India Studies in Business and Economics

N.S. Siddharthan
K. Narayanan
Editors

Globalisation of Technology

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N.S. Siddharthan · K. Narayanan
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Editors
N.S. Siddharthan
Madras School of Economics
Chennai, Tamil Nadu
India

K. Narayanan
Department of Humanities and Social Sciences
Indian Institute of Technology Bombay
Mumbai, Maharashtra
India

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Preface

Forum for Global Knowledge Sharing (Knowledge Forum) is a specialised, interdisciplinary global forum. It deals with science, technology and economy interface. It aims at providing a platform for scholars belonging to different institutions, universities, countries and disciplines to interact, exchange their research findings and undertake joint research studies. It is designed for persons who have been contributing to R&D and publishing their research findings in professional journals. The papers included in this volume are drawn from those presented in an international seminar on "Creation and Diffusion of Technology" held at Indian Institute of Technology Bombay on 18 March 2016 and in the 11th annual international conference on the theme "Globalisation of Technology and Development" held at Indian Institute of Technology Madras during 3–5 December 2016. Both these events were organised by Knowledge Forum in partnership with TATA Trusts.

We thank the contributors for sharing their research papers to be included in this volume. We would like to place on record our sincere gratitude to all the peer reviewers, discussants and participants of the seminar and conference for their useful comments and suggestions on these papers. The discussion in these two events motivated us to select the included papers on the theme of "Globalisation of Technology". The edited volume opens up new research agenda for empirical studies on the theme of multinationals and technology, and also provides useful insights for policy formulation to promote innovative activities from an emerging economy perspective.

Chennai, India — N.S. Siddharthan
Mumbai, India — K. Narayanan

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About the Editors

N.S. Siddharthan is an Hon. Professor at the Madras School of Economics, Chennai, and Hon. Director, Forum for Global Knowledge Sharing. His current research interests include technology and globalisation, international economics, multinational corporations, and industrial organisation. He has published several papers in internationally acclaimed journals such as *The Economic Journal*, *Oxford Bulletin of Economics and Statistics*, *The Journal of Development Studies*, *Economics of Innovation and New Technology*, *Applied Economics*, *Development and Change*, *Journal of Economic Behavior and Organization*, *Journal of Business Venturing*, *Japan and the World Economy*, *Journal of International and Area Studies*, *International Business Review*, *Developing Economies*, *Weltwirtschaftliches Archiv*, *Transnational Corporations*, *The Indian Economic Review*, *The Indian Economic Journal, and Sankhya*. He has also authored books with publishers such as Springer, Routledge, Oxford University Press, Macmillan, Allied, Academic Foundation and New Age International Publishers.

K. Narayanan obtained his Ph.D. in Economics from the Delhi School of Economics, University of Delhi, India, and carried out his postdoctoral research at the Institute of Advanced Studies, United Nations University, Japan. His research interests and publications are in the fields of industrial competitiveness, technology transfer, ICT, international trade, energy economics and the socio-economic impacts of climate change. He has published in several journals of international repute, including *Research Policy*, *Journal of Regional Studies*, *Technovation*, *Oxford Development Studies*, *Journal of Industry*, *Competition and Trade*, *Foreign Trade Review*, *Transnational Corporations Review*, *The Journal of Energy and Development*, *Water Policy*, *Current Science*, and *Economic and Political Weekly*. He has jointly edited six books on globalisation, investments, skills and technology. He also guest edited special issues of journals such as *The IASSI Quarterly, Science, Technology and Society*, and *Innovation and Development*. He is actively engaged in a Web-based research group, Forum for Global Knowledge Sharing, which brings together scientists, technologists and economists. Dr. Narayanan is currently Institute Chair Professor at the Department of Humanities and Social Sciences, Indian Institute of Technology Bombay, Mumbai, India.

Chapter 1
Introduction to the Volume

N.S. Siddharthan and K. Narayanan

1.1 Introduction

Many countries in the world embarked on the path of globalisation during the last three decades. This period witnessed rising world trade, international flow of capital and other resources, as well as growing knowledge and technology sharing among developed and emerging economies. One of the reasons for the speed of globalisation during this period is the advances in technology. In particular, the developments in information and communication technologies (ICT) have enabled the emergence of small and medium high-tech firms and contribute to innovations, improve efficiency and reduce costs. They could network with large corporations and collaborate. The Internet and digital technology which speeded up the developments in ICT also have changed the way we live, the methods of organising production and marketing of industrial firms. For example, Internet has enabled instant communication between two firms located in different continents, that too at a very low price. In addition, technological development in the transportation industry has brought about transformation in the air, road, rail and sea travel. Researchers have pointed out that knowledge building, innovation and scientific–technological advance are the critical ingredients for economic growth and competitive advantage in the contemporary world. However, the knowledge building processes, especially in science and technology, could be tumultuous, complex, interactive and nonlinear. This requires continuous decisions and actions on the part of the innovator as well as those engaged in the search process.

N.S. Siddharthan (✉)
Madras School of Economics, Chennai, Tamil Nadu, India
e-mail: nssiddharthan@gmail.com

K. Narayanan
Department of Humanities and Social Sciences, Indian Institute of Technology Bombay, Mumbai, India
e-mail: knn.iitb@gmail.com

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Each specific innovation strategy calls for different group sizes, skills, management styles, incentives, planning horizons, innovation approaches, pricing strategies, supporting policies and reward systems. Because of complexity and differential capabilities, innovation increasingly is being performed not by formal teams, but by collaborations of independent units in entirely different organisations and locations. All technological strategies, whether at the national, corporate or micro-organisational level, need a sophisticated balance between a set of clearly structured and highly motivating goals and some very independent (yet interdependent) organisational modes specifically adapted for the particular problems at hand. The importance of knowledge sharing, instead of mere technology transfer from developed to developing country firms, in the ongoing technological revolution is well documented by Siddharthan and Rajan (2002). They argue that in a world of short product life cycles, firms will need to continuously upgrade their technology through networking and interaction with other firms and R&D organisations. The multinational corporations have been relocating their R&D units in other countries to take advantage of such technological (especially Internet) revolutions and attempting to emerge as global innovators.

The literature also points out that developing countries need to acquire greater technological capability and high flexibility to succeed in the more demanding and asymmetric global environment (Dahlman 2008). It is likely that the pressures of globalisation and greater international competition generate strong protectionist retrenchment in both developed and developing countries. The world as a whole will be better off if developed countries focus on increasing their flexibility to adjust to changing comparative advantage resulting from rapid technical change, and developing countries focus on increasing their education, infrastructure and technological capability. The focus of attention here is that technology is an increasingly important element of globalisation and that the acceleration in the rate of technological change identifies the prerequisites necessary to participate effectively in globalisation. Earlier studies (Narayanan and Bhat 2011) observed that multinationals from emerging economies who enjoy specific ownership (e.g. in the Information Technology industry and small, family oriented businesses) and know-how advantages do invest in similar developing as well as developed countries to make their presence felt globally. These investments are usually supported by learning by exporting, productivity and technological advantages that they have acquired over a period of time.

If one looks at the changes that are taking place in fast-growing emerging economies, especially Brazil, India and China, the efforts made are very visible. The increased emphasis of documenting their technological efforts and achievements by these countries is reflected in the number of applications for patents and trademark, apart from the number of people engaged in R&D. Table 1.1 provides details on the number of patent applications and trademark applications during the period 2005–2007 and 2010–2014. China records a threefold increase in the number of patent applications, while India witnessed almost 50% increase. In addition, Brazil also reports an increase in the number of patent applications during the reference period. In terms of trademark applications, there is a substantial increase in most of these

Table 1.1 Patent and trademark applications in three largest developing countries

Country	Patent applications (2005–07)	Patent applications (2010–14)	Trademark applications (2005–07)	Trademark applications (2010–14)
Brazil	20,001	29,061	99,793	150,508
China	209,663	664,735	694,149	1,603,829
India	29,509	42,378	104,200	200,465

Source Authors' compilation from WTO statistical database

Table 1.2 Researchers engaged in R&D and national R&D intensity in three largest developing countries

Country	Researchers in R&D (per million people) (2005–07)	Researchers in R&D (per million people) (2010–14)	R&D intensity (expenditure as % of GDP) (2005–07)	R&D intensity (expenditure as % of GDP) (2010–14)
Brazil	590.9	698.1	1.0	1.2
China	955.9	1023.8	1.4	1.9
India	135.3	156.6	0.8	0.8

Source Authors' compilation from WTO statistical database

countries, with China topping the list. India witnessed double the number of applications for trademark during this time period.

