foreign scientists programme is deficient in a number of areas. The advisory members of the brain gain programme appear to be officials of the academy of sciences and retired government officials who have little links with industry. Also, the brain gain programmes do not specifically connect strategic technological catch-up initiatives—for example to transfer key semiconductor technology as in Taiwan—with the returnees. If in Taiwan groups of experts returned to run particular high-tech firms, in Malaysia the returnees have often come individually and without any strategic purpose. Even when the purpose is defined, a number of them have faced complete changes in their job descriptions.[13]

Although the brain gain programme covers the costs of relocating academics and researchers, the organisational linkages to support it is still underdeveloped. Both Public Higher Education Institutions (PHEIs) and Public Research Institutions (PRIs) do not encounter problems in recruiting foreign talent especially from India, Myanmar and the Middle East through the existing mechanisms. However, the infrastructure these organisations have established to attract the Malaysian diaspora has hardly evolved. To make matters worse, there is no database on Malaysians residing abroad. The lack of such critical information has obviously denied the government the opportunity to entice them directly.

The New Economic Model of 2010 originally targeted innovation as the instrument to transform the Malaysian economy from a middle-income country to a high-income country by 2020, but political developments towards the end of 2010 suggest that the ethnic constraints will remain to restrict the restructuring process (Malaysia 2010). While the ethno-discriminatory obstacle is a major problem, the government has not integrated its brain gain programme with its technological catch-up plans. The problems of Malaysia's initiative to attract back Malaysian experts working abroad against the background of efforts to promote structural transformation to higher value added activities can be explained by the problems hampering the country's efforts to promote high-tech industrialisation.

Given that the focus on human capital from abroad—both the Malaysian diaspora and foreigners—took a quantum leap when the government sought to stimulate the transformation of the economy to higher value added activities from the 1990s, it is worth examining the high-tech industries that were targeted for this purpose. Industries classified as strategic on this basis included semiconductors, other electronics, automotives, avionics, scientific instruments and biotechnology.

[13] Interview by Rasiah on August 2, 2007 with three returnees at the University of Malaya.

Semiconductor assembly and packaging activities began in Malaysia when National Semiconductor started operations in Penang in 1971. Subsequently the flagship firms of Intel, Hewlett Packard, Advance Micro Devices, Motorola, Hitachi, Mostek, Texas Instruments and Harris Semiconductor Technology relocated operations to make Malaysia a major exporter of semiconductor chips. After cyclical swings of demand, the industry shifted from simple low value added labour-intensive operations in the 1970s to higher value added activities as continuous improvement and automation began to proliferate in Malaysia from the 1980s. Indeed, rising adoption of cellular manufacturing techniques and automation led several semiconductor firms to outsource work on fabrication, tooling, stamping and machinery assembly to local companies in Penang (Rasiah 1994).

Unfortunately, the inability of the Malaysian economy to provide the human capital to sustain technological progress led to a hollowing out of the industry as China, Vietnam and the Philippines became more attractive for low-cost assembly and packaging. Rising demand for high value added activities in the industry was one of the propellants for a shift in government policy to attract the Malaysian diaspora and foreign human capital. Intel, Alterra, Avago, Motorola, AMD, Osram, Infineon, and Silterra managed to upgrade technologically by mopping up the Malaysian labour market of experienced engineers and technicians at the expense of local firms. Indeed, the government approved the hiring of foreign engineers and scientists and R&D grants to foreign IC MNCs in 2005. As a consequence, the IC industry has gained the relocation of two foreign wafer fabrication and seven foreign design plants since 2005. The number of researchers per million persons and R&D expenditure in GDP rose from 90 persons and 0.2 %, respectively, in 1996 to only 372 persons and 0.6 %, respectively, in 2006 (UNESCO 2010, Tables 19 and 26). In contrast, the R&D expenditure in GDP of Korea and Singapore grew from 2.6–1.5 %, respectively, in 1996 to 3.2–2.4 %, respectively, in 2006 (UNESCO 2010, Table 26).

Despite the brain gain policies, the government has failed to attract sufficient engineers and scientists to stimulate greater spread of design and R&D activities in Malaysia. The government also has yet to go beyond ethnic lenses to hire the diaspora with sufficiently long experience with buyers and sellers and R&D labs on the world stage. Examples of Malaysian experts who were not approached to relocate to run firms such as first Silicon and Silterra include the previous chief executive officer of Qimonda and the first Malaysian Managing Director of Intel Penang. Both individuals carry with them the requisite experiential and tacit knowledge to take the path Morris Chang took to position TSMC at the frontier.

Overall, Taiwan's focussed project-based targeting has been successful, while Malaysia's focus-less ethnic-coloured programme has been unsuccessful. India's liberal hands-off non-ethnic approach seems to be more successful largely because of the capacity it created from the IITs and IIMs, as well as the Indian Institute of Science. Not only has this attracted the off-shoring of R&D to India by flagship foreign MNCs, but domestically developed capabilities have also provided the synergy required to attract the diaspora. Malaysia has not only been unable to attract back significant numbers of experts but the share of R&D scientists and engineers in the population has also continued to lag far behind that of Korea, Singapore and Taiwan.

14.4 Conclusions and Policy Implications

By far, Taiwan's experience with the diaspora has been the most impressive as the government was able to appropriate the experiential knowledge gained from studying and working abroad to successfully attract them to strengthen research and teaching in the universities and R&D labs and launch and manage high-tech companies. The successful application of this saw the evolution of the IC ecology in Taiwan to world-class status. Although Malaysia attempted to follow this approach, it has largely failed to attract significant numbers of its diaspora because of institutional shortcomings. Despite not having any explicit brain gain policies, India has experienced a major return of Indian scientists, engineers and entrepreneurs to complement national technological development plans.

The experience of Taiwan shows the significance of strategic networking, India of anecdotal supports in a range of critical centres of learning, and Malaysia of a nationwide framework to attract the diaspora either by simply an open framework to welcome those applying to return or when firms or organisations target them to return. Although Taiwan's framework has been sectoral based on targeting to support strategic industries, the sum of all the strategic industries has offered the country a myriad of capabilities that co-evolved to support high-tech industrialisation. The shift to higher value added activities in Taiwan has been so complete that low-end manufacturing has been successfully relocated abroad. The return of the Argonauts has been instrumental in stimulating entrepreneurial synergies, though they have been complements rather than initiators in India. Despite massive exposure to education abroad, most Malaysians residing abroad have not returned to participate in the government's brain gain programme.

The three experiences generate important ramifications for effective public-private partnerships to breed and subsequently attract tacit and experiential knowledge targeted at driving technological upgrading. The Indian experience could also be valuable where the government invested heavily in higher education in IITs, IIMs and the Indian Institute of Science, while the private sector started to appropriate the rewards once the economy started to liberalise. The Malaysian experience should be a lesson for avoiding ethnic-based restrictions that can only impede the generation of creative synergies to drive technological catch-up.

The successful expansion of R&D indicators, initially by the government before the private sector responded to contribute more in Taiwan, shows that public expenditure on R&D has no substitutes at least in the initial phase of rapid economic development. The experience of Taiwan in hiring, as well as in interacting with national talent abroad to build the national knowledge base to orientate R&D and design to major markets and to file patents in the USA, should be taken seriously by latecomer countries. Malaysia's extremely low R&D endowments have disadvantaged the capacity of its firms to drive technological catch-up. India's massive size has restricted aggregate R&D figures from going up, but the expansion of quality education and training in the IITs, IIMs and IISc and specialised research centres suggests that the statistical progression is likely to follow China's path once a critical mass is established. Clearly, then, countries seeking to stimulate technological upgrading should address R&D deficiencies in their national, regional and sectoral innovation systems.

References

Anandakrishnan M (2009) Capitalizing on Indian expatriate experts. In: Rasiah R, Thiruchelvam K (eds) Brain gain review. MOSTI, Putrajaya

Belassa B (1982) Development strategies in semi-industrial economies. John Hopkins University Press, Baltimore

Bhagwati JN, Hamada K (1974) The brain drain, international integration of markets for professionals and unemployment. J Dev Econ 1(1):19–42

Clair B, Linden G (2009) Chips and change: how crisis reshapes the semiconductor industry. MIT Press, Cambridge

Dossani R, Kenney M (2008) Implications of globalization for software engineering. National Academy of Sciences, National Academies Press, Washington, DC

Glaser WA (1978) The brain drain: emigration and return. Pergamon Press, Oxford

Hirschman AO (1958) The strategy of economic development. Yale University Press, New Haven

Hong Y-Y (2003) Innovation engine (in Chinese). Tian-Xia Magazine, Taipei

Huang Q-Y (1995) Computer kingdom R.O.C. (in Chinese). Tianxia Yuanjian, Taipei

Kapur D, McHale J (2005) Give us your best and brightest: the global hunt for talent and its impact on the developing world. Center for Global Development, Washington, DC

Lin J-Q (2005) A research on the recruiting policy for Taiwan's IC talents. Master's Thesis, Public Administration and Policy Department, National Ji-Nan University

Lin Y (2009) The contribution of the diaspora to Taiwan's high tech industrialization. In: Rasiah R, Thiruchelvam K (eds) Brain gain review. MOSTI, Putra Jaya

Lowell LB, Gerova SG (2004) Diasporas and economic development: state of knowledge. Paper prepared for World Bank, Sept 2004

Malaysia (1995) Guidelines in the recruitment of Malaysian scientists residing overseas and foreign scientists. Service Circular No. 3 of 1995 Public Services Department, Kuala Lumpur

Malaysia (2008) Brain gain Malaysia, fast tracking innovation. http://www.bgm.mosti.gov.my/index.php. Accessed 15 Sept 2008

Malaysia (2010) The economic transformation plan. Government Printers, Putrajaya

Malhotra K (2009) The challenge of converting brain drain into brain gain for developing countries. In: Rasiah R, Thiruchelvam K (eds) Brain gain review. MOSTI, Putra Jaya

Marshall A (1890) Industry and trade. Macmillan, London

Marx K (1956) Capital: the process of circulation of capital, vol II. Progress Publishers, Moscow

Mathews JA, Cho DS (2000) Tiger technology—the creation of a semiconductor industry in East Asia. Cambridge University Press, Cambridge

Mazlan K (2009) Tapping the expertise and skills of Malaysian diaspora for economic development. Presentation at Workshop on RMK 10 Brain Gain Malaysia Programme, Putrajaya International Convention Centre, 18 June 2009

Meyer JB, Brown M (1999) Scientific diasporas: a new approach to the brain drain. Prepared for the world conference on science, UNESCO-ICSU, Budapest, Hungary

NASSCOM (2006) Globalization of engineering services: the next frontier for India. National Association of Software and Service Companies, NASSCOM. http://www.nasscom.in/Nasscom/templates/NormalPage.aspx?id=49790

Organization for Economic Co-operation and Development (OECD) (2002) International mobility of the highly skilled. Policy Brief, July 2002

Parthasarathy B (2010) The computer software industry as a vehicle of late industrialization: lessons from the Indian case. J Asia Pac Econ 15(3):247–270

Rajghatta C (2009, Nov 18) Indian students in US cross 100,000 mark. The Times of India
Rasiah R (1994) Flexible production systems and local machine tool subcontracting: electronics component transnationals in Malaysia. Camb J Econ 18(3):279–298
Rasiah R (2004) Technological capability in East and Southeast Asian electronics firms: does network strength matter? Oxf Dev Stud 32(3):433–454
Rasiah R, Lin Y (2005) Learning and innovation: the role of market, government and trust in the information hardware industry in Taiwan. Int J Technol Glob 1(3–4):400–432
Rosenberg N (1982) Inside the black box. Cambridge University Press, Cambridge
Saxenian AL (1994) Regional advantage: culture and competition in silicon valley and route 128. Harvard University Press, Cambridge
Saxenian AL (2006) The new argonauts: regional advantage in a global economy. Harvard University Press, Cambridge
Schumpeter JA (1934) Fundamentals of economic development. Harvard University Press, Cambridge
Sequin B, State L, Singer PA, Daar AS (2006) Scientific diasporas as an option for brain drain: re-circulating knowledge for development. Int J Biotechnol 8(1–2):78–90
Thiruchelvam K, Kamarul ZA (2009) Malaysia's experience at attracting human capital from abroad. Brain gain report, Ministry of Science, Technology and Innovation, Putra Jaya
Thiruchelvam K, Kamarul ZA, Koh AK (2003) A study on the returning scientist scheme in Malaysia. Report prepared for Ministry of Science, Technology and the Environment
Tung RL (2008) Brain circulation, diaspora and international competitiveness. Eur Manag J 26:298–304
UNESCO (United Nations Educational, Scientific and Cultural Organization) (2010) Science and technology report, UNESCO, Paris. http://www.stats.uis.unesco.org/unesco/ReportFolders/reportFolders.aspx . Accessed 18 Sept 2010
Xu JY (2000) Development of Taiwan's semiconductor industry: government interference, cross national social network and development of high technology (in Chinese). Proceedings of the history of Taiwan industrial development, National Scientific Industrial Museum, Kaoshiung, pp 101–132
Zhang J-Y, Bo-Long Y (2001) Vitality: how Taiwan creates the miracle of semiconductor and personal computer industries (in Chinese). China Times Culture, Taipei

Chapter 15
Unveiling Innovation Dynamics and Development Processes: A Mexican Perspective

Elisa Calza and Mario Cimoli

15.1 Introduction

Over the past decades, Mexico has undergone a significant process of economic restructuring, characterised by important structural reforms, privatisation of services and openness to world economy. The country incorporated most of the recommendations of structural adjustment, implementing trade liberalisation and the 'right macroeconomic policies' in order to restore macroeconomic balance after years of crises and volatility. Mexico's experience is very significant and illuminating when it comes to analyse the implications of these policies on the economic system and on its development.

This chapter looks at the effects of the economic reforms on Mexican innovation dynamics, in light of the transformations that these same reforms induced on the country's economic and productive system, focusing in particular on the accumulation of domestic technological capabilities. Starting from the framework of analysis presented in the book *Developing Innovation Systems: Mexico in a Global Context*, we analyse how macroprices (such as interest rate and exchange rate) and macroeconomic fundamentals affected the pattern of generation and diffusion of innovation through their interaction with the productive system, and what this implied for the development of the institutions for science, technology and innovation (STI) and of endogenous technological capabilities.

This chapter aims also at debating the 'classical' notion of a National Innovation System (NIS) as an unquestionably powerful tool for development, questioning the

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assumption that the existence of an NIS should be per se a sufficient condition to sustain innovation dynamics, as if the construction of links, networks and institutions could almost naturally guarantee the take-off of innovation and development processes. Innovation is one of the main drivers of development and the concept of NIS has undoubtedly represented an important contribution to understanding innovation mechanisms and shedding light on the functioning of this sort of 'black box'; however, considering the NIS as a mighty panacea could be misleading when applied to the case of developing countries.

This chapter addresses a certain 'too-confident' and unconditioned trust in NIS potentialities in supporting innovation dynamics. The question is whether it makes sense to support the consolidation of an NIS with attractive and fashionable notions such as networks and institutions, while the economy remains characterised by an overvalued exchange rate, tight fiscal expenditure and unconditional openness to foreign markets. In such a context, are innovation efforts weakened and even neutralised despite a sound NIS? A broader view embracing the whole system of economic policies and incentives is needed to avoid the notion that NIS turns out to be a nice but empty and insubstantial conceptual framework, unable to effectively foster development processes if detached from consistent economic policies.

Our discussion moves from a structuralist perspective. According to this, real support to innovation should be grounded in the long-term consistency between economic and innovation strategies. The crucial point is the relative weight assigned to economic fundamentals with respect to the one assigned to the consolidation of an NIS in affecting innovation dynamics: embracing a structuralist perspective would allow recognising the different role of both macroprices and productive structure in triggering innovation dynamics, considering innovation as the actual product of a coevolution process between economic settings, productive structure and the Innovation System, a process characterised by co-dependence and constant feedback mechanisms.