Table 1.2 provides data on the number of researchers engaged in research and development (R&D) activities in these three large developing countries during the same two time periods. It also provides data on proportion of GDP spent on R&D in these countries. The number of people engaged in R&D per million populations has increased for all the countries. In terms of R&D expenditure as a percentage of GDP (R&D intensity), these countries spend less than 2% of their GDP. Only Brazil and China show an increase in this intensity. R&D intensity, however, is not the only indicator of the technological efforts in an economy. Investments for skill development, especially outlays for basic and higher (including technical) education, are very crucial for creating an innovation culture among the firms in these countries.

Furthermore, several developing countries have been increasing their investments in basic and ICT infrastructure as well as higher education. This should help them speed up the process of technological learning and innovations. The strong link between their economies and that of the rest of the world along with increased technological efforts taken in totality would help the firms in these countries become more competitive. Several multinational enterprises have been investing in China and India in establishing R&D units. Along with the USA, China and India are the top three destinations for foreign direct investments in R&D. According to Hegde and Hicks (2008), the main reason for the high flow of foreign direct investments to China and India is the increase in the research publications of these two countries in science and technology journals. They show that during the period of their study, the number of science and technology publications from China and

India doubled. They measure technological strength of the country by publications record and rapid increases in scientific publications. The papers included in this volume address the opportunities and challenges that arise with globalisation of technology.

Enterprises globalise in several ways—exports, sourcing of components and materials from other countries (B2B commerce), outsourcing, licensing of technology and production and foreign direct investments (FDI). Transaction costs and location advantages play a crucial role in the choice of the mode of globalisation. In this context, there are some important issues like what are the pull and push factors contributing to FDI? Does outward FDI from a developing country like India contribute to participation in international production network? Does FDI mitigate business cycle co-movements? The volume will discuss these issues and in addition will also deal with the consequences of FDI, in particular, technology, productivity and R&D spillovers. Furthermore, the volume also covers issues related to innovations, R&D, intra-industry trade and knowledge management.

The papers are organised in four parts.

1.2 FDI: Push and Pull Factors

For several decades till 1970s, most FDI originated from developed countries and in particular the USA and mainly went to other developed countries. During that period, almost 80% of FDI emanated from OECD countries and went to OECD countries. The developing countries received very little FDI. In other words, multinational enterprises (MNEs) were mutual invaders, and they mainly invested in countries that were also home to other MNEs. However, since late 1980s, MNEs have started investing in several Asian countries. Since then some of the developing countries like China, India and other Asian countries have developed their own MNEs and started investing in developed and developing countries. In this context, the Chinese and Indian multinationals have emerged prominent. Consequently, several types of FDI have emerged, and their respective determinants could differ.

FDI could be between: one advanced economy to another advanced economy; advanced economy to developing economy; and developing economy to advanced economy. Roy and Narayanan argue that the determinants of the three cases or groups are different, and it is wrong to club them in one group and analyse. In this context, the paper identifies pull and push factors and finds them different for these three groups. Furthermore, in most of the studies of this kind, multicollinearity also poses a problem. The paper suggests a way out of this problem.

Another motive for outward FDI (OFDI) could be to take part in the international production network. It could also be related to the promotion of exports to the host countries. The paper by Das addresses some of these issues. Production-network-related exports are mainly in the form of exports of parts and components to final manufactures. They could also be analysed in the framework of business-to-business (B2B) commerce. The study finds a significant impact of

Indian OFDI on the export of components and parts. It covered OFDI to both the developed and developing countries. It also found a significant relationship between inward and outward FDI in bilateral relations and trade. Furthermore, preferential trade agreements also contributed positively to OFDI from India. This could suggest that Indian firms prefer to manufacture in other countries where business environment is better and import them to India.

The next paper deals with certain other issues that are neglected in literature. In this context, Patnaik and Sahu pose two interesting issues, namely does FDI influence business cycle synchronisation? And do developing countries attract pollution-intensive industries through FDI? Their data set is composed of 25 Asian country pairs over the period 2007–2014. They conclude that FDI (both inward and outward) is negatively related to co-movements in business cycles. This suggests that FDI could act as a stabilising agent during business cycles. Regarding pollution-intensive industries, their data suggests a positive relationship between FDI and polluting industries.

1.3 FDI: Consequences

Regarding consequences, the volume mainly deals with technology and productivity spillovers from multinationals to local firms. It discusses both horizontal and vertical spillovers and the role of in-house R&D in influencing spillovers. Studies also deal with the impact of FDI and in-house R&D efforts.

Most developing countries attract FDI by granting tax and other concessions mainly to benefit from technology and productivity spillovers so that the host country firms benefit and become globally competitive. However, not all local firms would benefit by spillovers. Some could even become victims and close down. The literature in this area is rich. One of the earliest papers in this area (Kokko et al. 1996) showed that domestic firms with large technology gaps with MNEs may not benefit from spillovers and could even become victims of FDI as the MNE and these firms could be in different technological paradigms. Spillovers could be mainly to get technological trajectory advantages and not benefit by paradigm shifts. Several examples could be cited, for example, in the automobile sector, if the MNE comes with conveyer belt LAN-based method of production and the local firms are using batch method of production, there could be no spillovers. Later studies (Kathuria 2002; Hu et al. 2005) showed the local firms that were R&D intensive gained from spillovers and others lost. Some studies showed that when countries liberalised and large inflow of FDI came, during the initial years, spillovers might not be substantial—could even be negative. However, over the years, the spillovers could increase and prove beneficial (Siddharthan and Lal 2004; Liu 2008). Some studies also concentrate on vertical spillovers and benefit to down and upstream firms (Bitzer et al. 2008). MNEs also can benefit from the environment of the host countries. The benefit need not be confined to the joint venture or the subsidiary of the MNE operating in the host country. The MNE as a group can also benefit from the spillovers (Kafouros et al. 2012).

The paper by Mondal and Pant is in line of the studies mentioned in the previous paragraph, and it analyses the productivity spillovers from FDI for the Indian manufacturing sector for the period 1994–2010. They discuss both horizontal and vertical spillovers. The study shows that only firms that already enjoy initial technological capabilities gain from FDI spillovers. This finding is in line with the findings of earlier studies. Furthermore, firms that had huge technology gaps became victims of FDI inflows. This is also confirmed by other research studies. Large technology gaps involve paradigm shifts in technology, and firms that are in an earlier technological paradigm will not benefit by the presence of foreign firms.

The paper by Ghosh and Roy discusses the impact of FDI on firm-level R&D in the Indian manufacturing during the post-2000 period. The role of foreign ownership, imported foreign technology and total factor productivity (TFP) is studied. Most studies consider R&D as an important determinant of TFP. This study considers the reverse causality, namely the impact of productivity on R&D. Furthermore, it studies its differential impact based on the ownership of firms, that is, MNEs and others. It finds MNEs enjoying high productivity levels spend more on R&D. The study also finds older and more experienced firms investing more in R&D. Technology transfer by MNEs also contributes to innovative activities.

1.4 R&D and Innovations

The factors influencing the location of R&D units in a foreign country and in particular the role of intellectual property protection and product cycles in influencing the locations is an under-researched area. Likewise, innovative activities and mergers and acquisitions is also an under-researched area. The volume covers these important gaps in literature.

Till recently, multinationals performed most of their R&D in their respective home countries. If at all they established R&D units in host countries, it was to adapt their technology and products to the host country environment and market. During the 1980s, several firms established R&D units in technologically advanced countries to take advantage of the technological and research environment in the host countries. In more recent years, they have also been setting up R&D units in developing countries. Since the early 1990s, multinationals have started establishing their R&D units in developing countries like China and India. Further, during the last decade, the importance of intellectual property protection and the role of appropriability have been occupying a central place in most of the discussions on R&D. The developing countries have enacted laws to enhance intellectual property protection in accordance with the WTO guidelines. It was, more or less, assumed that enhanced intellectual property protection would facilitate investments in R&D and the world would be better off. However, the results of several research studies do not support this view. The classic paper by Cohen and Levinthal (1989) shows that technological opportunities and diffusion are much more important in determining in-house R&D expenditures than appropriability. Furthermore, Becker and Dietz (2004) show that strict intellectual property laws stand in the way of R&D collaborations. This has resulted in several firms opting for informal R&D collaborations and there by bypass the strict protection law (Bonte and Keilbach 2005).

In this context, the paper by Valacchi relates innovations and the location of R&D units by MNEs to intellectual property protection and product life cycles. The interrelationships between the three features have not been analysed so far in a unified model, and this is the first major work in this area. In particular, she asks the question: Does stronger IPR attract more innovation? She has used a multi-country and multi-sector data base of more than 15,000 innovating firms. She finds that strong IPR attracts innovative activities of products with long product life cycles. In contrast, products with short life cycles and technologies with faster obsolescence rates are not sensitive to IPR protection. This finding is important as most high-tech industries like electronics and biotechnology have short product life cycles, and all these industries are R&D intensive. Some earlier studies have also found that IPR was not very important in influencing the location of R&D units. However, the main contribution of Valacchi study is that it relates it to product life cycles.

Most studies on innovations either ignore or do not give importance to mergers and acquisitions (M&A). It is more or less taken for granted that the main motive for M&A is to improve market share and consolidation. However, in recent years, several M&A have taken place to improve R&D capacities. Some of the firms that spend less on R&D have been adopting this method of acquiring technology, namely acquiring R&D-intensive firms. This route is also gaining importance. Blonigen and Taylor (2000) found a significant inverse relationship between R&D intensity and acquisition activities. They also present cases of such acquisitions where the chief executives of the firms clearly state that they acquired the firm in question as it is R&D intensive while their own firm was not and the acquisition was a strategy to get access to the R&D output of the firm.

The paper by Saraswathy addresses this important issue. The study based on Indian data shows that cross-border M&A have resulted in an increase in technology imports against royalty and technical fee payments and a reduction in R&D intensity in India. The inference is that after cross-border M&A, the MNE does most of the R&D in the foreign country which is the home country of MNE and transfers the innovations to India against royalty and other payments.

R&D expenditures depend on three factors: appropriability, technological opportunity and R&D spillovers. Technological opportunity mainly depends on the research undertaken by the universities and research laboratories. Appropriability depends on the level of intellectual property protection. Complete protection would ensure the absence of spillovers. In case spillovers are important for R&D spending, then one needs to go slow on IPR. The paper by Shukla analyses the inter-firm differences in R&D intensities for the electronic goods sector in India. The paper suggests a complementary relationship between in-house R&D and R&D spillovers from other firms. As in the case of earlier studies included in this volume, age of the firm representing learning by doing has turned out to be an important determinant. Furthermore, older firms benefit more from R&D spillovers. In addition, smaller forms are more R&D intensive. Larger firms reap economies of scale advantages, and consequently, their R&D expenditures increase less than proportion to their size.

1.5 Technology and Competitiveness

Under this theme, the volume will cover technological issues relating to intra-industry trade and the role of information technology and technology clusters and agglomeration effects.

The paper by Bagchi relates technology to intra-industry trade revealed comparative advantage and vertical integration. The results indicate that in the intra-industry trade, low-technology goods dominate the Indian exports indicating a downward trend in terms of trade. However, there is evidence that the Indian manufacturing sector is shifting to relatively higher technology products due to imports and intense competition. But this is yet to get reflected in intra-industry exports. Nevertheless, Indian industry and exports are undergoing a process of structural change, and in future, the weightage of technology-intensive differentiated products exports is likely to increase.

The last paper by Paul, Jaganth, Minz and Rahul is on auto-component sector. This is export-oriented modern sector where India has been doing well. This industry is part of a dynamic value chain. The industry is dominated by small and medium enterprises, but the final consumers are large firms assembling automobiles. In short, the market structure is monopsonistic. The main contributor for the growth of firms belonging to both the organised and unorganised sectors turns out to be investment is information technology and ISO certification. In addition, quality of labour also contributed to growth. Furthermore, locating the firm in technology and auto-clusters also helped in its growth.

To sum up, the papers included in this edited volume highlight the changing technological objectives of firms in the era of globalisation. Most of the firms in developing countries are adjusting themselves to the growing demand for dynamism in their technological efforts to stay competitive.

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Part I
FDI: Pull and Push Factors

Chapter 2
Pull Factors of FDI: A Cross-Country Analysis of Advanced and Developing Countries

Indrajit Roy and K. Narayanan

Abstract In a cross-country bilateral FDI flow setup, we examine macroeconomic determinants of FDI flow to advanced economies (AE) from AE, to AE from developing economies (DE), to DE from AE and to DE from DE. It is observed that determinants vary significantly across these broad groups. Further, we construct composite index based on these macroeconomic determinants and rank the countries within these broad groups of FDI flow to understand macroeconomic enabler in the host country which attract FDI. We also propose a new methodology to circumvent multicollinearity issue which arises as selected determinants of FDI are found to be interrelated.

2.1 Introduction

Firm invests in a foreign country in search of profit and safety or strategic needs. Empirical studies have shown that foreign direct investment (FDI), which is a major component of cross-border capital movements, is helpful for technological progress, productivity improvements and thereby plays a critical role for the long-term growth and development of the FDI recipient countries. As a result, countries are keen to attract and retain FDI by way of strengthening various socio- and

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I. Roy (✉)
Department of Statistics and Information Management, Reserve Bank of India, Mumbai 400051, India
e-mail: iroy@rbi.org.in

K. Narayanan
Department of Humanities and Social Sciences, Indian Institute of Technology Bombay, Mumbai 400076, Maharashtra, India
e-mail: knn@hss.iitb.ac.in

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macroeconomic parameters as well as governance issues which are believed to be scrutinized by the multinational enterprises (MNEs) before making FDI. Therefore, for the policy makers, identification of macrovariables in the order of relative importance is important.

In the recent past, we have witnessed spurt in FDI and it is growing at much faster rate than global exports growth. According to UNCTAD (2015), world FDI stock to GDP has sharply increased from 9.8% in 1990 to 34.5% in 2013 and during the same reference period sales of foreign affiliates to GDP also has increased from 21.2 to 44.8%, whereas, exports of goods and services moderately increased from 19.4 to 30.6%. Although FDI predominantly initiates at advanced economies (AE), we are now witnessing a new phenomenon of significant reverse flow of FDI from developing economies (DE) as well. Also the characteristics of MNE's of DE are quite different as compared to MNE's of AE. According to UNCTAD (2015), DE's share in total outward FDI reached to 35% in 2014, up from 13% in 2007. MNEs of DE have expanded their foreign operations mostly through Greenfield investments as well as cross-border M&As. According to UNCTAD (2015), during 2007–2014, 52% (average) of FDI outflows by DE MNEs were in equity and there is not much variation in the share over the period, whereas, AE MNEs' FDI is in the nature of reinvested earnings and the reinvested earnings as a percentage of their FDI outflows has increased from 34% in 2007 to 81% in 2014.

Two types of exogenous macroeconomic parameters are at work to influence FDI decision of MNEs. Pull factors or host country-specific factors, i.e. macroeconomic characteristics specific to host country (recipient of FDI) which attracts FDI, together with various push factors or home country factors, i.e. macroeconomic factors in the home country (source country of FDI) which act as driving force for outward FDI, significantly determine the direction and intensity of FDI flow to the host country.

Usual trend of FDI movement among the countries within AE has changed significantly in the past two decades or so and DE are now witnessing a large amount of FDI flow to-and-from AE. Intuitively, countries with stable macroeconomic situation, good development indicators with political stability and strong institutions attract more FDI. As a result, FDI flows are not homogeneous across countries and also there are diverse motives of MNEs behind FDI and what really pulls FDI to a country still remains an open question and literature survey indicates a large variation in determinants for bilateral FDI flow.