Almost 20 years after the implementation of the first reforms, Mexico's economic growth remains too low to close the gap with wealthier developed countries and it still struggles to compete with other large emerging economies in terms of productivity growth; thus, it is reasonable to raise doubts about the effectiveness of the strategies followed so far. The main lessons from the Mexican experience is that the efforts spent in supporting innovation dynamics, even through the consolidation of an NIS, may be vain and inconclusive for development if they are not complemented by adequate macroeconomic policies and consistent industrial policies, which are the only way to effectively strengthen the development of endogenous capabilities and boost innovation.

We believe our discussion and conclusions may be particularly useful for other emerging and developing countries that are currently struggling towards the consolidation of a sound economic pattern, in particular for those developing countries that present similar characteristics as Mexico—such as macroeconomic instability, scarce relevance of the high-technological sector over total value added, external openness of the economy and dependence on foreign markets as export destinations and as the source of technological imports.

This chapter is structured as follows. The next section is dedicated to the discussion of the macroeconomic policies implemented in Mexico over the past 20 years, focusing on how these policies affected productive structure, institutions and innovation dynamics. The third section presents the state of innovation in Mexico, with specific focus on the processes of generation and accumulation of technological capabilities within the post-reform Mexican productive system. The fourth section addresses the concept of coevolution among different dimensions of innovation dynamics and proposes a critical debate around the shortcomings of the 'classical' approach to NIS in a developing context. The last section concludes with general assessments of current Mexican innovation dynamics and some recommendations.

15.2 Macroeconomic Fundamentals, Productive System and Institutional Infrastructures: The 'Locus' of Innovation After 20 Years of Economic Reforms

This section looks at the impacts of the economic reforms on Mexican innovation dynamics, in light of the transformations that these same reforms induced on the country's economic and productive system. Our analysis will follow three fundamental dimensions of innovation dynamics where innovation takes place and develops: macroeconomic regimes, the productive system, and institutions shaping the NIS.

15.2.1 Macroeconomic Regimes: A History of Achievements and Shortfalls

Mexico's experience is very interesting in order to analyse the outcomes of the implementation of market-oriented economic reforms, since it reveals a mix of policies which turned out to have controversial effects on innovation dynamics and on endogenous capabilities. Since macroeconomic regimes primarily shape the economic context and delineate trade conditions with the rest of the world, they play a significant role in defining the economic incentives that affect production and industrial performance, determining how agents participate in the innovation process and how technological progress occurs. This is particularly true in the case of developing economies, whose industrialisation path relies on borrowing and import of foreign technology (Cimoli and Dosi 1995).

In previous decades, Mexico went through the implementation of various macroeconomic regimes. Between the mid-1950s and the early 1970s, the Mexican economy went through an economic phase of 'Import Substitution' (ISI): a regime of intensive protection took place, where high trade barriers were complemented with policies aimed at promoting industrialisation by favouring the use of domestic suppliers and imposing requirements of local contents for industrial investments (Cimoli 2000).[1] Public investments were directed to the creation of infrastructures and capacities in scientific and technological research, represented by the organisation of an institutional structure for Science and Technology and the formation of specialised human resources. Despite the creation of suitable conditions for the accumulation of domestic technological capabilities, the country was not able to take advantage of this favourable situation to push scientific and technological take-off (Cimoli 2000; Cimoli et al. 2009), and during the 1970s the shortcomings of the ISI model became evident.

With the aim of reducing some drawbacks of the ISI pattern such as excess protectionism and wastage of resources, between 1970s and early 1980s a new phase took place that was defined as the 'transition period'. Mexico started dismantling its tariff system and some anti-export biases were eliminated, allowing for some degree of foreign competition in order to improve quality and competitiveness. Around the mid-1980s, the Mexican economy started to show signs of great instability and volatility, turning into a very unfavourable environment for innovation and investments, with the consequent phenomena of capital flight and deterioration of the balance of payments (Capdevielle 2000; Capdevielle and Dutrenit 1995).

The 1990s were years of radicalisation and consolidation of the economic reforms, implementing structural adjustment programmes designed under the influence of the Washington Consensus. Mexico is probably the best example of the application of a recipe of pure market-led/inflation-targeting macroeconomic policies. The aim of the economic reforms was stabilising macroeconomic behaviour through price stabilisation policies and public and external deficit reduction, allowing for exchange rate fluctuations. Moreover, based on the 'less State–more market' assumption, reducing State intervention in the economy and deepening the degree of openness to world trade were other major pillars of this policy mix, this last one resulting in progressive tariff elimination and culminated in Mexico joining the North American Free Trade Agreement (NAFTA) in 1994.[2]

The macroeconomic reforms were deep and pervasive, but at the same time their effects turned out to be ambiguous: the 'rules of the game' changed radically and the new macroeconomic regime designed private investments and export as the main economic drivers, changing the set of incentives for the productive system and reducing the degree of public interventions in the economy. This implied a complete 'watering down' of existing industrial policy, followed by the privatisation and the massive sale of state enterprises,[3] with the elimination of any subsidies and incentives based on criteria such as national features of production, favouring

[1] This development strategy was grounded on the 'infant industry' argument. The idea of infant industry is based on the idea that although developing countries may have a potential competitive advantage in manufacturing, their lack of experience does not allow them to compete with developed countries, and thus they need temporary protection while acquiring capabilities (Cimoli 2000; see also Fransman and King 1984; Lall 1982).

[2] Mexico joined the agreement in January 1994, with the aim of eliminating all tariff and non-tariff barriers over goods and investments over no more than 15 years.

[3] By the mid-1990s more than 1000 of the 1155 public enterprises that existed in 1982 had been sold to private organisations. This attitude has not changed in the last decade, and still today the

horizontal interventions and subsidies to import of production inputs (Moreno-Brid and Ros 2009). This absence of any industrial policy is still a feature of the Mexican economy (Cimoli et al. 2009).

Since the implementation of the reforms, Mexico has made visible progress in terms of macroeconomic stabilisation, keeping inflation under control and managing successfully to reduce fiscal deficit, which between 2007 and 2009 fell below 2 % of GDP. The economy had been growing at a reasonable rate of 3.5 % yearly between 1995 and 2000, and also the external debt of the public sector had been notably reduced, reaching 6.1 % of GDP in 2008, which is 15 % points below its 1998 level.[4] However, after 20 years of economic reform, the Mexican economy is still burdened by many limitations and bottlenecks, and most are the same that the economic reforms aimed at eliminating.

Mexican long-term economic performance is still far from being impressive: during the early 2000s—when international conditions were potentially favourable for such an open economy. Mexican economic growth fluctuated around a modest average rate of 0.7 %, between the lower limit of −0.03 % in 2001 and the upper limit of 1.39 % in 2003 (Fig. 15.1). Despite the growth episodes of the last decade, the level of Mexican per capita GDP is still not outstanding even when compared with other Latin American countries (Fig. 15.2).

Investments did not respond as well as expected to economic reforms and fiscal stabilisation. The scarcity of investment is also explained by the frailty of the credit system, which has been affected by a chronic credit crunch since bank reforms in

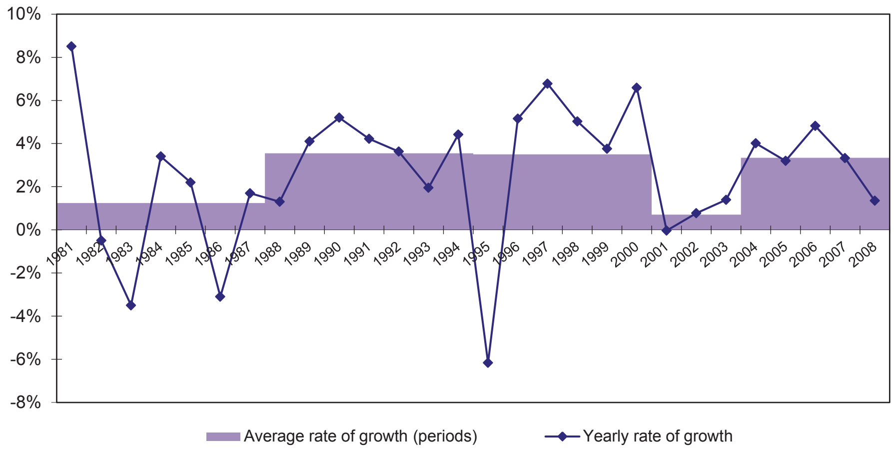

Fig. 15.1 GDP rate of growth 1981–2008. (Source: Authors' elaboration based on PADI Statistical Database)

only sector where private participation is restricted and regulated is basic petrochemicals (Moreno-Brid 2009).

[4] In dollars, the external debt of the public sector corresponded to US$ 56,000 (check accuracy of the zeros) million in 2008, 40 % less than its value in 1998 (Moreno-Brid 2009).

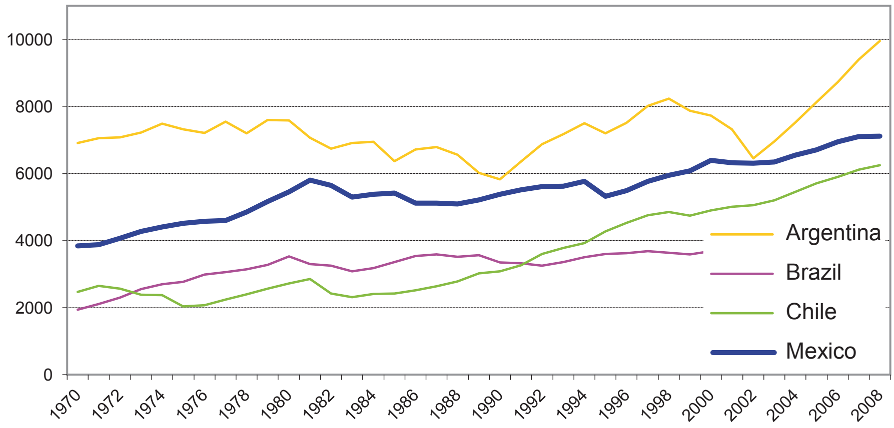

Fig. 15.2 Argentina, Brazil, Chile and Mexico: GDP per capita 1970–2008 (constant US dollar 2000). (Source: Authors' elaboration based on PADI Statistical Database)

the 1990s and the internalisation of the major banks of the country. Furthermore, Mexican investment figures were even worsened by the contraction of public investments as a consequence of the cut in public expenditure, which thus could not act either as a 'spare wheel' or as a stimulus to drag-in private investment (Moreno-Bird and Ros 2009).

Comparing the rate of growth and trade balance over past decades, the limitations of this kind of pure market-led/export-based model become evident. After 20 years of economic reforms, the Mexican economy still presents a trade deficit as large as it was in the 1970s, while the economy is growing on average one-third of its growth at that time (Fig. 15.3; Cimoli et al. 2010; Moreno-Brid 2009).

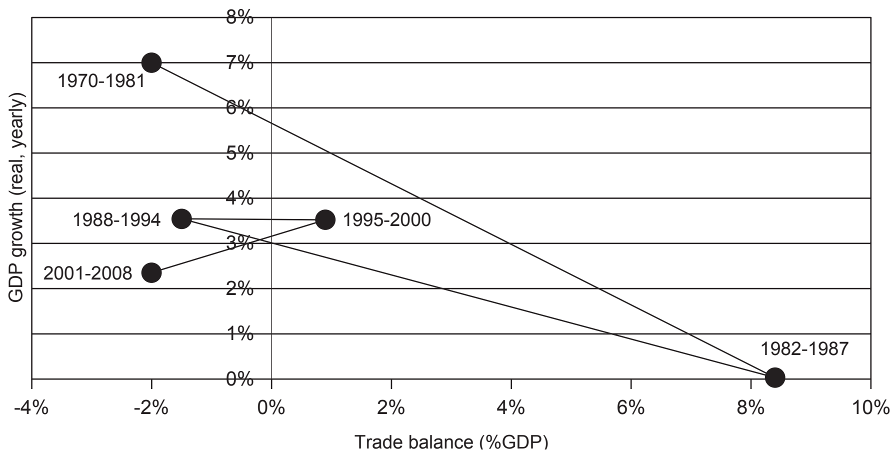

Fig. 15.3 Trade balance and GDP growth 1970–2008. (Source: Moreno-Brid and Ros 2009; see also Cimoli et al. 2010)

15.2.2 *Mexican Productive System: A Never-Ending Traverse*

The Mexican productive system was deeply affected by the different macroeconomic regimes that came in force during past decades. The 1990s reforms signalled a marked evolution for the Mexican productive system in general, and for its manufacturing sector in particular. The limitation of State interventions, privatisations and elimination of industrial policies deprived Mexican firms of the shelter of public protection, leading them to undertake a process of production rationalisation and increase of efficiency under the influence of market-led incentives (Cimoli et al. 2009). The liberalisation of trade forced the production system to become more competitive and to modify its priorities, redirecting efforts and productions towards foreign markets instead of domestic demand. Firms had to improve their organisational efficiency and modernise their productive processes through the incorporation and adaptation of foreign production techniques implemented through the use of imported technology.

These changes had multiple and controversial consequences on the productive systems. First, after years of losing ground in terms of participation in total value added, during the 1990s the manufacturing sectors (in particular hi-tech and engineering-intense sectors) started growing faster than other industrial sectors in terms of total value added contribution (Garrido and García 2010). Second, since the signing of NAFTA, manufacturing exports increased dramatically, doubling its participation in total GDP between 1994 and 2008[5] (Fig. 15.4). Third, not all

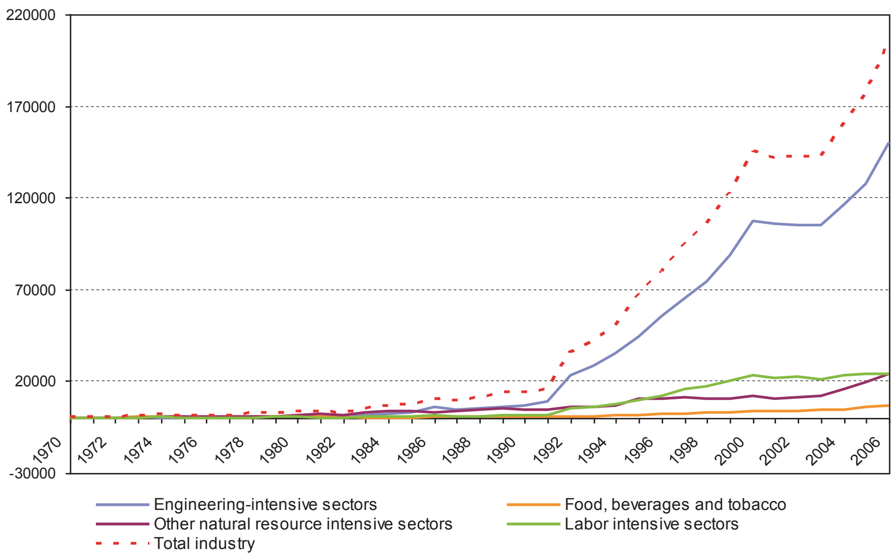

Fig. 15.4 Industrial exports 1970–2006. (Source: Authors' elaboration based on PADI and BADECEL Statistical Databases)

[5] At the beginning of the 1990s industrial export represented almost 15 % of GDP, while in 2010 their value reached 30 % of GDP, 87 % of which is originated by manufacturing segments (Garrido and García 2010).