This paper re-examines the wide range of macroindicators of 22 countries[1] (both AE and DE) for the period 2010–2012, in order to find out macroeconomic determinants (mainly net of pull and push factors) which influence MNE's investment decision and also investigate whether these determinants are different for FDI flow (a) to AE from AE, (b) to AE from DE (c) to DE from AE and (d) to

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[1]**Advanced Economies studied in this paper**: Australia, Austria, Belgium, Canada, France, Germany, Italy, Japan, Norway, Spain, Sweden, Switzerland, UK, USA;

Developing Economies studied in this paper: China, Brazil, Russia, Mexico, India, South Africa, South Korea and Thailand.

DE from DE. The paper also contributes to the literature by way of devising a novel way to circumvent multicollinearity[2] issue in the multiple regression equation. The new approach followed in the paper is a two-step process. It constructs composite indices (primary composite index—PCI and secondary composite index—SCI) by way of weighted linear combinations of the explanatory variables with optimum weight structures in such a way that PCI and SCI are uncorrelated and together can explain the variation of the dependent variable better than the usual principal component analysis approach. Further, FDI flow to a country partly depends on prevailing macroeconomic situation and collective information of these macroeconomic determinants to FDI flow is reflected in the constructed composite index CI. Therefore, correlation or any other measure of association of any macroeconomic indicator with the CI will reflect the intensity of influence of individual macroeconomic indicator on FDI flow. Moreover, CI can be used to rank the countries within the four broad groups of FDI flow to understand the macroeconomic enabler in the host country to attract FDI and the rank for a country may vary across broad groups.

2.2 Survey of Literature

2.2.1 Theoretical Background

A large number of studies examine micro- and macroaspect of FDI theories. Microeconomic theory of FDI emphasizes on market imperfections and motive of MNEs to expand their market share and ownership advantage (product superiority or cost advantages, economies of scale, superior technology, managerial advantage, etc); therefore, MNEs will find it cheaper to expand directly into a foreign country. Also explanation of FDI includes regulatory restrictions (tariffs and quotas), risk diversification. Macroeconomic theories on FDI explain why MNE chooses a particular foreign location and for that purpose depends on international trade theory and also investigates comparative advantages including environmental dimensions in choosing a location.

Despite the 'liabilities of foreignness' how MNEs successfully compete with the local firms are explained by Hymer (1960) and argued that MNEs have certain ownership advantage (technological advantages, financial advantages, organizational advantages). Also product cycle theory of Vernon (1966) which relates different stages of production life cycles with FDI actually connects micro and macroaspects of FDI theory. Johanson and Vahlne (1977) suggest gradual internationalization of firms through different stages. However, recent studies have shown that new firms especially from the emerging markets with little experience on foreign markets, penetrate and integrate early with other foreign markets [these

[2]Multicollinearity: Detail given in Appendix 2.

firms are termed as 'Born global' into the literature (Hashai and Almor 2004)]. The eclectic paradigm, also known as OLI paradigm, was developed by Dunning (1977, 1988). OLI paradigm is a combination of three factors, i.e. ownership (O) advantage (industrial organization theory), location (L) advantages (international immobility of some factors of production) and internalization (I) advantage (transaction cost economics) which explain different types of FDI. A firm should possess some sort of comparative advantage over other firms of the host country and the firm believes that it would gain immensely by internalization of these assets which implies that an internal expansion is preferred instead of depending on market (e.g. licence agreement with another firm). The ownership advantage of the firm can be better exploited when it is combined with the favourable factor inputs located in the host country. Williamson (1981), Teece (1986) and Casson (1987) have worked on OLI paradigm and focused on firm's decision to internalize the production process by investing abroad instead of licensing in an imperfect markets.

'Ownership' advantage as described by Dunning (1977) states that firm may go for FDI if it has enough ownership advantage to counter the 'Liability of Foreignness' in foreign countries. This explains nicely the outward FDI initiative of AE MNEs who are assumed to have significant 'Ownership' advantages (O^+). However, DE MNEs may not have such 'ownership' advantages; instead, they are facing some kind of ownership disadvantages (O^-) which obstruct it from growing further or it may be facing threat from rivals (domestic/foreign firms)—threat to its existence. Therefore, DE MNEs which have intentions and means are eager to make good their 'ownership deficiency' (O^-) and go for FDI in search of critical asset of its need, which will help these firms back at home. By initiating FDI, firms from emerging markets may or may not gain in the short run but likely to be gainful in the long run. Hence, firms which either possess ownership advantages (O^+) or ownership disadvantages (O^-) may initiate FDI. OLI framework suggests that firm may initiate FDI to a foreign location which provides significant 'Location' advantage (L^+). Location advantage explains resource seeking motives of some firms and their FDI. However, there are firms in DE which are facing insufficient and inefficient infrastructure (soft/hard), i.e. location disadvantage (L^-) at home country and are opting to some foreign locations which offer better infrastructure. Therefore, location advantages (L^+) at host as well as location disadvantages (L^-) at home may trigger FDI, i.e. combination of pull and push factors are at work to determine direction and level of FDI.

Numerous studies focused on how exogenous macroeconomic factors influenced MNEs FDI decision. These include economic activities (size, openness and stability of the economy), legal and political system, business environment, investment incentives and infrastructure. These determinants can largely be categorized into pull factors and push factors which influence location choice of MNEs overseas investments. In case of Horizontal FDI, access to markets on the face of trade frictions and in case of vertical FDI, accesses to low wages to aide production process are important motives of MNEs for FDI (Markusen 1984; Helpman 1984). Also there are unconventional reasons, such as FDI to a staging foreign location as a production centre to exports further to other neighbouring countries, hub-and-spoke model of vertical integration where sub-processes/intermediate products are produced at various foreign locations and then integrated to final product at another location and thereby improving efficiency and economies of scale (Ekholm et al. 2003; Bergstrand and Egger 2007; Baltagi et al. 2004).

2.2.2 Industrial Policy and Foreign Direct Investment

Industrial policy (IP) refers to Government interventions on tariff, subsidies, tax break beyond its optimal value. Loosely speaking there are two types of IP, i.e. (a) pro-market IP (free market, i.e. market liberalization and privatization) stimulate market competition and benefit new entrants with the objective to spread innovation and technology know-how and set-off a Schumpeterian process of creative destruction (Khan and Blankenburg 2005, 2009) and (b) pro-business IP aim to protect existing industries especially infant-industry and development of existing business. Both pro-market as well as pro-business IP are subject to criticism including corruption (Acemoglu et al. 2013; Farla 2015; North et al. 2009; Rodrik et al. 2004). There are views that market is self-regulated and therefore, while complementary policies such as building roads and ports are non-controversial, however, as such specific IP may not be necessary, at least for the advanced economies. IP adopted by different countries in totality is a zero-sum game or in worse case, it could lead to an inefficient allocation of resources in which countries are not specialized according to its comparative advantage.

However, some studies argue that advanced economies at the early stages of development practiced pro-business IP and protected the then infant-industry to help it to grow (Chang 2002; Aghion et al. 2012). Although low competition, as part of pro-business IP, may have long-term negative effects on existing industries, in many cases infant-industry benefits from anti-competitive policy. Generally, countries at early stages of development focuses on pro-business IP including import substituting industrialization with an exports oriented strategy (ISI-EOS) and at later stage move to pro-market IP. In the Indian context, Rodrik and Subramanian (2005), observed that high levels of growth in the 1980s were triggered by pro-business IP rather than by pro-market IP.

Therefore, developing countries which largely follow pro-business IP may attract FDI as part of ISI-EOS, whereas, advanced economies which largely follow pro-market IP anyway promote competition and open to free flow of capital and FDI. Moreover, presence of externalities (such as learning externalities from exports might justify exports subsidies, whereas, knowledge spillovers from foreign companies could justify tax incentives for FDI) is the main theoretical reasons for deviating from policy neutrality and opt for pro-business type IP. Pro-business IP or infant-industry protection policies may be justifiable if the country consider that it possesses latent comparative advantages in the protected industries or it perceive that the international price for this industry is higher than justified by the true opportunity cost of this good (Harrison and Rodriguez-Clare 2009). Import substitution strategy may allow expansion of manufacturing sector, but production may take place in unsophisticated ways and without increasing in productivity. Positive spillovers arise only when modern technologies, which are possible to get quickly through FDI, are used in a sector. Instead of providing production or exports subsidy, productivity enhancing collective action, for example as observed by Hernández et al. (2007), providing necessary infrastructure in terms of making available reliable cargo flights for flower exports made a vast difference to bloom flower exports business in Ecuador.

2.2.3 Determinants of FDI

In this section we describe the most important determinants of FDI as identified by the literature.

2.2.3.1 Size of the Economy

Macroeconomic performance indicators such as growth rates of the economy, development of socio-economic infrastructure and other supportive policies creating a stable and enabling environment and indicate potential of host environment (Kumar 2005) and is linked to prospect of profitable FDI. The market size of an economy is an important determinant of FDI inflows. MNEs are attracted to countries with large and expanding markets with greater purchasing power, so that firms can expect higher profit from their investments (Jordaan 2004). Large market is required for efficient utilization of resources and exploitation of economies of scale (Charkrabarti 2001). GDP or per capita GDP as a proxy to market size is one of the robust determinant for horizontal FDI inflows but irrelevant for vertical FDI (Schneider and Frey 1985; Tsai 1994; Asiedu 2002). However, there are some other studies (Jaspersen et al. 2000) which observed negative effect of GDP on FDI. Yet some other studies (Loree and Guisinger 1995; Wei 2000; Hausmann and Fernandez-Arias 2000) observed no significant impact of GDP on FDI.

2.2.3.2 Economic Openness

'Tariff jumping' hypothesis suggests that foreign firms that seek to serve local markets may decide to set up subsidiaries in the host country if it is difficult for the host country to import its products, in other words, FDI occurs as trade protection generally imply higher transaction costs associated with exporting. Empirical studies suggest that the effect of openness on FDI depends on the type of FDI. When FDI is market-seeking, trade restrictions, i.e. less openness can have a positive impact on FDI (Blonigen 2002; Jordaan 2004).

2.2.3.3 Economic Stability

Financial situation of a country may change due to various reasons and unlike other kind of capital flow, FDI cannot be easily withdrawn when the financial situation of the host country worsen. Therefore, FDI inflow might be sensitive to the financial risk of the host country. High foreign debt (relative to GDP) reduces repayment capability as well as causes currency depreciation of borrowing country and increase the financial risk of the country. High fiscal deficit and current deficit of a country lead to high financial risk. A high inflation rate in the host country may also prevent FDI inflow as the real local currency value of capital invested in the host country and future return may become lower with high inflation. High inflation may also result in depreciation of the local currency and may also discourage FDI inflow (Asiedu 2002; Chakrabarti 2001).

2.2.3.4 Legal and Political System

FDI involves high sunk cost and therefore it makes investors very sensitive to uncertainty (Helpman et al. 2004). Unless MNEs are confident about institutional soundness, significant risk premium will be included in the sunk costs to capture these uncertainties. Under very high political risk environment, MNEs may even believe that the host country's government might appropriate some of the returns on FDI or even implement enforced nationalization. Therefore, political risk and Institutional quality are important determinant of FDI. Good governance is associated with higher economic growth. Poor institutions that enable corruption tend to add to investment costs and reduce profits. The high sunk cost of FDI makes investors highly sensitive to uncertainty, including the political uncertainty that arises from poor institutions. However, literature survey on political risk to FDI Inflow is mixed. Some studies reported that FDI flows are affected by many factors pertaining to legal and political system of the host country such as ethnic tension, government stability, internal and external conflict, corruption, institutional quality, legal system (Wei 2000; Gastanaga et al. 1998; Baniak et al. 2005). Regulatory framework, bureaucratic hurdles and 'red tapes', judicial transparency, corruption in the host country are found insignificant (Wheeler and Mody 1992). Some studies did not find any significant effect of democracy and political risk on FDI inflow (Asiedu 2002; Noorbaksh et al. 2001).

2.2.3.5 Business Environment and Infrastructure

The business environment in the host country is also key driving force for FDI inflows. Empirical studies suggest that labour costs is a key determinant for FDI inflows. Some studies suggest that productivity of labour and its cost, human capital play a key role in explaining FDI (Noorbakhsh et al. 2001). Tax policies, bureaucracy of host country are also important determinant of FDI inflows

(Cassou 1997; Hartman 1984; Bénassy-Quéré et al. 2007). Studies have identified clustering effects, where foreign firms appear to gather either due to linkages among projects or due to herding, as a large existing FDI stock is regarded as a signal of a benign business climate for foreign investors. The investment climate is important institutional instrument which help in attracting FDI inflows (Narula and Dunning 2000). Cleeve (2008) used tax holidays, repatriation of profits and tax concessions as an indicator for investment incentives but did not find significant effect on FDI inflows. However, Gastanaga et al. (1998) and Wei (2000) observed statistically significant effect of corporate taxation on FDI. The infrastructure of a particular country is also an important factor for FDI investors. A developed communication and transportation infrastructure have a positive influence on inward FDI flows (Guisinger 1985; Wheeler and Mody 1992). Schneider and Frey (1985) argued that large share of working-age population with secondary education attract FDI.

2.2.3.6 Exchange Rate

Generally speaking a stable exchange rate may not have an impact on FDI decision, as investment in foreign location can be considered as future stream of profit denominated in host currency and when it converted back to home currency of MNEs (repatriation) at the same exchange rate then obviously exchange rate per se does not affect present value of foreign investment. However, there are views which suggest that MNEs are more willing to invest in a country when host currency is weak, i.e. low-cost investment (Bloningen 1997). Also there are opposite view-points (currency area hypothesis), which suggest that MNEs are less likely to invest in a country which has weak currency as a strong currency in the host often indicates greater competitiveness. Foreign assets become more expensive for a firm when host currency is appreciated vis-à-vis home currency therefore may impact negatively to FDI inflow into the host country (Chakrabarti 2001; Cassou 1997; Froot and Stein 1991). Few studies show opposite result. On the other hand, if exchange rate for a particular host country (vis-à-vis home country of MNEs) is volatile, risk-averse MNEs may be reluctant to invest in that host country. However, in certain cases higher volatility may lead to increase FDI, if such exchange rate uncertainty is linked with exports demand shocks then risk-averse MNEs increase FDI instead of exports as observed by Goldberg and Kolstad (1995) for US FDI in Canada, Japan, and the UK. As MNE intends to repatriate some of the proceeds of FDI to host country or other location they prefer consistency in exchange rates or less uncertainty in exchange rate (Campa 1993). Based on US FDI with Canada, Japan, and the United Kingdom, Goldberg and Kolstad (1995) conclude that risk-averse MNEs will increase FDI when exchange rate uncertainty increases if such uncertainty is correlated with the exports demand shocks in the markets they intend to serve, i.e. FDI will replace exports when exchange rate uncertainty is high.

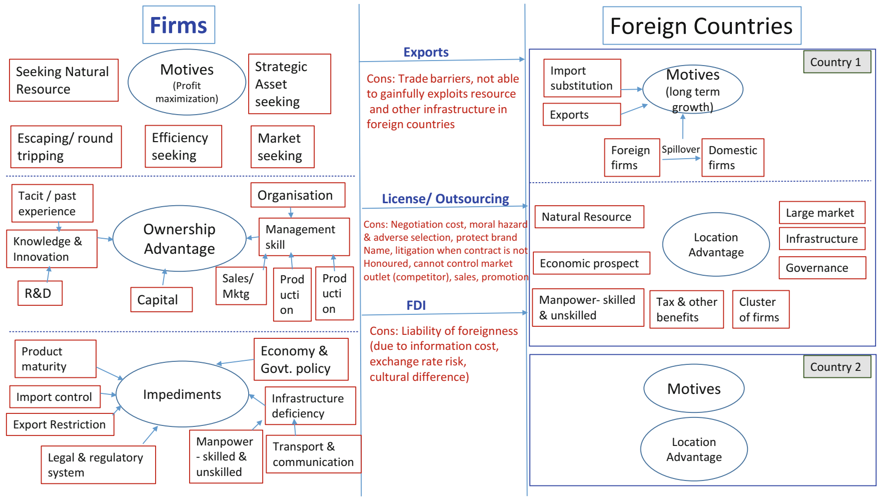

Chart 2.1 FDI framework

2.2.4 Summary of Survey of Literature

Brief summary of theoretical background dealing with investment decision as well as the factors that determine FDI flow from host country perspective used as the analytical framework in this paper is given in Chart 2.1.