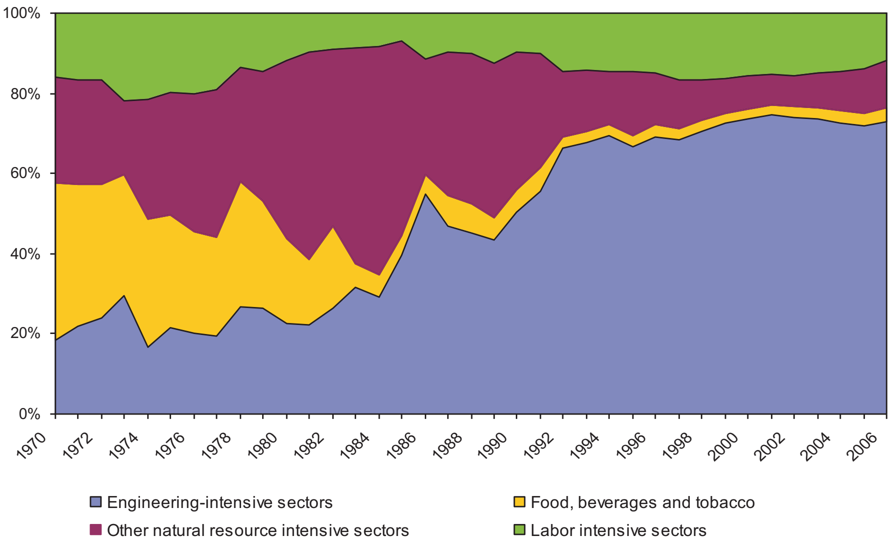

Fig. 15.5 Industrial export composition 1970–2006 (current US dollar, million). (Source: Authors' elaboration based on PADI and BADECEL Statistical Databases)

industrial sectors could benefit equally from the trade openness, since the observed export growth was concentrated in a few industries, inducing a deep change in the Mexican industrial export pattern: hydrocarbons ceased to be the most exported item (in value) and its relative importance was eroded by the increase of manufacturing exports, in particular engines and automotive components, electronic equipment and other electronic instruments (Fig. 15.5).

These macroeconomic and trade reforms pushed the manufacturing sector towards a peculiar configuration, defined as *industria maquiladora* (or *maquila*). The *industria maquiladora* is the natural flip-side of the liberalisation of trade policies: the compliances of NAFTA require production to be fully exposed to external forces and, in order to work properly, the productive system needs a fully liberalised trade regime that facilitates the import of foreign inputs and the commercialisation of productions on foreign markets (Capdevielle 2000; Capdevielle and Dutrenit 1995).

A first characteristic of the *maquila* system is the reduced content of local contribution to the value added of the final product. Since competitiveness is not based on the creation of new products or on the development of new processes, the *maquila* system itself does not provide any incentive to increase the level of technological sophistication. Domestically produced goods are mainly concentrated in traditional sectors and became specialised in the most labour-intensive segments of the whole productive chain (such as automotive, textiles and basic electronics), which implies the development of relatively easy and elementary processes, using low-skilled labour and reducing production to the mere assembly of imported inputs (ECLAC 2007, 2008).

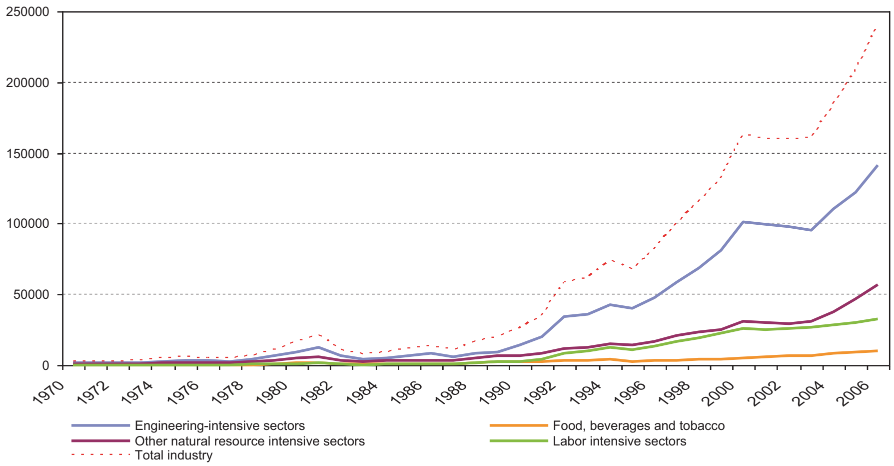

Fig. 15.6 Industrial imports 1970–2006. (Source: Authors' elaboration based on PADI and BADECEL Statistical Databases)

A second feature is concentration. In terms of export destinations, at the outbreak of the 2008 financial crisis almost 80 % of the total export value was directed to the USA, which made the Mexican economy extremely dependent on US demand and vulnerable to abrupt changes (ECLAC 2007, 2008). Turning to firm concentration, global multination enterprises (MNEs) and large firms dominated the post-reform transformation of the productive system, while domestic firms were not given options other than satisfying the new external-led requirements of being internationally competitive and rationalising their production (Capdevielle 2000; Capdevielle and Dutrenit 1995). This resulted in a dramatic polarisation of firm magnitude across sectors from the mid-1980s, where the large majority of productive plants (95 %) are constituted of microplants with a maximum of ten employees (Garrido and García 2010).

Another feature is the dependence on the import of capital goods and technology for production processes (Capdevielle 2000; Fernandez 2000). Coherent with the logic of the *maquila*, imports rose symmetrically with exports, in particular of capital and more technologically sophisticated goods, which serve as input for a production system increasingly dependent on imported technology (Fig. 15.6). The value of imported products, services and other primary goods is so high that the trade surpluses with the USA (originated from the export of *maquila* products) and the surplus from oil exports are not sufficient to compensate for the commercial deficit the country has with the rest of the world (Fig. 15.7).

Two major issues lie behind this import boom. The first is a real exchange overvaluation, which made it more convenient to acquire even simple technology from abroad. This favoured the consumption of foreign technology at the expense of domestic production and of local investments, whose lack had to be compensated by the inflow of foreign direct investments (FDI) (Garrido and García 2010). Thus,

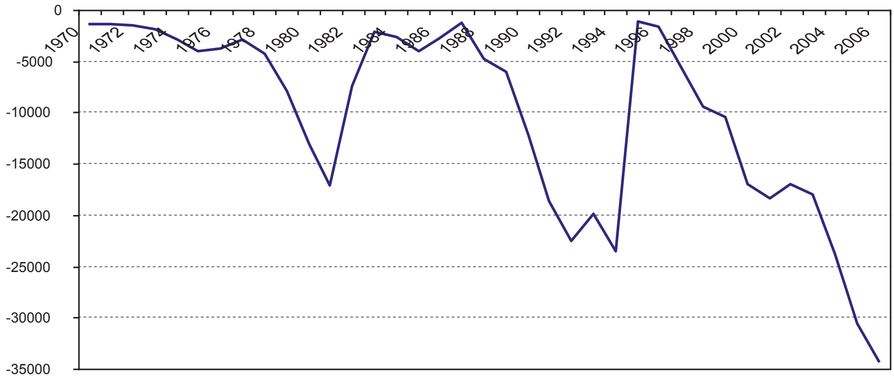

Fig. 15.7 Industrial trade balance 1970–2006 (current US dollar, million). (Source: Authors' elaboration based on PADI and BADECEL Statistical Databases)

firms have to accept FDI or become involved with MNEs to guarantee their export channels and to receive the investments needed to implement production processes based on the purchase of foreign technology (Cimoli 2000).

A second—and strictly related—issue is the simplification of the local productive chain. The *maquila*'s dependence on foreign capital goods resulted in scarce local sourcing and a limited purchase of Mexican-produced inputs (Capdevielle and Dutrenit 1995). The observed rise in imports simply reflects the new relationship between domestic exporting firms and their foreign suppliers: national firms are no longer motivated to maintain an inward orientation that may benefit the development of local markets, since their initial providers and final consumers are out of domestic boundaries. These inhibited the creation of domestic intra- and intersectoral linkages among local firms and caused the dismantling of domestic productive linkages, leading to a loss of articulation in the existing domestic productive networks and scarce local contribution to the value of industrial output.

Were economic reforms and trade liberalisation, implemented through the promotion of an export-based development strategy, a good strategy in terms of long-term economic performance? In the Mexican experience, the reforms turned out to have many limitations.[6] The Mexican productive system still faces a peculiar dichotomy within the domestic manufacturing sector, where a small group of modernised firms became more successful than a much larger group of small and much less efficient domestic companies. Furthermore, these large, highly efficient, well-financed successful exporter firms are characterised by weak linkages with local actors and institutions, while they are fully globally integrated within international value chains (Capdevielle 2000; Capdevielle and Dutrenit 1995). This

[6] However, the Mexican experience does not imply that trade openness cannot contribute to economic growth. This depends on the pattern of static comparative advantages and the dynamic potentialities of the economic structure: if comparative advantages force the economy to concentrate efforts and specialise in dynamics sectors, with higher returns and higher positive externalities, then trade openness may be beneficial for the economy.

results in an increase of the heterogeneity within the productive system, where positive externalities from innovation and technology adoption are limited to some export-oriented sectors and to some successful and globally integrated firms.

Thus, the export-based economic strategy—induced by trade liberalisation—had probably been a good growth strategy only for Mexico's foreign supplies, but not for Mexican producers and exporters. This expansion of internationally competitive export sectors has not been able to drag the growth to other industrial sectors and to generate spillovers towards the rest of the economy, while the destruction of existing backwards and forward linkages implied that only a limited group of actors could benefit from the economic achievements of the *maquila* system (Garrido and García 2010).

In this way, Mexico's most successful manufacturing sectors turned out to be 'disconnected' from the rest of the industrial sector and of the economy, due to this lack of interrelation with the domestic environment (Garrido and García 2010; Moreno-Brid and Ros 2009). This 'disconnection' had dramatic consequences in terms of generation and diffusion of endogenous technological capabilities, which are crucial for innovation processes, since the constant need for foreign capital and the dependence on external imports for most sophisticated inputs minimised the incorporation of domestically developed technological capabilities.

15.2.3 National Innovation System: Evolution of the Institutional Infrastructure

The notion of NIS reassumes the systemic interactions that take place in innovation processes across different levels and between various components of inventions, research, technical change and learning. The central idea is that what appears as innovation at the aggregate level is the result of an interactive process that involves many actors at the micro level, and that many of these interactions are governed by nonmarket institutions (Soete et al. 2009). Indeed, the NIS can be defined as "a set of institutions whose interactions determine the innovative performance of national firms" (Nelson 1993), where institutions are in the broad sense of habits and practices, or routines.[7] This definition stresses the importance of firms as the core institutions within the NIS, since this is where these technologies are developed and incorporated (Cimoli 2000).[8]

During the past 20 years, a quite well-articulated institutional infrastructure for innovation activities has been set up in Mexico, involving firms, research centres, universities, government institutions, laws and regulations. Mexican institutional

[7] For more details see Freeman (1987), Dosi (1988), Dosi et al. (1990), Edquist (1997), Lundvall (2004), Soete et al. (2009), Nelson and Winter (1982).

[8] Other similar definitions of the NIS can be found in Lundvall (1988) and Meltcafe Metcalfe (1995).

infrastructure has been found to be quite adaptive and dynamic, as it evolved along different economic and political phases.[9]

The development of a Mexican 'institutional infrastructure' for innovation began during the ISI phase, with the public sector playing a fundamental role in the development of a national infrastructure for STI activities. In this period, STI and industrial policies were co-ordinated to promote the development of innovation activities, and this mix of STI and industrial policies allowed the creation of the first national industrial base (Cimoli et al. 2005; ECLAC 2002). The *Consejo Nacional de Ciencia y Tecnología* (CONACYT) (1970) and other public institutions were created to generate scientific and technological research in sectors considered as crucial for national industrial development, such as energy, petrochemicals, telecommunications and transport (Casalet 2003).[10]

Between the mid-1970s and the 1980s—the 'transition period'—the support for a significant involvement of the State in economic issues started to lose ground. The most significant document of this period was the *Programa Nacional de Desarrollo Tecnologico y Cientifico* (PRONDETYC) (1984–1988), which recognised the concept of an NIS and the role of scientific research in triggering development. However, due to increasing fiscal management problems, R&D expenditures were still stuck around 0.26 % of GDP in 1988 (that in value corresponded to almost the same expenditures as in the 1970s).

In order to integrate technology issues with the development of the productive system, the first *Programa Nacional de Fomento Industrial y Comercio Exterior* (PRONAFICE) (1983–1988) was released. The document already has the flavour of macroeconomic reforms that were about to be implemented: its approach towards the productive system invokes a reduction of economic protection through the dismantling of the tariff system, opening up to international trade, and promoting an industrialisation pattern that would consolidate Mexican integration into global production chains (Sollerio 2007).

The transformation of the Mexican NIS culminated in the 1990s. The already weakened industrial policy was eliminated and sectoral productive policies were substituted by neutral, horizontal policies, which did not have to interfere too much with the 'natural' functioning of the market and mainly relied on demand-based subsidies as the preferred instrument. Coherent with the general spirit of fiscal austerity, public expenditure in STI started to be seen as unnecessary, since private sector demand was expected to become the main actor affecting and financing STI activities.

The *Programa Nacional de Ciencia y Modernizacion Tecnologica* is the most significant document of the reforms period. Fully embodying the spirit of the reforms, it stated that international competitiveness had to be a leading factor for

[9] A summary of the evolution of Mexican STI institutions can be found in the Appendix.

[10] Examples are: the *Instituto Nacional de Investigaciones Nucleares* (ININ), *Instituto de Investigaciones Eléctricas* (IIE), *Instituto Mexicano de Tecnologíadel Agua* (IMTA), *Instituto Mexicano del Petróleo* (IMP), and the *Servicio de Información Consultoría y Capacitación Tecnológica* (INFOTEC).

technological modernisation, and that the scientific and technological backwardness of the country were precisely due to its excessive level of protection. The *Programa* proposed the gradual elimination of any protection over domestic technological development and introduced important changes in the criterion of allocation of financial resources for STI activities.

Firms did not received any fiscal incentive to invest in R&D activities, and, in order to further limit fiscal expenditure, even public research centres were forced to auto-finance, generate and rely on their own resources (Sollerio 2007). The assignation of eventual subsides become linked to proved quality achievements; however, since research quality was evaluated in terms of academic production, this generated a kind of 'adverse selection' over beneficiary institutions, and excellence centres became more likely to receive significant support, besides what their real needs were. Despite this stress on quality, overall R&D expenditure did not rise significantly with respect to past years, reaching 0.34% of GDP between 1990 and 1994.

In the 2000s, the first significant publication for the consolidation of an NIS was the *Programa Especial de Ciencia y Tecnologia* (PECYT) (2000–2006). The document tried to help strengthen the circulation of information within the system and favoured the participation of the private sector in total R&D expenditures. Resources invested in R&D slightly increased between 1995 and 2000, reaching 0.4% of GDP; however, despite the target of 1% of GDP by 2006, R&D expenditures only slightly exceeded 0.4% of GDP in 2006. In 2002, the *Consejo General de Ciencia y Tecnologia*[11] was established as responsible for STI policy and the supreme authority of the CONACYT.

The *Programa de Ciencia y Tecnologia e Innovacion* (PECYTI) (2008–2012)[12] has not marked any significant change in the STI policies. The document explicitly addresses for the first time the issue of a balanced regional distribution of STI resources and activities, and proposed an ambitious target of 2% of GDP for R&D expenditures by 2025. Its importance lies in the fact that it opened the way for the reform of the *Ley de Ciencia y Tecnología*, issued in June 2009, which includes for the first time a boarder concept of innovation as "the generation of new product, design, process, service, method or organisation, or increasing current values". It also proposes to rethink the articulation between education/basic science and applied science/technology and innovation, supporting the creation of Technology Transfer Offices within universities and research centres in order to facilitate their responsiveness to private sector demand for innovation. Despite its improvements with respect to previous STI programmes, the PECYTI fails to provide a clear positioning to STI policies in relation with other economic and productive policies. Thus, Mexican NIS still lies as an isolated element not fully integrated with other public policy issues (Sollerio 2007) (Fig. 15.8).

[11] Together with the *Consejo General de Ciencia y Tecnologia,* in 2002 the *Foro Consultivo Cientifico y Tecnologico* was also established, as permanent advisor to the government on STI policy issues.

[12] The PECITI is part of the *Plan Nacional de Desarrollo* (PND) 2007–2012.