2.3 Methodology

Effect of various macroeconomic factors in terms of intensity and direction may be different for FDI flow to AE from AE, to AE from DE, to DE from AE and to DE from DE. Also as macroeconomic factors both pull factors and push factors works simultaneously to influence FDI inflow to a country which is actually outward FDI of another country, therefore, we consider net factors (Pull factor—Push factor) as possible determinants of inward FDI (bilateral).

Various empirical studies suggests numerous macroindicators which may have possible association with the FDI. Out of these macrofactors some of the factors exhibit very low empirical association with FDI for any of the four groups of countries under study. These indicators are also sometime highly correlated among themselves which lead to multicollinearity issue in the multiple regression equation. Multicollinearity issue at times may be very severe and may lead to spurious results, for example, indicators which show pair wise (with FDI) highly significant correlation (significant in the regression/panel equation involving single determinants) shows insignificant association in the multiple regression involving multiple determinants to explain FDI.

2.3.1 Principal Component Analysis (PCA[3])

PCA reduces the dimensionality of data while retaining variation as much as possible present in the interrelated variables. PCA transform original data set into uncorrelated principal components (PCs). PCs are linear combination of constituent indicators and are ordered so that most of the variation present in the original data set are retained by the first few PCs (selected based on certain criteria, for example, Eigen value greater than one). To avoid multicollinearity issues, various studies employed PCA, where PCs itself or composite index based on PCs are used to explain FDI in regression equation. Sometimes PCA is used for macroeconomic indicators pertaining to a segment of an economy or set of related indicators which are logically related with high correlation among themselves and PCs of each segment are used as substitute of original variables to regress the dependent variable (FDI). In the usual PCA approach, as generally only first few components are chosen (with eigenvalue more than 1), some of the components with lower eigenvalue which may show good association with the target variable are ignored. Few indicators which are not closely associated with majority of other indicators may have higher loading/share in the non-selected PCs. As a result, there may be non-selected PCs which possess relevant information to explain variation in the target variable, but put in no use and thereby result in below potential performance in explaining the target variable.

2.3.2 Two-Stage Multicollinearity Correction (TMC) Method

To tackle the multicollinearity issue of interrelated determinants, we use a new approach which produces composite indices similar to PCs. This is generally a two-stage process and each stage compute a composite index of determinants taking into consideration the strength of association of these determinants with the target variable (FDI).

2.3.2.1 Pre-processing

All variables (determinants as well as the target variable) standardized to (0, 1) scale by min-max method by subtracting minimum value of that variable and then dividing it by the range of the same variable (Roy and Biswas 2012).

Step 1: Initial list of macroeconomic determinants of FDI are analysed on panel regression framework to find out whether empirically significant association exist

[3]Detail given in Appendix 3.

with FDI. The pruned list of determinants possesses certain degree of explanatory power in explaining the variance of the dependent/target variable. Composite indices are constructed as weighted average of the different combination of estimated values of the target variable (based on the panel regression equation involving single explanatory variable to the target variable) where weights are some measure of association (e.g. correlation) of corresponding estimate with the target variable. Such composite indices are constructed based on many combinations of the selected determinants with an aim to identify one which has maximum correlation with FDI. This is termed as primary composite index (PCI), which is essentially certain linear combination of selected determinants and it contains common information of interest pertaining to association of these selected set of determinants with the dependent variable. PCI is used as the baseline indicator to regress the dependent variable.
Step 2: If some determinants, which represents certain aspect of an economy, are highly correlated (among themselves) but have relatively weaker association with the target variables then, if somehow large proportion of such determinants are selected from a sector in the sample, by construction that sector of the economy will unduly dominate PCI by mere over representation in the selection of variables and other important sectors may lose out although they might have stronger association with the target variable (variable selection bias).

- Therefore, to explore further, whether there are any residual information related to association of any selected indicator beyond the PCI constructed in the previous step (to capture under representation or over representation of individual indicator in the PCI), we regress each of the selected determinants on the PCI and extract the residual which represent information over and above contribution made to PCI by the indicator. Moreover, some other indicators which may have hidden association with FDI but somehow masked with noises and as a result in its original form these indicators have not shown significant association with FDI. Some of these indicators (which were not part of PCI as they were not significantly associated with FDI), however when regressed on PCI the resultant residuals may be significantly associated with FDI. These residuals series (corresponding to each determinants) form the basis of the second information set which is further examined to check whether it contains any useful information or explanatory power for the dependent variable. This is done by way of regressing dependent variable (i.e. FDI) individually on each of these residuals. A secondary composite index (SCI) is constructed as weighted average of the estimated values of the dependent variable obtained from those regression equation where residuals of the determinants turn out to be significant in explaining the dependent variable; and weights are some measure of association (*e.g.* correlation) of corresponding estimate with the target variable. As these residuals are uncorrelated with PCI, SCI is also independent to PCI.

- SCI which is again certain linear combination of the selected variables and also uncorrelated with PCI may show good association with the dependent variable, albeit inferior to PCI in terms of explaining power. However, when both PCI and SCI which are independent by construction are used as explanatory variables to regress the dependent variable they better explain jointly than individually.

2.3.3 Construction of Indices (PCI and SCI)

Let X_{it} be the value of ith determinants/indicator at time t, where $i = 1(1)n$; $t = 1(1)T$ and Y_t be the value of target variable at time t.

Let

$$x_{it} = (X_{it} - \min(X_{it}))/(\mathrm{Max}(X_{it}) - \mathrm{Min}(X_{it})),$$
$$\text{time period } t = 1(1)T; 0 \leq x_i \leq 1; \text{and}$$
$$y_t = (Y_t - \min(Y_t))/(\mathrm{Max}(Y_t) - \mathrm{Min}(Y_t)), \text{for all } t; 0 \leq y_t \leq 1;$$

Let

$$y_t = c_i + b_i * x_{it} + e_t \tag{2.1}$$

where $e_t \sim N(0, \sigma^2)$, c_i and b_i are unknown coefficient.

Let $\widehat{Y}'_{it}$ be the estimate (Panel regression RE/FE) of y_t in Eq. (2.1) corresponding to ith indicator, and r_i be the corresponding correlation with Y_t. For various combinations of these indicators, which are significantly associated with Y_t, composite indices (PCI_{jt}) are computed.

Let

$$\mathrm{PCI}_{jt} = \sum\nolimits_{j \in (\text{combination of } i)} \widehat{Y}'_{it} * w'_i * D_i;$$

where $w'_i = \frac{r_i}{\sum_i D_i * r_i}$ and $D_i = 1$ if b_i is statistically significant else 0.

Let

$$\rho_j = \text{correlation } \left(\mathrm{PCI}_{jt}, Y_t\right).$$

$\mathrm{PCI} = \mathrm{PCI}_j$ where ρ_j is maximum.

Let

$$x_{it} = p_i + q_i * \mathrm{PCI}_t + z_{it} \tag{2.2}$$

where $z_{it} \sim N(0, \sigma^2)$, p_i and q_i are unknown coefficient, i = all determinants under study.

Let $\widehat{z}_{it}$ be the residual estimated from of Eq. (2.2) corresponding to ith indicator.

Let

$$y_t = q_i + s_i * \widehat{z}_{it} + u_{it} \tag{2.3}$$

where $u_{it} \sim N(0, \sigma^2)$, q_i and s_i are unknown coefficient corresponding to ith indicator.

Let $\widehat{Y}''_{it}$ be the estimate of y_t in Eq. (2.3) corresponding to ith indicator and l_i is the correlation coefficient of $\widehat{z}_{it}$ with Y_t.