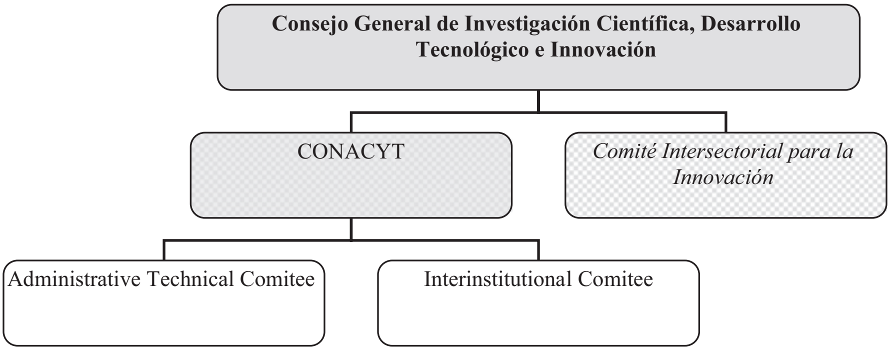

Fig. 15.8 Government actors in the National System of Science, Technology and Innovation. (Source: Garrido and García 2010)

Mexican NIS is far from being fully developed and articulated, still characterised by many weaknesses: R&D expenditures have maintained a low profile and are concentrated on the acquisition of foreign technology, while incentives to innovate have remained linked to market priorities. This inhibited the generation of endogenous capabilities and constrained even further the domestic supply of technological and capital goods, consequently limiting the articulation of the NIS (Sollerio 2007). Finally, the principal focus of Mexican NIS is too biased in favour of scientific and research activities: the prime actors are universities and research centres, which employ most of the researchers, while very few work in firms or private enterprises.

In sum,[13] STI programmes and plans have been constantly released in past decades, but they failed to significantly affect innovation outcomes. Macroprices and macroeconomic goals have always prevailed over STI targets and innovation dynamics. STI programmes have often been more rhetorical than truly committed to the effective strengthening of STI policies, and their lack of clear long-term priorities reflects the lack of continuity across political terms (Cimoli 2000; Garrido and García 2010).

15.3 Innovation Dynamics

15.3.1 At the Root of Innovation: Technological Capabilities

Economic development is the process through which a country transforms its productive and employment structures on the basis of learning and the accumulation of technological capabilities. Technological capabilities are the intangible resources needed to endogenously generate and manage technological change, the acquisition of embodied technology and labour skills, the management of organisations and the assimilation of knowledge; thus, they are at the base of innovation dynamics (Cimoli 2000; Cimoli and Porcile 2009).

[13] See also Table 3, p. 46.

The acquisition of technological capabilities is not a linear and instantaneous process: it is a dynamic and heterogeneous phenomenon, which is built over time and through a complex learning activity. Technological capability generation and accumulation are sensitive to changes in macroeconomic fundamentals and are not neutral to the configuration of the production settings (Cimoli and Porcile 2009). Thus, according to this coevolutionary perspective, the institutional infrastructure of the NIS should provide adequate conditions for technological capabilities to be developed, bringing together macroeconomic priorities and production capacities.

Production capacity provides a concrete base for the development of technological capabilities and the evolution of technological capabilities affects in turn the consolidation of sector-specific production capacity. It is true that an invariant sequence of industrial sectors cannot be univocally associated with a correspondent pattern for the upgrading of technological capabilities; but, on the other hand, a certain sequence of sectors can be identified in the development of national production capacities within the predominant mode of sectoral technological patterns. In other terms, different sectors can be associated with different combinations of productive capacities and technological capabilities, which determine different learning processes and—consequently—ways of carrying out innovation. Sectors are dissimilar not only because they produce different goods, but also because they present different technological patterns (Cimoli 2000).[14]

This interplay between production capacity and technological capabilities is what gives rise to structural change. The importance of structural change for development was first explored by development theory pioneers;[15] they investigated the role of the transformation of productive and employment structures in fostering economic development, driven by technological innovation and the reallocation of production factors from low-productivity sectors to high-productivity ones. Since some industrial activities imply more sophisticated 'learn and search' processes, which cannot be reduced to simply acquisition and adaptation of foreign technology but require a more complex absorption and assimilation process, they tend to raise sectoral productivity and to produce positive externalities for the whole economy by generating rents based on knowledge and learning activities rather than on the availability of natural resources or cheap labour—thus, they drag economic growth upwards and allow for the development of endogenous technological capabilities (ECLAC 2002, 2007). This happens, particularly in manufacturing, especially hi-tech and engineering-intensive sub-sectors (Cimoli and Porcile 2009; Cimoli et al. 2010).

In sum, the continuous accumulation of endogenous technological capabilities is a necessary condition for sustained and long-term economic growth; at the same time, a proper development of technological capabilities seems not to be possible without major structural changes that expand the manufacturing sector and involve endogenous skills in a set of core technologies (Cimoli et al. 2009).

[14] This is precisely the idea that underlies the conceptualisation of various classifications of industrial sectors, such as the one proposed by Pavitt (1984) according to sectoral efforts in acquisition of knowledge leading to innovation. For more details see Katz (1984) and Cimoli (1988).

[15] Hirschman, Prebisch, Rosenstein-Rodan, Gerschenkron, Chenery and Sirkin are some of the classical authors in development theory.

Market signals alone are often not enough to foster the accumulation of technological capabilities, and in some case they compromise their generation. It is during the catching-up phase that the distance from market signals becomes more important, precisely because learning-intensive industries are still fragile (Amsden 1989; Ha-Joon 1994, 2001; Cimoli et al. 2009). Effective learning necessarily relies on active policies, which—together with the institutional framework—have to provide incentives as well as to impose costs and sanctions on industries and firms that fail to achieve the targeted rate of learning (Cimoli and Porcile 2009).

Looking at Mexican experience, it becomes clear that an increasing weight of the manufacturing sector does not automatically mean that technological capabilities can soundly develop. During the ISI period, public policies succeeded in having a major impact on the intensity and direction of technological learning and in diversifying the industrial sector, since the granted protection allowed for building up capabilities, skills and institutions (Cimoli and Porcile 2009; Katz 1987; Katz and Ablin 1978; Lall 1982). However, the after-reforms macroeconomic context modified this pattern of learning in Mexico (Cimoli and Katz 2003; Teitel 2004). The consolidation of the *maquila* manufacturing system led to a concentration of most technological modernisation within large exporter firms and in some dynamic export-oriented segments of the manufacturing sector, which turned out to be unable to generate technological capabilities and to boost productivity growth of the whole industrial sector. The way foreign technology was incorporated in the productive system constrained even further the generation of endogenous technological capabilities, since it led to a progressive weakening of productive domestic chains (Sollerio 2007).

Mexican scarce accumulation of technological capabilities is the natural outcome of the type of economic reforms implemented from the 1980s. Aggravated by the complete absence of any industrial policies since the 1980s, Mexican productive transformation constrained the scope for learning, giving rise to the current situation of scarce technological opportunities and weak, heterogeneous and highly dispersed technological capabilities. This had not only the effect of inhibiting the creation of domestic supply of technological and capital goods, but—as a vicious circle—also limited the surge of a more sophisticated domestic demand being capable of boosting innovation (Cimoli 2000; Villavicencio et al. 1995).

In Mexico, learning and innovation processes have been responsive primarily to price and market signals, rather than tailored and co-ordinated STI policies. Policy makers and politicians need to have in mind that the consolidation of Mexican competitiveness in the global context could be achieved only through the accumulation and upgrade of local endogenous technological capabilities.

15.3.2 Innovation: Facts and Figures

Trade openness and economic deregulation promoted by the economic reforms of the 1990s could have hypothetically been beneficial to innovation. Unfortunately, by looking at some indicators related to innovation and innovation activities, it can be noticed that none of these hypothetical effects occurred.

Table 15.1 Total gross domestic expenditure on R&D (percentage of GDP). (Source: Authors' elaboration based on RECYT and UNESCO databases)

1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
0.31 %	0.34 %	0.38 %	0.43 %	0.37 %	0.39 %	0.44 %	0.43 %	0.47 %	0.50 %

R&D expenditure is more representative of innovation efforts than innovation as a process (Table 15.1), but it is useful to have an idea about the commitment towards innovation and its potentials. Mexican performance in terms of total R&D expenditure is still far from being impressive, especially due a scarce private sector participation in financing as well as in performing STI activities, which has not yet replaced the public sector as the main executor and financial supporter (Fig. 15.9).

The number of researchers employed in R&D activities relates to scientific and technological research outcomes, but it can be used to get an idea of innovation potentials and the quality of the scientific base of the NIS. The share of researchers[16] in the labour force[17] has been increasing during past decades, but its rise since 2003 is more marked and led to doubling the rate between 2003 and 2006 (Fig. 15.10).

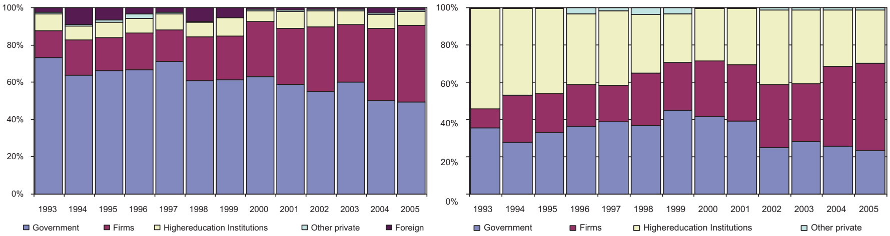

Fig. 15.9 R&D expenditures, financing sector (*left*) and performing sector (*right*) 1993–2005. (Source: Authors' elaboration based on RECYT database)

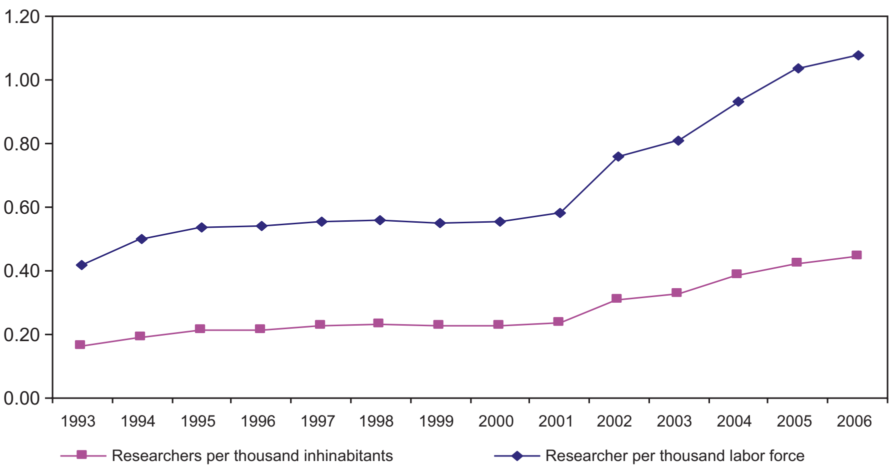

Fig. 15.10 Number of researchers. (Source: RICYT)

[16] Support and administrative staff are not included.

[17] Labour force is represented by economically active population (see RICYT).

This means that all the efforts and resources spent on human resources formation were somehow effective in creating a minimal 'critical mass' for research activities.

Turning to patents activity, the number of patents requested and granted by residents has remained more or less constant since 1990, while patents of non-residents have increased, especially in past years (Fig. 15.11). The dependency rate[18] (Table 15.2) shows how large is the gap between the patent applications of residents and non-residents, reflecting the lack of local R&D and innovation activities, as largely discussed in previous sections. This gap has been increasing since the beginning of the 1990s, and its 2007 value is almost four times its 1990 value. Moreover, the low ratios between patents released and researchers represent the bias of the NIS towards scientific research, without being able to use it as a springboard for boosting innovation activities (Table 15.3).

Innovation is not a linear process; hence, it is not easily quantifiable and summarised by input–output indicators, which do not allow one to grasp its systemic and dynamic nature. As an outcome of the interplay between productive system, macro-settings and institutional infrastructures, innovation is strictly related to productivity. For this reason, productivity could be even more representative of the innovation dynamics than other input–output indicators (Capedivielle et al. 2000; Cimoli 2000).

In Mexico, productivity growth not only slowed down, but actually turned negative after the economic reforms.[19] Total factor productivity (TFP), which had been growing at an average yearly rate higher than 2 % between 1960 and 1979, declined to a rate of −0.5 % in 1980–2003. The higher loss in terms of productivity occurred precisely during the first years of implementation of the reforms, but the rate returned positive (+0.7 %) during the last part of this period (1996–2003). This generalised shrink in labour productivity between 1980 and 2003 has been associated with a particularly severe fall in the productivity of service sectors and coincided with a significant increase of employment participation in this same sector, demonstrating how the economy had not been able to generate employment in sectors with a higher labour productivity[20] (Ros 2008).

This behaviour of the TFP is perfectly consistent with and confirmed by the pattern followed by industrial labour productivity: Total Labour Productivity[21] declined from the beginning of the 1980s until the mid-1990s, but it went back on a path of positive growth after the mid-1990s, even if with fluctuations (ECLAC 2007, 2008) (Fig. 15.12, left axis). In terms of international comparison with US labour productivity, the productivity gap increased continuously (Fig. 15.12, right axis). However, this increase has not been shared homogeneously across industrial sub-sectors: it is mostly due to a rise in productivity of natural resource-intensive and exporting segments (such as the automotive subsector), while other manufacturing sectors progressively lose ground (Fig. 15.13) (ECLAC 2007, 2008, 2010). This pattern

[18] Number of patent applications of nonresidents over residents (RICYT).

[19] See also Capdevielle (2000), ECLAC (2002, 2007, 2008), and Cimoli (2005).

[20] See also Moreno-Brid and Ros (2009).

[21] The ratio between GDP and the total active population, weighted according to sectoral participation in total employment (based on ILO data), is taken as the indicator for labour productivity.