Let

$$\mathrm{SCI}_t = \sum\nolimits_{i=1}^{k} \widehat{z}_{it} * w''_i * E_i;$$

where $w''_i = \frac{l_i}{\sum_i E_i * r_i}$ and $E_i = 1$ if s_i is significant in Eq. 2.3 else 0.

Both PCI_t and SCI_t are linear combination[4] of x_i's. Also by construction, PCI_t and SCI_t are uncorrelated/independent, therefore, these can be used together to explain y_t without any multicollinearity issue.

$$Y_t = a + b_1 * \mathrm{PCI}_t + b_2 * \mathrm{SCI}_t + \varepsilon_t \tag{2.4}$$

PCI_t and SCI_t thus constructed based on interrelated determinants with special focus to Y_t would explain the variation in Y_t as much as PCs of PCA can do or might be better. Composite Index (CI) is the estimated value of Y_t in Eq. (2.4). CI can also be constructed as weighted average of PCI and SCI and weights are corresponding correlation of PCI and SCI with FDI. CI reflects relative aggregated macroeconomic situation of a country relevant for attracting FDI and can be used to rank countries in terms of attractiveness to FDI flow.

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[4] $\mathrm{PCI}_t = \sum\nolimits_{i=1}^{k} \widehat{Y}'_{it} * w'_i = \sum\nolimits_{i=1}^{k} \left(\widehat{c}'_i + \widehat{b}'_i * x_i\right) * w'_i$ is a linear combination of x_i.

$x_{it} = p_i + q_i * \mathrm{PCI}_t + z_{it} \geq z_{it} \quad x_{it} - (\widehat{p}_i + \widehat{q}_i * \mathrm{PCI}_t) \quad = x_{it} - (\widehat{p}_i + \widehat{q}_i) * \left(\sum\nolimits_{i=1}^{k}\left(\widehat{c}'_i + \widehat{b}'_i * x_i\right) * w'_i\right)$ $= x_{it} - \sum_{i=1}^{k} \widehat{f}'_i * x_i + \mathrm{L} = \left(1 - \widehat{f}_i\right) * x_i - \sum_{j=1}^{k} \widehat{f}'_i * x_{j \neq i} + L$; i.e. z_{it} is the linear combination of x_i and similarly $\widehat{Y}''_{it}$ is also linear combination of x_i and therefore SCI is also linear combination of x_i.

2.4 Data Source and Variables Construction

Secondary data of annual frequency were used in this paper and were sourced from the World Bank Development indicators (WDI) database and United Nations Conference on Trade and Development (UNCTAD) data base for the period 2010–2012. The time period was chosen so as to include maximum covariates of all selected countries. The inflow of FDI to host country is related to macroeconomic indicators associated to host country as well as home country, i.e. net of pull and push factors. The covariates for FDI considered in this paper are primarily based on review of the literature. Covariates are selected as proxy to market size, market demand, population, infrastructure, technology, FDI openness and political stability of the host and home country. The data set contains bilateral FDI flow (more than 450 combination countries) and associated selected determinants. These lists of bilateral FDI flows do not include FDI flows to-and-from offshore finance centres (OFC) whose characteristics are significantly different as compared to standard FDI flows and so are its determinants, partly because such financial flows may also involve substantial round tripping investment. Following indicators are examined as possible determinants of FDI.

2.4.1 Technology

Access to modern technology helps in increasing productivity of the firm and also has positive spillover effect. Possession of advanced technology act as firm specific advantage (FSA) and MNE's employ them in foreign countries where it can reap more benefits than simply being at home (Hymer 1960; Dunning 1988). Also strategic asset seeking firms of developing economies (DE) invest overseas to explore technological advantages and human capital in advanced economies (AE) and also to gainfully combine with their existing technological capabilities. We use (i) difference of 'Researchers in R&D (per million people)' at host and home (d_RD), (ii) difference of Trademark applications at host and home (d_Trademark), (iii) ICT goods imports (% total goods imports) by home country (home_ict_imp), (iv) ICT goods exports (% of total goods exports) by home country (home_ict_exp), (v) Sum of ICT goods exports (% of total goods exports) by host and ICT goods imports (% total goods imports) by home country (ict_-exportimport), (vi) sum of ICT goods imports (% total goods imports) by Host and ICT goods exports (% of total goods exports) by Home and (ict_importexport) (vii) difference of education expenditure (% of GNI) as technology and human capital factors of FDI inflow (host-home) at host and home (d_edu_exp).

2.4.2 Industrial Activities

Manufacturing activities at host as well as at home country of MNE are important consideration for cross-country FDI flow. (viii) CO_2 emission (metric tons per capita) is assumed as proxy for manufacturing activities and difference between host and home (d_Co2) is considered as possible determinants of FDI flow. Also (ix) difference of Manufactures imports (% of merchandise imports) of host and home country (d_mfg_imp) is considered as determinant of FDI flow.

2.4.3 Infrastructure

Infrastructure base is important enabling factors for FDI flows. Lack of infrastructure at home may act as push factor whereas availability of infrastructure at host country may act as pull factors of FDI. (x) difference of Electric power consumption (kWh per capita) at host and home (d_elec), (xi) difference of Air transport, passengers carried/population at host and home (d_Air), (xii) difference of Automated teller machines (ATMs) (per 100,000 adults) at host and home (d_ATM) are used as possible determinants of FDI inflow.

2.4.4 Exchange Rate

Exchange rates as determinant to FDI flow has been examined both in terms of year-on-year change in the exchange rate between host and home countries as well as volatility of exchange rates. (xiii) Appreciation/depreciation of bilateral level of the exchange rate (yoy_exch_rate) as well as (xiv) volatility of exchange rates (coefficient of variation exch_rate_cv) are analysed to understand its effect on FDI flow. In this paper we use coefficient of variation of exchange rate, i.e. standard deviation of annual (bilateral) exchange rate for last 10 years/average annual exchange rate for the same period as the proxy for uncertainty of exchange rate and also year-on-year change of annual average exchange rate.

2.4.5 Market Size, Prospects and Cost of Production

GDP reflects host countries' market size whereas GDP growth indicates pace of economic development and are thought to be positively associated with FDI inflow. However, Nunnenkamp et al. (2012) did not find any such correlation. Moreover, for countries which witness consistent raise in GDP, generally, other macroeconomic indicators are also found to be favourable (e.g. lower inflation) which indicates competence of Governments and monetary authority and thereby increase the prospect of FDI inflow. Large working-age population, lower interest rate helps firms to produce products at lower costs thereby may have positive influence on FDI flow. In this paper we use (xv) difference (Host–home) of Population ages above 65 (% of total) (d_popuabove65), (xvi) difference of Real interest rate (%) at host and home (d_real_int), (xvii) difference of compensation of employees (% of expense) at host and home (d_sal), (xviii) difference of GDP growth (annual %) at host and home (d_GDP), (xix) difference of Inflation in term of GDP deflator (annual %) at host and home (d_infl), (xx) difference of S&P Global Equity Indices (annual % change) at host and home (d_sp) and (xxi) log of host GDP (host_gdp_avg2010).

2.4.6 Miscellaneous Indicators

(xxii) Geographical distance between capital of two country (d_distance), (xxiii) difference of Customs and other import duties (% of tax revenue) at host and home (d_custom), (xxiv) sum of Cost to import (US$ per container) at host and Cost to exports (US$ per container) by home country (d_imp_and_exp), (xxv) difference (host–home) of Political Stability and Absence of Violence/Terrorism: Estimate (host_home_pol_stability), (xxvi) Control of corruption (d_cont_corruption), (xxvii) Rule of law (d_rule) (xxvii) Regulatory quality (d_regul) (xxviii) Central government debt as % of GDP (d_fisc_def) (xxviii) Current account balance as % of GDP (d_cur_act) (xxix) to (xxxii) inward and outward FDI stock to GDP ratio (host/home_ifdi/ofdi_gdp_avg2010), at home country as well as host country were considered.