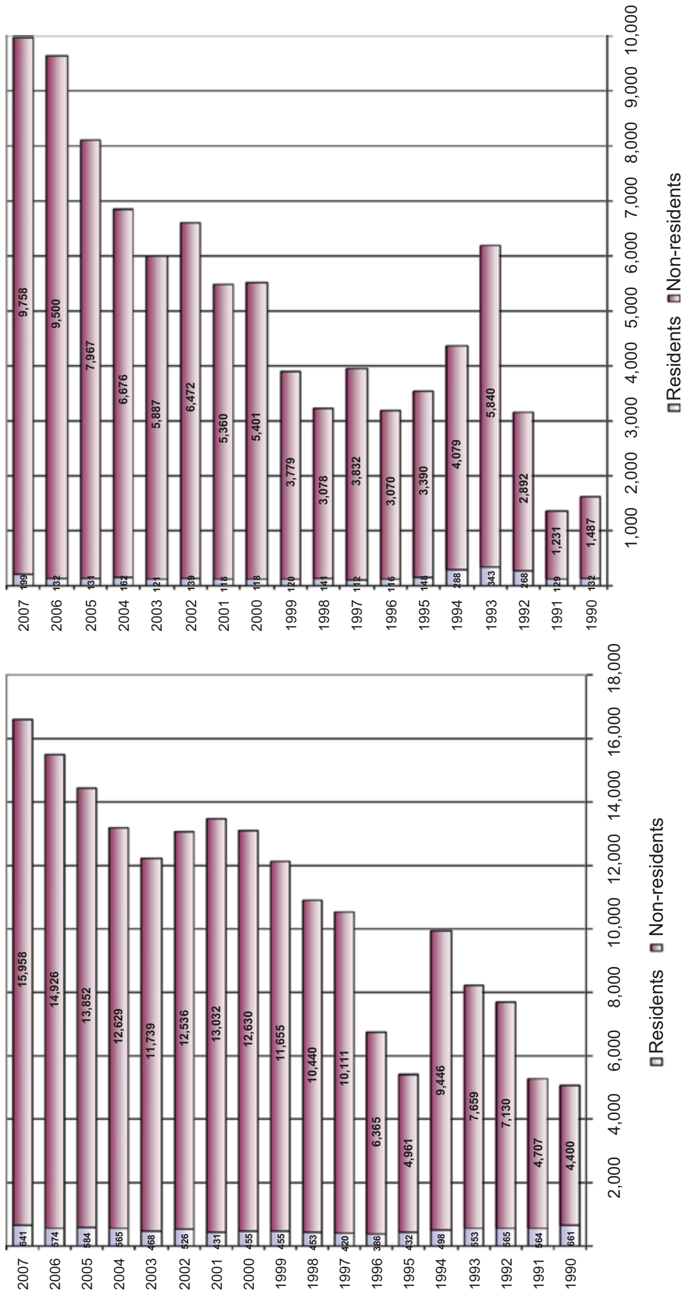

Fig .15.11 Patent applications (*left*) and granted (*right*), 1990–2007. (Source: Authors' elaboration based on RICYT)

Table 15.2 Dependency rate 1990–2007. (Source: RICYT)

1990	1991	1992	1993	1994	1995	1996	1997	1998
6.7	8.3	12.6	13.8	19.0	11.5	16.5	24.1	23.0
1999	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*
25.6	27.8	30.2	23.8	25.1	22.4	23.7	26.0	24.9

Table 15.3 Patents granted to residents per thousand researchers 1993–2006. (Source: Authors' elaboration based on RICYT)

1993	1994	1995	1996	1997	1998	1999
24.32	16.88	7.62	5.83	5.23	6.35	5.48
2000	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*
5.31	5.04	4.46	3.61	4.08	2.98	2.82

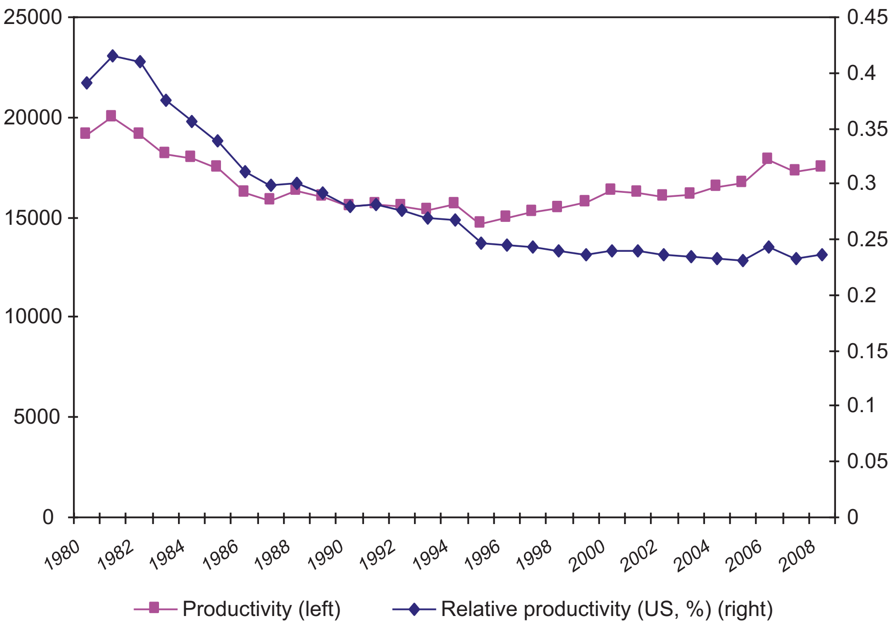

Fig. 15.12 Productivity and relative productivity with the USA. (Source: Authors' elaboration based on PADI Statistical Database)

clearly suggests that liberalisation policies—contrary to what was expected—have increased dramatically the heterogeneity in productivity within the industrial sector.

In sum, over the past 20 years, Mexican productivity performance has been deeply affected by the implementation of economic reforms, and its growth turned negative in those segments of the manufacturing sector that were less advantaged by the reforms. This corresponded to an increase in internal as well as in external

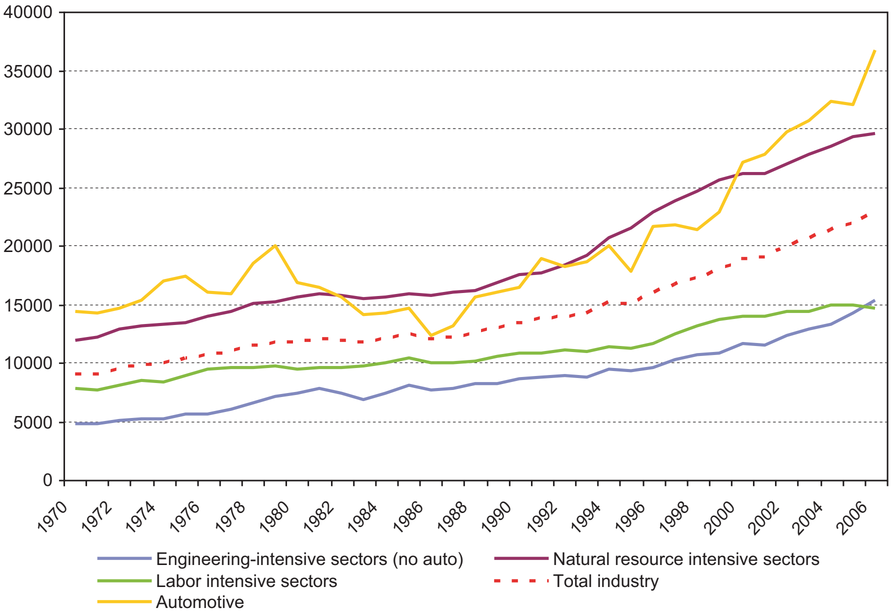

Fig. 15.13 Industrial productivity (total and decomposed) (Sectors are classified as follows: engineering-intensive (no auto) (CIIU 381, 382, 383, 385); automotive (CIIU 384): engineering-intensive (CIIU 381, 382, 383, 384, 385); labour-intensive (CIIU 321, 322, 323, 324, 332, 342, 352, 356, 361, 390); natural resources-intensive (CIIU 331, 341, 351, 354, 355, 362, 369, 371, 372).) 1970–2008. (Source: Authors' elaboration based on PADI Statistical Database)

heterogeneity, and to the progressive inhibition of innovation activities and weakening of learning processes in some 'marginalised' segments of the manufacturing sector that were not functional to the consolidation of these same reforms. This happened not just by impeding the generation of endogenous technological capabilities, but even contributed to the destruction of already existing ones, developed during the ISI period (Cimoli 2000).

15.4 Besides the Notion of NIS

15.4.1 Coevolution and Consistency: What Is in It for Innovation Dynamics in Mexico?

In the first chapter, a detailed description of the historical evolution of the macroeconomic regime, productive system and institutional infrastructure has been presented. In this description, it is possible to recognise the existence a bi-directional relationship between the development of a productive system and of an institutional infrastructure, which is affecting the same productive settings by providing incentives for modernisation and innovation activities.[22] These processes are coevolutionary in nature and characterised by constant feedback mechanisms. In the same way, the interaction between the productive system and institutions is not independent of the evolution of macroeconomic regimes.

This is particularly evident in the case of Mexico, where the macroeconomic reforms of the 1990s had a great influence on the productive system, as well as on the consolidation of an institutional infrastructure for innovation. Since the implementation of economic reforms, macroeconomic priorities always had a prominent weight with respect to other development targets. As STI policy targets became subsidiary and functional to the achievement of macroeconomic priorities, the equilibrium and the coherence that existed during the ISI phase across productive, macroeconomic and institutional targets deteriorated, leading to the recognised superiority of the 'right' macroprices as the main and primary variables in influencing economic decisions.

This attention on setting the 'right' macroeconomic fundamentals affected the coevolution of the three dimensions of innovation, which became quite unbalanced. The productive system became subject to market-led incentives and had to adjust its dynamics and composition in order to accomplish the new rationalisation and trade liberalisation policies. The development of an institutional infrastructure for the NIS tried to compensate for the contraction of State involvement in STI activities and the elimination of industrial policy, but the construction of linkages and connections among NIS actors and institutions were destroyed by incentives to rely mainly on imported technology. Given the heavy limitations imposed on the productive system and on institutions by this obsession for the 'right macroeconomic fundamentals', it is not surprisingly that it resulted in scarce outcomes in terms of innovation activities and accumulation of technological capabilities.

In sum, in Mexico macroeconomic priorities and production policies seem to compensate each other in a non-complementary, unbalanced way. In contrast, innovation would require the co-ordination of different policies (STI, macroeconomic, educational, industrial, etc.) and the implementation of coherent incentives. Innovation needs to become a common goal, whose centrality for the development process has to be shared across the whole economic system.

15.4.2 The Role of the NIS Through a (Structuralist) Developmental Perspective

This coevolutionary approach permits one to express some considerations about the role of the NIS in boosting innovation dynamics and to discuss its utilisation in a developing context. The concept of NIS emerged in the 1980s to explain the differences in the innovative performances of industrialised countries and without doubt it represented an important contribution to the understanding of the complexity of innovation mechanisms as a 'systemic process'. The NIS approach has

[22] This constitutes the core of the coevolutionary outlook as emphasised by Nelson (1994).

been increasingly used to analyse innovation activities in developing countries too, but the explanatory power of this concept in the case of a developing context has probably been overestimated. The risk is that this notion could turn out to be a nice but empty and insubstantial conceptual framework, not suited to boost development if detached from consistent economic policies.

A development strategy based on the 'classic' conceptualisation of the NIS would focus on boosting the linkages and synergies between the parts of the system, the nodal points and crucial learning linkages, and the missing interactions that reduce the innovative performance of the economy (Johnson and Lundvall 2000). However, although this definition aspires to be a practical recipe for development, it does not take adequately in consideration the real situation faced by many developing countries, and thus it may not be suitable for dealing with innovation issues in a developmental perspective.

First of all, institutions are commonly fragile in developing countries, and are characterised by: a weak system of property rights (including intellectual); lack of fair and efficient legal system; low level of capabilities and credibility of public institutions; and a high degree of informality in overall economic activities. This situation creates higher uncertainty in the normal functioning of the economic system, which hampers risky decisions like formal innovation. Second, in a development context it is more likely that markets are not fully developed and economic activity still needs to be supported and guided. Thus, not only the development stages of these groups of countries, but their innovation policy targets as well as the specific obstacles that have to be overtaken in order to achieve their innovation targets may widely differ. Finally—and it is probably the more relevant issue in discussing why the notion of NIS may fail to perform well in a developing context—the fulfilment of macroeconomic priorities may represent a heavy burden for an innovation-based development strategy.

It does not make sense to support the consolidation of a national institutional infrastructure for innovation to foster the participation of the private sector in innovation activities and to boost the consolidation of linkages within the NIS, if macroprices in practice nullify any effort in favour of innovation and market-led incentives make it more convenient to dismantle local production chains and to rely on foreign technology. Relying almost exclusively on the Innovation System's potentialities in supporting innovation may be a great mistake, especially when the economy remains characterised by an overvalued exchange rate, tight fiscal expenditure and unconditional openness to foreign markets that nullify all the efforts, despite the existence of an articulated institutional infrastructure. In such a context, innovation dynamics cannot develop soundly, in the sense that the limited innovation activities are too circumscribed to produce positive spillovers that will drag overall productivity and stimulate economic growth.

Mexican experience is a good example of how the primacy of macroeconomic goals could turn out to be detrimental in terms of innovation achievement, since all efforts for consolidating institutions and networks—thus, a functioning Innovation System—could be easily neutralised by set economic fundamentals, such as booming prices of exported commodities, overvalued exchange rate and pro-cyclical fiscal policies.

In sum, the construction of an NIS is useless if it is not matched by economic policies whose economic fundamentals are set consistently with the innovation and technological patterns of capabilities development. Thus, understanding NISs may help shade light on innovation dynamics, but this cannot be expected to automatically translate into concrete development advances, if it fails to embrace in broader view the whole system of economic policies and incentives.

15.5 Conclusion

Since the reforms in the 1990s, Mexico has been unable to improve significantly its innovation dynamics and outcomes. Despite STI programmes and plans, macro-prices and macroeconomic priorities have prevailed over innovation goals, which have been re-oriented in order to fulfil macroeconomic targets. Thus, almost a decade since the release of the book "Developing Innovation System. Mexico in a Global Context", the Mexican innovation pattern still suffers from the same long-lasting structural limitations.

In this concluding section, we briefly summarise the most critical points and long-lasting weaknesses that still constrain the functioning of the Mexican NIS, presenting some recommendations as concluding remarks. These limitations, together with emerging global challenges, have to be actively addressed by effective industrial and innovation policies in order to improve innovation outcomes and productivity performances. If actions are not taken, the innovation perspectives in Mexico will inevitably be still locked into a low-performance scenario, as they have constantly been for the past 20 years.

15.5.1 Long-Lasting Weaknesses and Emerging Challenges of Mexican NIS

Macroeconomic Issues Stabilising the economy is fundamental in order to reduce uncertainty and to increase investors' and managers' confidence that is necessary to back long-term investment in innovation. However, the Mexican experience clearly shows that the obsession for 'getting the macroprices right' could also turn out to be highly detrimental in terms of innovation performance, if macroeconomic priorities are not consistent and co-ordinated with more general productive, technological and innovation goals.

External Dependence Trade liberalisation policies and NAFTA have generated a peculiar production system—the *maquila*—characterised by an aggressive export-led strategy with high incentives for export activities, for import of most technologically dynamic products and intermediates, and for the involvement of MNEs and foreign firms. This turned out to be detrimental for the consolidation of a well-integrated industrial system and the accumulation of endogenous technological capabilities.

Weak Local Linkages and Production Networks The consolidation of the *maquila* system has been successful in modernising only a small part of the economy, with a bias in favour of large domestic firms and MNEs. The weak connections with domestic productive firms and NIS institutions led to an increase of heterogeneity and to the deterioration of local production chains, limiting the development of local supply-demand interactions.

Low Technological Opportunities Mexican competitiveness is more grounded on traditional—such as cheap labour—than sophisticated and technological competitive advantages. Industrial production risks getting locked into a vicious circle of 'sectoral specialisation-low technological opportunity', where the most productive sectors (natural resource-based, export-oriented manufacturing, etc.) are characterised by mature technologies and relatively easy processes, which do not incorporate high value added in their final output.

Scarce R&D Efforts and Lack of Financing R&D expenditures have maintained a low profile and incentives to innovate have remained linked to market priorities: activities are concentrated within large exporting firms and MNEs and are mainly dedicated to adapting foreign technology, modernising processes and improving efficiency, rather than performing innovation activities and developing new products and processes.

Poor Articulation of Institutional Infrastructure The coevolution among institutional infrastructure, productive system and economic reforms is a very complex, nonlinear process. Despite all the declarations, Mexican STI policies and programmes represented mainly a rhetorical expedient, lacking the necessary power and ability to induce an optimal evolution of the NIS.

15.5.2 Recommendations

Getting 'Right Macroprices' for Innovation The Mexican experience shows that spending efforts and resources in the consolidation of NIS institutions and in incentives is useless in terms of innovation outcomes, if macroeconomic policies go in the opposite direction. However, Mexico still lacks an integrated strategy with active and articulated policies and incentives under the common target of innovation for economic development. Unblocking this situation requires a new policy approach, where macroeconomic priorities are set consistently with productive system needs in terms of technological learning and capabilities accumulation, and with the functional roles of NIS institutions. This requires a clear political will to co-ordinate also other various policy areas such as education, production and scientific research in a consistent innovation perspective.

(Re)Turn to Industrial Policies as Source of Technological Capabilities Adequate pro-development macroeconomic policies are necessary, but cannot substitute *in toto* industrial policies. After 20 years of liberalisation and economic deregulation and the lack of any long-term industrial strategies, it is now important to redefine the role of the State, particularly with respect to market forces. The priority of new industrial policies should be finding a new systemic approach to competitiveness and proposing new strategies for innovation and technical change, in order to be able to face emerging challenges—from Asia on traditional productions to the emergence of new technological paradigms. In the case of Mexico, this implies a redefinition of the relative importance of *maquila* productions within the manufacturing sector, reducing the dependence on natural resources and on oil revenues, and shifting from a 'pure *maquila*' system towards a 'full-package' model based on innovation and dynamic comparative advantages. The development of a domestic market should be fully supported, in order to be able to act as 'spare wheel' and to sustain local producers when international markets are contracting and new international competitors are emerging.

R&Ds: Resources for a Renewed Competitiveness With its current limited resources and very low investments in R&D, Mexico could not aspire to be more than a second-order player in innovation activities. R&D expenditures suffer not only from the lack of participation of the private sector, but also from shrinking public sector participation. Thus, a strategy to strengthen the magnitude and the quality of Mexican R&D should include the implementation of long-term programmes of public investment to modernise R&D infrastructure and the creation of links and synergies across actors (public and private, within the production chain, between research centres and firms, etc.) to jointly perform R&D activities. Private investments in R&D have to be boosted through a renovation of the financial and banking system, where private banks receive incentives in order to make their priorities conform to broader targets of national development. In this sense, the consolidation of a 'developmental bank' could facilitate firms' access to credit and to co-ordinate long-term industrial strategy with immediate financial need.

Towards a New Institutional Infrastructure for Innovation Some points have been raised about the traditional conception of NIS, as if it was the only tool that matters in supporting innovation. On the contrary, STI institutions may fail to perform adequately if they are not adequately enforced. An institutional infrastructure for STI needs to be capable of assigning the right incentives to effectively increase the participation of the actors within the NIS and promote the transfer and absorption of knowledge flow. Thus, STI institutions need to enjoy the same authority as other political actors, in order to design effective, unconditioned STI policies. In practice, this implies co-ordination and consistency among different public policies—economic, fiscal, trade, productive, educational and STI—without relegating STI policy to a subsidiary position. Today this co-ordination is still more of a theoretical guideline than a real target, and it is likely to remain like this until a new long-term vision about the future of the country is developed.

Appendix

Mexican institutional infrastructure for innovation

ISI: Until Mid-1970s

1970: ConsejoNacional de Ciencia y Tecnología (CONACYT)
1972: Ley sobe el Registro de la Transferenci de Tecnollogia y el Uso y Exploracion de Patentes y Marcas
1973: Ley parapromover la Inversión Mexicana y Regular la Inversión Extranjera
1976: Ley de Invenciones y Marcas
1970s: Instituto Nacional de Investigaciones Nucleares (ININ), Instituto de Investigaciones Eléctricas (IIE), Instituto Mexicano de Tecnología del Agua (IMTA), and the Instituto Mexicano del Petróleo (IMP), Servicio de Información Consultoría y Capacitación Tecnológica (INFOTEC)

The Transition Period: Mid-1970s–1980s

1976: Plan Nacional Indicativo de Cinencia y Tecnologia
1978–1982: Programa Nacional de Ciencia y Tecnologia
1984–1988: Programa Nacional de Desarrollo Tecnologico y Cientifico (PRONDETYC)
1983–1988:*Programa Nacional de Fomento Industrial y Comercio Exterior* (PRONAFICE)

Macroeconomic Reforms: 1990s

1990–1994: Programa Nacional de Ciencia y Modernizacion Tecnologica
1995–2000: Programa de Ciencia y Tecnologia
1998: *Ley para el Fomento de la Investigacion Cientifica y Tecnologica*

2000s

2000–2006: Programa Especial de Ciencia y Tecnologia (PECYT)
2002: Ley de Ciencia y Tecnologia
2002: Consejo General de Ciencia y Tecnologia, Foro Consultivo Cientifico y Tecnologico
2008–2012: Programa de Ciencia Tecnologia e Innovacion(PECYTI)
2009: *Ley de Ciencia y Tecnología (reform)*

References

Amsden A (1989) Asia's next giant: South Korea and late industrialization. Oxford University Press, New York

Capdevielle M (2000) Production system and technological patterns. In: Cimoli M (ed) Developing innovation system: Mexico in the global context. Continuum-Pinter Publishers, New York, pp 57–75

Capdevielle M, Dutrenit G (1995) Competitividad, dinamismo y patróntecnológico de las exportaciones manifactueras mexicanas en los ochentas. In: Soto E (ed) Globalización, economía y proyecto neoliberal en México. UAM-GRESAL, Mexico City

Casalet M (2003) Política científicas y tecnológicas en México: evaluación e impacto. Facultad Latinoamericana de Ciencias Sociales (FLACSO), México

Cimoli M (1988) Technological gaps and institutional asymmetries in a North-South model with a continuum of goods. Metroeconomica 39(3):245–274

Cimoli M (ed) (2000) Developing innovation system: Mexico in the global context. Continuum-Pinter Publishers, New York

Cimoli M (ed) (2005) Heterogeneidade structural, asimetrías tecnológicas y crecimiento en América Latina, Naciones Unidas-BID, LC/W 35, Santiago, Chile

Cimoli M, Dosi G (1995) Technological paradigms, patterns of learning and development. An introductory roadmap. JE vol Econ 5(3):243–269. Working Paper no. 83, IIASA, Luxemburg, Austria

Cimoli M, Katz J (2003) Structural reforms, technological gaps and economic development: a Latin American perspective. Ind Corp Change 12:387–411

Cimoli M, Porcile G (2009) Sources of learning paths and technological capabilities: an introductory roadmap of development processes. Econ Innov New Tech 18(7):675–694

Cimoli M, Ferraz J, Primi A (2005) Science and technology policies in open economies: the case of Latin America and the Caribbean. ECLAC, Serie de desarrollo productivon. 165, Santiago de Chile (co-authors: CJ Ferraz and A Primi).

Cimoli M, Dosi G, Stiglitz EJ (eds) (2009) Industrial policy and development, the political economy of capabilities accumulation. Oxford University Press, Oxford.

Cimoli M, Porcile G, Rovira S (2010) Structural change and the BOT constraint: why did Latin America fail to converge? Camb J Econ 34(20):389–411

Dosi G (1988) "Sources, Procedure, and Microeconomic Effects of Innovation," Journal of Economic Literature, Vol. XXVI, September

Dosi G, Pavitt K, Soete L (1990) The economics of technological change and international trade. Harvester Wheatsheaf, New York

ECLAC (Comisión Económica para América Latina y el Caribe) (2002) 'Globalización y desarrollo' (LC/G.2157(SES.29/3)).Documento preparado para el vigésimo noveno período de sesiones de la ECLAC (Brasilia, Brasil, 6 a 10 de mayo), Santiago de Chile

ECLAC (2007) Progreso Técnico y Cambio Estructural en América Latina. Division of Production, Productivity and Management, United Nations, Santiago (Chile), Oct 2007

ECLAC (2008) 'La transformación productiva 20 años después: viejos problemas, nuevas oportunidades' (LC/G. 2367(SES.32/3)).Documento preparadopara el trigésimo segundo período de sesiones de la ECLAC (Santo Domingo, República Dominicana, 9 a 13 de junio de 2008), Santiago de Chile

ECLAC (2010) La hora de la igualdad: brechasporcerrar, caminosporabrir. Documento preparado para el trigésimo tercero período de sesiones de la ECLAC (Brasilia, Brazil, 1–3 June 2010), Santiago de Chile, (forthcoming)

Edquist C (1997) Systems of innovation: technologies, institutions and organizations. Pinter, London

Fernandez J (2000) The macroeconomic setting for innovation. In: Cimoli M (ed) Developing innovation system: Mexico in the global context. Continuum-Pinter, New York, pp 32–52

Fransman M, King K (eds) (1984) Technological Capability in the Third World. Macmillan, London
Freeman C (1987) Technology policy and economic performance: lessons from Japan. Pinter, London
Garrido C, Garcia B (2010) Politica para impulsar conductas innovadoras de las P y MEs durante la decada del dos mil. UAM Azacapotzalco, Mexico
Ha-Joon C (1994) The political economy of industrial policy. Macmillan, London
Ha-Joon C (2001) Infant industry promotion in historical perspective. A rope to hang oneself or a ladder to climb with? Document prepared for the conference development theory at the threshold of the twenty-first century, Economic Commission for Latin America and the Caribbean (ECLAC), Aug 2001
Johnson B, Lundvall B-A (2000) Promoting innovation systems as a response to the globalising learning economy. Paper presented at the seminar 'Arranjos e Sistemas Produtivos Locais e as Novas Políticas de Desenvolvimento Industrial e Tecnológico', Río de Janeiro
Katz J (1984) Latin American metalworking industries. In:Fransman M, King K (eds) Technological capability in the third world. Macmillan, London
Katz J (1987) Technology generation in Latin American manufacturing industries: theory and case-studies concerning its nature, magnitude and consequences. Macmillan, London
Katz J, Ablin E (1978) From infant industry to technology exports: the Argentine experience in the international sale of industrial plants and engineering works. Working Paper No. 14, Buenos Aires, Research Programme in Science and Technology
Lall S (1982) Developing countries as exporters of technology: a first look at the Indian experience. Macmillan, London
Lundvall B-Ã (1988) Innovation as an interactive process: from user-producer interaction to the national innovation systems. In: Dosi G, Freeman C, Nelson RR, Silverberg G, Soete L (eds) Technology and economic theory. Pinter, London, pp 349–269
Lundvall B-Ã (2004) National innovation systems-analytical concept and development tool, presented at the DRUID tenth anniversary summer conference 2005, Copenhagen, Denmark, June 2005
Metcalfe S (1995) Technology systems and technology policy in an evolutionary framework. Camb J Econ 19:25–46
Moreno-Brid JC (2009) La economía mexicana rente a la cirisis internacional', Nueva Sociedad, 220(marzo-abril):61–83
Moreno-Brid JC, Ros J (2009) Development and growth in the Mexican economy. Oxford University Press, Oxford
Nelson R, Winter GW (1982) An evolutionary theory of economic change. Harvard University Press, Cambridge
Nelson RR (ed) (1993) National Innovation Systems: A Comparative Analysis, Oxford, Oxford University Press
Nelson RR (1994) The co-evolution of technology, industrial structure, and supporting institutions. Industrial and Corporate Change 3(1):47–63
Pavitt K (1984) Sectoral patterns of technical change: towards a taxonomy and theory. Res Policy 13(6):343–373
Ros J (2008) La desaceleracion del crecimiento economico en Mexico desde 1982. El Trimestre Economico 73(3):537–560
Soete L et al (2009) Systems of innovation. UNU-MERIT Working Papers ISSN 1871–9872
Sollerio JL et al (2007) Evolucion del desarrollo cientifico y tecnologico de America Latina: Mexico. In: Sebastian J (ed) Claves del desarrollo cienfitico y tecnologico de Amreic Latina. Fundacion Carolina, Madrid
Teitel S (2004) On semi-industrialized countries and the acquisition of technological capabilities. ICER Working Paper, No. 19–2004, Torino, Italy, International Centre for Economic Research
Villavicencio D et al (1995) Aprendizaje tecnológico en la industrial química Mexicana. Perfiles Latinoamericanos 4(7):121–148

Chapter 16
Innovation Systems in Latecomer Development Sectoral Evidence from South Africa and Malaysia

Banji Oyelaran-Oyeyinka

16.1 Introduction

This chapter analyzes the determinants of innovation and firm performance resulting from collaborative learning in the South African and Malaysian computer sectors, which consist of firms specializing in software and hardware. The analysis focuses on two main propositions. The first is to examine the well-established notion that the microeconomic processes of interactive learning lead to innovation even in the context of a latecomer economy. The second proposition is that firms in a latecomer economy require state support to produce and innovate because markets do not function well. In such contexts, policy choices made are instrumental in explaining the success or failure of sectors. However, as the analysis in this chapter shows, state support is not just implementing a set of policies that succeed elsewhere; it is the ability of the state to set up institutions that reflect a harmony between knowledge and physical infrastructure, and the formal and informal institutional compensations are important to and structure the idiosyncratic exchange processes of developing economies.

Essentially, technical change or innovation is largely incremental but nonetheless useful in advancing productivity growth and has been classified into three different categories (Bell 1984). First, we have technical change that involves the introduction of new techniques (products and processes) into the economy through new investments in plants and machinery. This type of technical change broadens the industrial base of the economy. The second form of technological change involves evolutionary (incremental) improvement to existing techniques by effecting technical change to existing products and third is the generation of new knowledge through research within the firms or within separate research and development (R&D) institutions.

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So, what explains the process by which countries and firms move from one level or knowledge domain to the next and how? The observed structure of knowledge or sets of capabilities that one finds in an economy is a result of cumulative technological mastery and investment efforts made over a long time. In other words, technological change is cumulative and path-dependent processes that depend on national- or firm-level actions taken in previous times condition the current state of capabilities. The institutional arrangement that supports learning and collaboration among actors is usually referred to as the system of innovation. In short, technological capability acquisition processes are not just strongly cumulative in nature, but they have elements of strong path dependence (Dosi et al. 1988). The conceptual and empirical literature on technological capabilities (TCs) that blossomed in the late 1980s received considerable attention from the mid-1980s through the early 1990s (Bell and Pavitt 1993, 1995; Dahlman et al. 1987; Lall 1990, 1992; Westphal et al. 1985). Several authors refined the typologies and elaborated on them but essentially the key ideas revolve around the same concepts.[1] The essential elements of the framework are as follows:

1. TC focuses on efforts to "make effective use of technological knowledge in production, investment, and innovation" (Westphal et al. 1985, p. 171).
2. The process has strong heuristic elements of feedback from previous experiences to current states and as such skills and knowledge gained in previous domains become a part of the organizational memory of firms and nations that create a new capability domain resulting in more efficient techniques and systems.[2]
3. The build-up of capabilities, therefore, entails individual and organizational "learning" (Dahlman et al. 1987; Dahlman and Westphal 1982; Katz 1984, 1987; Lall 1987, 1990, 1992). The process is reconceptualized as essentially efforts by organizations to master technological functions through learning driven by explicit investment.
4. Firms and nations require explicit investment capabilities in order to identify, prepare, design, set up, and commission a new industrial project (or an expansion of it). In other words, if the processes of capability buildup must continue, this set of skills and experience will be built in a coevolutionary process with technical capacity.
5. As technical change and innovation do not take place in isolation and are only possible within a network of other actors, firms and countries require a systemic framework. This has been conceptualized as "linkage capabilities" with knowledge and experience required to foster interactive learning (see Point 3 above).[3]

[1] Nelson and Winter (1982) developed the notion of "routines." Bell (1984), Scott-Kemmis and Bell (1988), and Katz (1987) used "technological capacity" to describe the learning processes involved in building up a minimum base of essential knowledge to engage in innovative activity.

[2] Dahlman et al. (1987) conceived TC as the ways to use existing technology to produce more efficiently and to use the experience gained in production and investment to adapt and improve the technology in use.

[3] Linkage capabilities are defined as the forging of cooperation between workers, managers, and the broader set of actors making up the milieu of the firm.

However, capability acquisition is largely driven by interactive learning, which is conducted with a multiplicity of firms and nonenterprise actors in any system. A firm needs external knowledge on a continual basis to regenerate itself, failing which it might well stagnate or regress. The stagewise gradation of firm/country from one level of knowledge and technological capability to the next higher one over time reflects the heuristic feedback loops involved between policies and institutions that promote interactive learning and thus help to build capacity. The mode of learning is also related to the level of capability that a firm or country has accumulated. The amount of learning and skills required to move from the lowest domain of artisanal and indigenous manufacturing to the second lowest knowledge domain of modern manufacturing are embedded in primary and secondary schooling capacities, apprenticeship training, training to read engineering designs and blueprints and organization of production. To move from this phase to the next higher knowledge domain to design and reengineer products and innovation requires not only primary and secondary schooling but also tertiary education that equips individuals with technical and analytical skills and public sector investments in building basic R & D capabilities for standards, metrology, and other infrastructure. The learning associated with transitioning to this knowledge domain is more systematic and systemic, rigorous, and has to be sustained over a long period of time and be capable of being replicated across several sectors. It also requires an unlearning of several of the conventional ways of conducting the innovation business in these countries. For a country to move from this point to the final knowledge domain learning becomes concentrated in R & D activities and can be measured using conventional indicators, such as patents, skilled employees, and so on. At this level, the absorptive capacity of firms and entities relies on concentrated efforts in key facilities by highly specialized individuals who conduct research and design activities (Cohen and Levinthal 1990). This is the level where the orthodox measure of R & D as a source of national knowledge begins to apply.

Catching up is as much a mountain climbing metaphor as it is a marathon challenge where firms and countries practically run the gauntlet and whereby failure is costly. The notion of the latecomer, therefore, signifies the fact that the entity (country or firm) is late in meeting up certain key capabilities compared with both the forerunners as well as competitors. Economic history shows that whereas countries move easily from the lowest knowledge domain to the next higher one, moving further up into knowledge domains that focus on incremental design and innovation and then to frontier innovation is ridden with lack of success. Several countries on a supposedly sound catch-up path often do not move as predicted or regress along this path mainly due to their inability to manage the coordination efforts required in setting up a sound basis to move to the next knowledge domain.

In this chapter, we use the empirical data collected in South Africa and Malaysia to illustrate these interlinkages between state policy, TCs, and interactive learning. Sections 2 and 3 present the results of our innovation surveys in the South African and Malaysian computer sectors, respectively. Our empirical analysis focuses specifically on factors that impact upon new product development in the sector, and a discussion on the actors and triggers for innovation. We then discuss the comparative insights on learning and collaborative behavior as well as state support in Sect. 4. The South African data used in this chapter were collected during a 2006 survey, which comprised 82 South African firms from the computer sector, of which 19 firms are computer hardware firms. The Malaysian data were collected between 2004 and 2006 from two computer clusters, namely, Penang and Johor.[4] The survey covered 360 firms from both clusters. These two sectors are justified on the strength of their relative successes in the two countries: while ICT hardware succeeded in Malaysia driven in part by state support and consistent foreign direct investment (FDI), but it failed in South Africa due to lack of state support while software thrived.

In the empirical analysis, we use *t*- and *z*-tests to stress the differences between the software and hardware sectors. In the South African data, we consider a probit model of innovation, which is estimated by maximum likelihood (ML) and a linear and a censored regression model of economic performance. The linear regression model is estimated by using ordinary least-squares (OLS), instrumental variables, limited information ML, and generalized method of moments, and the censored regression is estimated by using ML. Finally, we carry out a descriptive analysis using *t*- and *z*-tests to study the characteristics that distinguish collaborators from noncollaborators.

16.2 The South African Computer Sector

In South Africa, emerging high-tech activities in the computer sector have a strong geographic locus; such firms are concentrated in Gauteng and to a lesser extent in the Western Cape. We consider four types of actor interactions in our analysis to understand the innovation dynamics of the sector, namely: subcontractors, industry associations, main suppliers, and buyers. Appendix Table A.1 presents the definition of the dependent and independent variables used in the innovation and performance analysis, and Table 16.6 reports descriptive statistics for the whole sample, when contrasted with those of the hardware computer firms.

16.2.1 Sector Characteristics

The descriptive statistics presented in Appendix Table A.1 show that 66% of all firms are involved in new product development, while only 37% carry out innovation in the hardware computer sector. Hence, the percentage of firms that are involved in new product development in the software sector is much higher than in the hardware sector. However, productivity, that is, sales per employee (in millions

[4] The data collection was carried out by Prof. Rajah Rasiah for one of the authors' projects. A more elaborate discussion of the issue is found in Oyelaran-Oyeyinka and Rasiah (2008).

of dollars), is higher in the computer hardware sector than in the computer software sector. In other words, sales per employee are, on average, about $ 1 million in the whole computer sector and twice as much in computer hardware. The figures for export intensity, that is, the share of export sales in total sales, and increased net profit are, on average, similar for the computer hardware and software sectors. More specifically, export intensity is (on average) about 17 % in the whole sector and 13 % in the hardware sector, and net profit is increased for 88 % of all firms and for 84 % of the computer hardware firms. In short, the propensity to innovate is far higher in software firms, but many overall similarities exist in the two subsystems.

The descriptive table also shows that 23 % of the firms are computer hardware firms and also have a lower percentage of staff with university or technical degrees (human capital) as compared with the software firms. Not surprisingly, 73 % of workers in the whole sector have a university or technical degree, whereas the percentage is only 55 % in the hardware sector. The figures for firm size, upgrade activities, technology sources, government support, customer demand, technical capability, and training in the whole sector are contrasted with those of the same variables in the hardware sector. On average, hardware firms are much larger in size than software firms. More specifically, the former are, on average, three times as large in terms of employees, and four times as large in terms of sales than firms in the software sector. Second, the percentage of firms that upgrade with reverse engineering and original design is, on average, larger in the software than in the hardware subsector, while firms that upgrade with original brand is larger in the latter subsector compared with the former. Firms that upgrade with quality control are, on average, similar across the two sectors. And finally, when the figures on technology sources of the whole sector are compared, we find that software firms depend more for their technology on local expertise and in some cases on a combination of local and foreign expertise such as licensing from clients and buyers relative to hardware firms. Other sources of technology include hiring of skilled employees, collaboration with universities and public institutes, and reverse engineering. For hardware firms, the technology source is largely from foreign expertise and component suppliers. The two subsectors draw equally from joint venture partners, transfer from the parent firm and suppliers of equipment.

16.2.2 Triggers and Actors: Empirical and Econometric Analysis of Innovation

Innovation was measured by the number of new products and process developments applied by the firms in the past 5 years. The survey shows that a relatively large percentage of the firms in the sector can be classified as "innovators," as 66 % of the firms have been involved in a new product development within the past 5 years of operation, and 76 % have developed a new service. Our survey shows that software firms are more innovative than hardware firms (75 % versus 37 %), small firms

Table 16.1 Types of innovation. (Source: empirical survey by authors, 2006)

	All (%)	Software (%)	Hardware (%)	Small (%)	Large (%)	Sup (%)	Nsup (%)
New products	66	75	37	70	36	76	58
New services	76	78	68	76	73	88	67

Table 16.2 Origin of innovation. (Source: survey by authors, 2006)

	All (%)	Software (%)	Hardware (%)	Small (%)	Larger (%)	Sup (%)	Nsup (%)
Licensing	22	24	16	23	18	21	21
Own development	88	95	63	92	64	91	85
Foreign technical support	17	17	16	17	18	18	15
Others	6	3	16	6	9	9	4

more than larger ones (70 % versus 36 %), and those firms receiving state support tend to be more innovative than those that do not (76 % versus 58 %). State support is often critical because of the uncertain nature of innovation.

Table 16.1 shows the distribution of innovation activities related to new products and services and between different classes and sizes of firms, those that receive support (Sup) and those that do not receive state support (NSup).

The survey also sought to understand the triggers for such innovations, and the extent to which licensing and foreign support through technical training has contributed to new product development in the sector. Most of these new products and services were obtained through own in-house development, particularly in the case of software firms, whereas hardware companies rely more often on licensing and foreign technical support (Table 16.2). This pattern of behavior is not surprising given that computer manufacturing remains in a nascent phase in the country as with much of the region.

Approximately one third of the firms tend to innovate at the global level particularly the software firms. This result seems to be at odds with the lower exporting rate that observed for the software subsector. However, the reason lies in the fact that much of their innovation was directed at solving local needs and their ability to respond creatively to those needs and constraints in the South African and African environments. With innovations driven largely by strong "localization" efforts, the incidence of low exports is not so surprising.

On the various factors that help to build innovative capabilities, the survey finds that the quality control and reverse engineering are the major upgrading paths for the firms surveyed. The "other" upgrading factors involve different dimensions, such as growing interaction with their customers' needs and learning by doing (original brand) (Table 16.3).

Table 16.3 Nature of innovation. (Source: empirical survey by authors, 2006)

	All (%)	Software (%)	Hardware (%)	Smaller (%)	Larger (%)	Sup (%)	Nsup (%)
Quality control	38	40	32	39	27	33	40
Reverse engineering	38	44	16	41	18	45	33
Original design	32	38	11	37	0	45	23
Original brand	6	3	16	4	18	3	8
Adaptive engineering	1	2	0	1	0	0	2
Others	68	65	79	68	73	67	71

16.2.3 Factors Affecting New Product Development

Table 16.4 reports ML estimation results of the probit model that studies the likelihood of being involved in new product development.[5] The estimated coefficients as well as their standard errors are reported in the first pair of columns, while the slope parameters (marginal effects) and their standard errors are reported in the second pair of columns.

The first pair of columns suggests that, other things being equal, upgrade using original design, the effect of government assistance, collaboration, overseas technical training, and competitive challenge from Asia all have a strong and significant effect on the likelihood of a firm being involved in new product development. In

Table 16.4 Probit estimation results and marginal effects: new product development**.** (Source: empirical survey by authors, 2006)

Variable	Coefficient	Standard error)	Slope	(Standard error)
Original design	2.125***	(0.732)	0.385***	(0.083)
Government assistance	2.255**	(0.900)	0.259***	(0.083)
Capability, more management training	−1.611***	(0.494)	−0.399***	(0.115)
Training, overseas technical	1.166**	(0.542)	0.252**	(0.104)
Customer demand, conformity to standards	0.816*	(0.428)	0.215*	(0.113)
Asian competition	1.454**	(0.648)	0.233***	(0.081)
Hardware firms	−1.756***	(0.609)	−0.566**	(0.190)
Intercept	0.070	(0.368)	–	–
Number of firms	82			
Log-likelihood	−27.758			

* Significance levels 10 %
** Significance levels 5 %
*** Significance levels 1 %

[5] We always report estimation results that include only the joint significant explanatory variables.

addition, response to the demanding customers is not strongly significant. Finally, improved capability through more managerial training and belonging to the hardware sector decreases the likelihood of being involved in new product development.

The second pair of columns shows that the magnitude of the effects of the explanatory variables on the likelihood of being involved in new product development.[6] Ceteris paribus, involvement in upgrade activity, particularly with regard to original design, access to government assistance, investing in overseas technical training, facing more demanding customer demand with regard to conformity to standards, and facing severe and very severe challenge from Asian competition significantly increase the probability of being involved in new product development by 0.385, 0.259, 0.252, 0.215, and 0.233, respectively (Table 16.4). In other words, competitive pressure is a major inducement to innovate.

16.2.4 Interfirm Collaboration in South Africa

This section presents only a descriptive analysis of collaboration, as the sample does not allow the estimation of an econometric model of collaboration.[7] We identify six types of collaboration in the sample, namely, collaboration with other firms, subcontractors, industry associations, main suppliers, domestic buyers, and foreign buyers. Descriptive statistics show that almost 100 % of the firms collaborate with other firms and with domestic buyers, 63 % collaborate with subcontractors, 57 % collaborate with industry associations, 89 % collaborate with main suppliers, and 54 % collaborate with foreign buyers.

Table 16.5 presents the correlation matrix of the six types of collaboration. It suggests that the six types of collaboration are hardly significantly correlated. Three

Table 16.5 Correlation between types of collaboration. (Source: empirical survey by authors, 2006)

	Other firms	Subcon-tractors	Industry associations	Main suppliers	Domestic buyers	Foreign buyers
Other firms	1.000					
Subcontractors	0.044	1.000				
Industry association	0.023	−0.041	1.000			
Main suppliers	0.197*	0.138	−0.066	1.000		
Domestic buyers	−0.025	−0.120	−0.136	−0.056	1.000	
Foreign buyers	0.170	0.259**	0.187*	0.065	0.012	1.000

* Significance levels 10 %
** Significance levels 1 %

[6] Since all the explanatory variables reported in Table 16.3 are binary, their marginal effects are calculated as discrete changes of those variables from 0 to 1 (see Greene 2003, p. 676 for more details).

[7] The sample is not sufficiently informative to achieve this.

exceptions are collaboration with foreign buyers, which is positively, statistically, and significantly correlated with collaboration with subcontractors and members of industry associations, and collaboration with main suppliers, which is positively, statistically, and significantly correlated with collaboration with other firms. Table 16.6 presents the characteristics of the collaborators contrasted with those of the noncollaborators through *t*- and *z*-tests of equality of means and percentages across the two populations of firms.

16.2.4.1 Collaboration with Subcontractors

The first pair of columns of Table 16.6 shows the characteristics of collaborators and noncollaborators with subcontractors. Firms that collaborate with subcontractors have, on average, a larger share of export in total sales and are older than those that do not collaborate with subcontractors. The percentage of firms collaborating with subcontractors has greater net profits, higher product quality, and better product innovation capabilities than those that do not. In other words, the more established firms tend to focus on collaboration with an aim to enhance exports and quality and predictably tend to earn higher net profit.

16.2.4.2 Collaboration with Industry Associations

The characteristics of collaborators and noncollaborators with industry associations are reported in the second pair of columns of the table. Firms that collaborate within industry associations have, on average, smaller productivity, and are smaller with respect to the three measures of size than those that do not collaborate within an industry association. Furthermore, a larger percentage of collaborators receive government assistance and have product innovation with improved capability, while a larger percentage of noncollaborators have in-house management and local training. This is not surprising because it is often the small and medium firms with less internal capabilities that participate more actively in collective support programs provided by governments and industry associations.

16.2.4.3 Collaboration with Main Suppliers

The characteristics of collaborators and noncollaborators with main suppliers are reported in the third pair of columns of the table. Collaborators in this category tend to devote more explicit investment for building management capability and in-house and overseas technical training compared with noncollaborators.

16.2.4.4 Collaboration with Foreign Buyers

Finally, the last pair of columns of the table shows the characteristics of collaborators and noncollaborators with foreign buyers. Firms that collaborate with foreign

Table 16.6 Characteristics of collaborators and noncollaborators. (Source: empirical survey by authors 2006)

Variable	Mean							
	Subcontractors		Industry association		Main suppliers		Foreign buyers	
	No	Yes	No	Yes	No	Yes	No	Yes
Product innovation	0.567	0.712	0.571	0.723	0.667	0.658	0.605	0.705
Productivity in 2005	0.609	1.217	1.435**	0.667**	1.662	0.912	0.702	1.247
Export intensity	0.098*	0.212*	0.128	0.203	0.141	0.171	0.003*	0.315*
Increased net profit	0.700*	0.981*	0.857	0.894	0.778	0.890	0.789*	0.955*
Size	79.500	59.577	119.743**	27.489**	36.111	70.658	89.079	47.682
Large firms	0.200	0.096	0.229**	0.064**	0.111	0.137	0.132	0.136
Turnover in 2005	139.782	154.306	317.426**	23.563**	390.322	119.239	155.886	143.039
Hardware firms	0.267	0.212	0.257	0.213	0.111	0.247	0.237	0.227
Age	4.233*	7.558*	7.543	5.447	4.333	6.589	5.000	7.500
Human capital	0.763	0.702	0.647	0.783	0.736	0.723	0.746	0.707
Asian competition	0.167	0.192	0.143	0.213	0.222	0.178	0.132	0.227
Government assistance	0.100	0.154	0.057*	0.191*	0.111	0.137	0.105	0.159
Capability, more management training	0.467	0.538	0.543	0.489	0.222*	0.548*	0.474	0.545
Capability, more technical training	0.833	0.712	0.771	0.745	0.556	0.781	0.816	0.705
Capability, improve quality	0.533*	0.699*	0.714	0.660	0.556	0.697	0.605	0.750
Capability, product innovation	0.467*	0.763*	0.486*	0.681*	0.556	0.603	0.474*	0.705*
Training, in-house technical	0.867	0.962	0.914	0.936	0.778*	0.945*	0.895	0.955
Training, in-house management	0.567	0.731	0.771**	0.596**	0.667	0.671	0.632	0.705
Training, overseas technical	0.267	0.404	0.429	0.298	0.111*	0.384*	0.211*	0.477*
Training, overseas management	0.067	0.077	0.114	0.043	0.000	0.082	0.026	0.114
Training, local training	0.733	0.615	0.800**	0.553**	0.556	0.671	0.737	0.591
Number of firms	30	52	35	47	9	73	38	44

The figures are, on average, statistically and significantly larger for * collaborators, ** noncollaborators buyers have, on average, higher export intensity than those that do not collaborate with foreign buyers. Furthermore, a larger percentage of collaborators have increased net profit, product innovation, improved capability, and overseas technical training.

In sum, the descriptive analysis of collaboration shows that many characteristics of firms that are collaborators and those that are noncollaborators are similar, but the partners they choose to interact with result in significant differences in terms of performance behavior.

16.3 Systemic Collaboration and Performance in Malaysia

In Malaysia, the government established the Kulim and Bukit Jalil high-tech parks in the 1990s although clusters such as Penang had been in existence for 20 years prior to these developments. The Malaysian survey focused on the computer and components clusters in Penang and Johor. Few firms are engaged in assembling computers, but most of them are engaged in computer components (e.g., capacitors, resistors, PCBs, diodes, and semiconductor chips) and assembly of completely knocked down (CKD) parts (e.g., monitors, keyboards, and LCD screens).

16.3.1 State Support and Patterns of Collaboration

To attract high-tech firms engaged in R & D activities to the clusters and high-tech parks, the government offered pioneer-status tax incentives. Electronics firms became the prime beneficiary of this initiative, although the rate of take-up has been relatively low compared to that of the free trade zones (FTZs) and LMWs. In addition, systemic coordination has been facilitated by strong cooperation between the state and firms for various requirements in the innovation process, and the comparison between Penang and Johor shows the impact of varying levels of state support. A notable example of this sort of policy coordination is the joint approach by the Free Trade Zone Penang Companies Association (FREPENCA) with PDC. This form of strategic intervention in developing infrastructure over time had been instrumental in fostering technological capacity. It has had the effect of facilitating transportation while the other cluster, namely, Johor has been unable to acquire comparative capacity to provide such service.

The knowledge infrastructure in Penang is also better than that in Johor, although the country, in general, does not have a significant number of R & D labs and, in comparative terms, lacks strong R & D human capital for the kind of growth that the sector has exhibited. Similar to the firms in South Africa, firms in both clusters in Malaysia also learned mainly through quality control activities and reverse engineering. TCs developed within firms in Penang are significantly higher and more varied compared with electronics firms in Johor and this can also be attributed to the interactions between local and foreign firms in the cluster.

Table 16.7 Systemic collaboration: computer and related component firms. (Source: empirical survey 2004)

	Foreign		T	Local		t
	Johor	Penang		Johor	Penang	
Ministries	2.75	3.05	−1.01	2.17	2.77	−0.97
Industry association	2.17	3.67	−3.15*	2.05	3.25	−2.95*
Training institutions	2.01	3.98	−3.25*	2.15	3.33	−3.02*
Universities	1.03	2.01	−3.11*			
State development corporation	2.35	3.57	−2.75*	2.11	2.63	−2.25**
R&D support units	0.1	0.3	−0.01	0.2	0.5	−0.10
Incubators	0	0	−0.00	0	0	0.00
Standards organization	2.01	2.15	−0.70	1.88	2.54	−2.45**
Horizontal interfirm links	1.87	2.45	−2.68*	1.90	2.33	−1.88
Vertical interfirm links	2.11	2.95	−2.45**	2.00	2.47	−2.01**
Complementary supplier links	2.21	3.13	−2.97*	2.02	2.94	−2.54**
N	*332*	*28*		*39*	*37*	

Likert scale score of firms (0–5 from none to highest possible rating)
*Significance level 1 %
**Significance level 5%

Empirical evidence comparing the two clusters (Table 16.7) shows a superior rating for firms in Penang compared to firms located in Johor in all the statistically significant two-tailed results. Knowledge infrastructure represented by R & D support was statistically insignificant, which is reflected in the lack of any sort of R & D relationships between firms (both foreign and local) and R & D institutions (e.g., university R & D, Malaysian Institute of Microelectronics System and the incubators put up in technology parks by the government). Collaboration between local firms and standards organizations is only statistically significant (at 5 % level). Interviews showed that local firms mainly sought the International Standards Organization 9000 series certification from the Standards and Industrial Research Institute of Malaysia (SIRIM).

Clearly one of the reasons for the relative superiority of Penang is that it was started much earlier and for much of this time there has been a consistent history of investment in the cluster since the 1970s.

16.4 Comparative Insights and Conclusions

Technological learning involves not only technical learning but also learning to build the right kinds of organizations and to foster the institutional forms within which policies would make the expected impact. For instance, most of the current work focuses on the success cases of East Asia's "advanced" latecomers to understand the reasons and different pathways to success, while much less has been done on the lagging ('falling behind') firms and countries. With these countries, learning has come to be conceptualized on the strength of the R & D carried out and patents taken just as in the case of industrialized countries. In the lagging latecomers, learning is difficult to quantify, measure, or even observe because much of the activity, including incremental technical change, is experiential and tacit in nature. Therefore, orthodox measures create a misleading impression of the learning processes in latecomer countries.

The empirical results reinforce the role of the state in supporting innovation through purposive action; we find evidence of the limitation of the state in deliberately building knowledge infrastructure. Furthermore, the two country analyses show that the focus should not simply be on enacting a long list of institutions that have worked elsewhere, but rather on the combination of specific institutional local innovation as well as working on generating coherence and harmony of institutions and policies that bring about change.

16.4.1 Composition and Capabilities Accumulation Among Actors

The main actors and capabilities in the computer hardware sector are engineers and scientists. The core knowledge infrastructure includes scientific laboratories as well as design and research centers. The availability of scientific infrastructure, firms, universities, and public research institutes determines the scope for specialization in any or all of the stages of the computer hardware industry, related to both physical and human capital, which are specific for each one of its substages.[8] Each of these substages requires a different combination of knowledge and skills of actors from various disciplines, some as diverse as physics, informatics, and computer science required to facilitate innovation. This scope of diverse actor competencies points to the limits of vision and action that a country might attempt. Fast followers such as Malaysia are well able to take advantage of the global knowledge pool in this sector but this might stretch the resources of most latecomers (Group 3). The firms in South Africa have adapted to the evolving domestic sector and have been largely driven by local consumption compared to Malaysia where the strategy has been to exploit global export market opportunities. Small firms largely dominate the sector with little prospects for significant global reach.

16.4.2 Impact of Policy Choices on Learning

Due in part to historical path-dependent factors and more directly as a consequence of choices made by the state, the nature and attributes of regional clusters differ in

[8] The substages comprise: (1) product design, (2) component manufacturing, (3) assembly, (4) software development, (5) marketing, and (6) distribution.

various respects, and this also impacts their performance. Policy choices made by different governments and in coordination with other nonstate actors have been instrumental in shaping the development of the clusters in both countries. For instance, there is the relatively hands-off approach to industrial coordination by state development corporations outside Penang (Malaysia), a limited intensity of interfirm relationships, and also limited potential of other clusters to develop and thrive.

However, the two countries' examples highlight the limitations of the state in deliberately building knowledge infrastructure. States have limited resources and different geographic zones have evolved from specific institutional settings that may not all be necessarily amenable to uniform policy intervention. The contrasting cases of Gauteng and Western Cape on the one hand and Penang Valley compared with Johor on the other illustrate this very well. In South Africa, there is evidence of purposive government intervention at building knowledge infrastructure especially at regional levels, but the outcomes have been far different from what obtains in Malaysia. In other words, while infrastructure is a necessary condition, it is not sufficient. What counts is the combination of factors as well as the coherence and harmony of institutions and policies that bring about change in given contexts.

Appendix 1

Table A.1 Descriptive statistics of the dependent and independent variables—South Africa. (Source: empirical survey by authors, 2006)

Variable	Mean	(Standard deviation)	Minimum	Maximum	Mean	(Standard deviation)	Minimum	Maximum
	All firms				Hardware computer firms			
Product innovator[a]	0.659	(0.477)	0	1	0.368	(0.496)	0	1
Productivity in 2005[b]	0.995	(1.715)	0.019	13.462	2.026	(2.931)	0.167	13.462
Export intensity	0.171	(0.292)	0	1	0.133	(0.271)	0	0.98
Increased net profit	0.878	(0.329)	0	1	0.842	(0.375)	0	1
Size[b]	66.866	(159.639)	2	1162	198.316	(290.389)	2	1162
Large firms[b]	0.134	(0.343)	0	1	0.421	(0.507)	0	1
Turnover in 2005[b]	148.992	(533.796)	0.075	3500	576.121	(1013.127)	1.200	3500
Hardware firms	0.232	(0.425)	0	1	–	–	–	–
Human capital[a]	0.725	(0.257)	0.138	1	0.550	(0.281)	0.138	1
Asian competition	0.183	(0.389)	0	1	0.158	(0.375)	0	1
Quality control	0.378	(0.488)	0	1	0.316	(0.478)	0	1
Upgrade, reverse engineering[a]	0.378	(0.488)	0	1	0.158	(0.375)	0	1
Original design[a]	0.317	(0.468)	0	1	0.105	(0.315)	0	1
Original brand[b]	0.061	(0.241)	0	1	0.158	(0.375)	0	1
Local expertise[a]	0.146	(0.356)	0	1	0.000	(0.000)	0	0
Foreign expertise[b]	0.159	(0.367)	0	1	0.474	(0.513)	0	1
Combination[a]	0.695	(0.463)	0	1	0.526	(0.513)	0	1
Licensing from clients[a]	0.744	(0.439)	0	1	0.474	(0.513)	0	1
Buyers[a]	0.183	(0.389)	0	1	0.053	(0.229)	0	1

Table A.1 (continued)

Variable	Mean	(Standard deviation)	Minimum	Maximum	Mean	(Standard deviation)	Minimum	Maximum
	All firms				Hardware computer firms			
Joint venture partner	0.622	(0.488)	0	1	0.474	(0.513)	0	1
Component suppliers[b]	0.280	(0.452)	0	1	0.579	(0.507)	0	1
Transfer from parent firm	0.146	(0.356)	0	1	0.158	(0.375)	0	1
Managers/skilled employees[a]	0.866	(0.343)	0	1	0.737	(0.452)	0	1
Suppliers of equipment	0.951	(0.217)	0	1	0.947	(0.229)	0	1
Universities and public institutes[a]	0.195	(0.399)	0	1	0.053	(0.229)	0	1
Technology source, reverse engineering[a]	0.512	(0.503)	0	1	0.211	(0.419)	0	1
Government assistance	0.134	(0.343)	0	1	0.158	(0.375)	0	1
Government support, innovation incentives[a]	0.280	(0.452)	0	1	0.158	(0.375)	0	1
Government support, avail. skilled manpower	0.171	(0.379)	0	1	0.158	(0.375)	0	1
Government support, local universities for R&D col.	0.220	(0.416)	0	1	0.263	(0.452)	0	1
Government support, R&D institutes for tech. sol.[b]	0.073	(0.262)	0	1	0.158	(0.375)	0	1
Government support, IPP	0.305	(0.463)	0	1	0.263	(0.452)	0	1
Government support, quality of IT sup. serv.	0.183	(0.389)	0	1	0.158	(0.375)	0	1
Government support, avail. venture capital	0.232	(0.425)	0	1	0.263	(0.452)	0	1
Government support, bank loans[b]	0.110	(0.315)	0	1	0.211	(0.419)	0	1
Government support, innovation subsidy	0.329	(0.473)	0	1	0.263	(0.452)	0	1
Government support, taxation policy	0.085	(0.281)	0	1	0.105	(0.315)	0	1
Government support, science cluster advantage[a]	0.537	(0.502)	0	1	0.316	(0.478)	0	1
Government support, procurement policy	0.232	(0.425)	0	1	0.263	(0.452)	0	1
Government support, spec. supp. for SMEs[a]	0.451	(0.501)	0	1	0.316	(0.478)	0	1
Government demand, faster delivery time	0.561	(0.499)	0	1	0.526	(0.513)	0	1

Table A.1 (continued)

Variable	Mean	(Standard deviation)	Minimum	Maximum	Mean	(Standard deviation)	Minimum	Maximum
	All firms				Hardware computer firms			
Government demand, packaging quality[a]	0.305	(0.463)	0	1	0.158	(0.375)	0	1
Government demand, conformity to standards	0.549	(0.501)	0	1	0.474	(0.513)	0	1
Government demand, price	0.634	(0.485)	0	1	0.737	(0.452)	0	1
Government demand, product quality	0.768	(0.425)	0	1	0.684	(0.478)	0	1
Capability, more management training	0.512	(0.503)	0	1	0.474	(0.513)	0	1
Capability, more technical training	0.756	(0.432)	0	1	0.842	(0.375)	0	1
Capability, improve quality	0.683	(0.468)	0	1	0.579	(0.507)	0	1
Capability, product innovation[a]	0.598	(0.493)	0	1	0.368	(0.496)	0	1
Training, in-house technical	0.927	(0.262)	0	1	0.947	(0.229)	0	1
Training, in-house management	0.671	(0.473)	0	1	0.684	(0.478)	0	1
Training, overseas technical[b]	0.354	(0.481)	0	1	0.579	(0.507)	0	1
Training, overseas management[b]	0.073	(0.262)	0	1	0.158	(0.375)	0	1
Training, local training[b]	0.659	(0.477)	0	1	0.789	(0.419)	0	1
Number of firms	82				19			

[a] These figures are larger on average in the software sector
[b] These figures are larger on average in the hardware sector

References

Bell RM (1984) Learning and the accumulation of industrial technological capacity in developing countries. In: Fransman K, King K (eds) Technological capability in the third world. Macmillan, London

Bell RM, Pavitt K (1993) Technological accumulation and industrial growth: contrasts between development and developing countries. Ind Corp Change 2(2):157–210

Bell M, Pavitt K (1995) Trade, technology, and international competitiveness, EDI development Studies, economic development institute of the World Bank. The World Bank, Washington, DC

Cohen WM, Levinthal DA (1990) Absorptive capacity: a new perspective on learning and innovating. Admin Sci Quart 35:128–152

Dahlman CJ, Westphal LE (1982) Technological effort in industrial development: an interpretative survey of recent evidence. In: Stewart F, James J (eds) The economics of new technology in developing countries. Francis Pinter, London

Dahlman CJ, Ross-Larson B, Westphal LE (1987) Managing technological development: lessons from the newly industrializing countries. World Dev 15(6):759–775

Dosi GC, Nelson FR, Silverberg G, Soete S (1988) Technical change and economic theory. Francis Pinter, London

Greene WH (2003) Econometric analysis, 5th edn. Prentice Hall, Upper Saddle River.

Katz J (1984) Domestic technological innovation and dynamic comparative advantage. J Dev Econ 16(1–2):13–37

Katz J (1987) Technology generation in Latin American manufacturing. Macmillan, Houndmills

Lall S (1987) Learning to industrialize: the acquisition of technological capability by India. Macmillan, London

Lall S (1990) Building industrial competitiveness in developing countries. OECD Development Centre, Paris

Lall S (1992) Structural problems of African industry. In: Stewart F, Lall S, Wangwe S (eds) Alternative development strategies in Sub Saharan Africa. Macmillan, London, pp 103–144

Nelson R, Winter S (1982) An evolutionary theory of economic change. Belknap Press, Cambridge

Oyelaran-Oyeyinka B, Rasiah R (2008) Uneven paths of development information: hardware innovation systems in Asia and Africa. Edward Elgar, London

Scott-Kemmis D, Bell RM (1988) Technological dynamism and technological content of collaboration: are Indian firms missing opportunities? Technology absorption in Indian industry. Wiley, New Delhi, pp 71–86

Westphal L, Kim L, Dahlman C (1985) Reflection on the republic of Korea's acquisition of TC. In: Nathan R, Claudio F (eds) International technology transfer: concepts, measures, and comparisons. Praeger, New York, pp 167–221

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