2.5 Results

This section presents the result of empirical analysis carried out in this paper. The results are presented in the following steps:

(i) Descriptive statistics of macroeconomic variables for all four groups viz. FDI flow (a) to AE from AE, (b) to AE from to DE, (c) to DE from AE and (d) to DE from DE.
(ii) Identification of the determinants of FDI inflow for each of the four groups based on estimation of coefficient using panel data analysis (random effect). For the sake of comparison, we have also used pooled regression.
(iii) Computation of Composite Index (CI) of identified determinants based on (a) Principal Component Analysis as well as (b) two-stage multicollinearity correction (TMC) and comparison thereof.
(iv) Ranking of countries within the four groups based on CI to gauge macroeconomic attractiveness.

2.5.1 Descriptive Statistics

Descriptive statistics is given in Table 2.1. Outward and inward FDI of developing economies (DE) are growing at fast pace, however, in absolute term it is much lower than that of advanced economies (AE). Moreover, the data reveals that majority of FDI outflow is from AE to AE itself. AE and DE may have different set of macrofeatures which are of interest with varied intensity to MNEs from AE and DE having different set of objectives. Various macroeconomic indicators as determinants to FDI inflow were examined. Average FDI flow to AE from AE is almost eight times of FDI flow to AE from DE. Macroindicators significantly vary across the groups.

Air transport in AE is much higher than DE and is highly correlated with FDI flow to AE from DE. Per capita emission of CO_2 in metric tons (d_Co2), assumed as a proxy for industrialization of a country, is found to be relatively higher in AE than DE and also positively correlated with inward FDI to AE from DE, however, negatively correlated with FDI flow to DE from AE. Per capita electricity consumption, assumed as proxy for infrastructure presence in the country, is much higher in the AE than in DE and also inward FDI at AE from DE is found to be positively correlated with it. Similar scenarios also observed for other infrastructure development indicators. Average fiscal deficit at AE is much higher than DE. Current account balance as % of GDP in AE is lower than DE and is negatively correlated with FDI flow to AE from DE. Proportion of population ages above 65 (non-working-age population) is much higher (max 23% in Japan and minimum 13% in USA) in the selected AE as compared to DE (Maximum 13.1% in Russia and minimum 5% in SA) and is negatively correlated with FDI flow. Average GDP growth, Inflation and real interest rate in AE are much lower than DE. Real interest rate is also observed to be a driver for FDI. MNE from AE with abundance of capital attracted to counties with relatively higher real interest rate. Political stability, control of corruption, rule of law and regulatory quality in AE are significantly better in AE than DE. Market size of the host country is an important determinant to attract FDI. Exchange rate volatility generally affect cross-border movement of capital. However, it is observed that for FDI to AE from AE reacts positively to higher volatility perhaps FDI replaces exports when exchange rate uncertainty is high, however, higher volatility in exchange rate negatively related to FDI flow to AE from DE.

2.5.2 Selection of Determinants

Although, pooled OLS indicate significant association of some of the indicators with the FDI, Random/Fixed effect panel regression model shows no such association (Table 2.2). To determine association of indicators with FDI we preferred random/fixed effect analysis of panel data over pooled OLS where country and time effect may distort the true association of indicators with FDI.

Table 2.1 Descriptive statistics

Variable description in	Average of determinants				Correlation with FDI			
	To AE from AE	To AE from DE	To DE from AE	To DE from DE	To AE from AE	To AE from DE	To DE from AE	To DE from DE
#obs	394	93	249	39				
FDI (mn $)	41059.69	5074.19	13970.65	3318.18				
d_edu_exp	−0.13	0.83	−0.38	1.12	0.108	0.106	0.252	0.021
d_air	−6.29	143.13	−138.29	2.19	0.084	0.189	0.068	−0.127
d_atm	9.01	41.10	−10.68	−4.37	−0.013	0.108	−0.154	−0.107
d_fisc_def	−0.73	39.87	−42.45	1.09	−0.059	−0.018	−0.151	0.499
d_Co2	0.14	4.23	−2.30	−0.88	0.096	0.194	−0.314	−0.234
d_sal	0.43	−2.03	5.77	6.70	0.075	−0.056	0.023	−0.187
d_cur_act	−1.08	−1.76	−1.26	−1.02	−0.066	−0.411	−0.043	−0.365
d_elec	−521.24	5036.42	−5000.78	−866.19	0.133	0.217	−0.074	−0.170
d_gdp	0.00	−3.31	2.86	−1.71	−0.019	−0.104	0.024	0.116
d_ict_exp	0.12	−5.07	3.93	−7.37	−0.014	−0.193	−0.241	−0.418
d_ict_imp	0.37	−1.92	2.41	−2.11	0.057	−0.092	−0.171	−0.364
d_infl	−0.15	−5.14	5.04	0.76	0.121	0.100	0.124	0.395
d_mfg_imp	−0.03	4.38	−14.12	−19.77	−0.177	−0.209	−0.205	−0.395
d_march_trade	−10.49	4.84	−6.57	10.63	−0.030	−0.245	0.096	−0.357
d_popu65	−0.11	8.31	−9.67	−0.06	−0.135	−0.319	−0.115	−0.208
d_real_int	−0.85	−4.32	4.09	4.44	0.106	0.097	0.405	0.496
d_rd	−89.92	2068.65	−2443.70	−826.86	−0.027	−0.169	−0.192	−0.272
d_time_exp	0.11	−8.26	6.38	−0.38	0.006	0.007	−0.003	0.289
d_trade	−9.70	−3.15	−5.18	2.74	−0.044	−0.220	0.037	−0.434
d_trademark	7309.68	−194948.86	69511.74	−409446.90	0.019	−0.087	−0.164	0.079

(continued)

Table 2.1 (continued)

Variable description in	Average of determinants				Correlation with FDI			
	To AE from AE	To AE from DE	To DE from AE	To DE from DE	To AE from AE	To AE from DE	To DE from AE	To DE from DE
d_imp_and_exp	2374.51	2622.58	2698.10	2280.18	0.068	0.061	0.096	0.270
d_pop_less_65yr	−2.05	−10.88	0.34	−8.92	−0.074	−0.032	−0.299	0.231
host_gdp_avg2010	3.06E+12	4.91226E +12	2.1683E+12	2.43608E +12	0.360	0.204	0.087	0.147
d_pol_stab	−0.06	1.12	−1.26	−0.09	−0.012	−0.046	0.113	0.095
d_cont_corruption	−0.05	1.88	−1.83	−0.01	−0.004	−0.017	0.026	0.022
d_law	−0.01	1.69	−1.60	−0.15	0.006	0.009	−0.129	0.050
d_regul	0.01	1.38	−1.22	0.04	0.017	−0.051	−0.074	−0.256
d_sp	−1.41	−2.02	4.66	3.40	−0.011	0.055	−0.168	−0.460
exch_rate_cv	0.09	0.15	0.16	0.15	0.235	−0.302	0.013	0.418
yoy_exch_rate	0.40	0.19	−4.73	−0.08	0.041	0.276	−0.106	−0.199
d_distance	5327.86	8380.18	8511.24	7463.31	−0.081	−0.115	−0.102	0.102

Table 2.2 Selection of determinants of FDI based on panel regression

	Pooled OLS				Panel (RE/FE)			
	To AE from AE	To AE from DE	To DE from AE	To DE from DE	To AE from AE	To AE from DE	To DE from AE	To DE from DE
FDI (mn $)								
d_edu_exp	y		y				−y	
d_air	y	y			y			
d_atm			−y				y	
d_fisc_def			−y	y	y	y	−y	
d_Co2	y	y	−y				−y	−y
d_sal					y			−y
d_cur_act		−y		−y		y		−y
d_elec	y	y						−y
d_gdp						y		
d_ict_exp		−y	−y	−y			−y	
d_ict_imp			−y	−y	−y			−y
d_infl	y		y	y		y	−y	
d_mfg_imp	−y	−y	−y	−y	−y			
d_march_trade		−y		−y		y		y
d_popu65	−y	−y	−y			y	−y	
d_real_int	y		y	y	y	−y	y	
d_rd			−y	−y				
d_time_exp				y				
d_trade		−y		−y				
d_trademark			−y				y	−y
d_imp_and_exp				y		y		y
d_pop_less_65yr			−y		y		−y	
host_gdp_avg2010	y	y			y			
d_pol_stab			y			y	y	
d_cont_corruption						−y		−y
d_law			−y		−y	y	−y	
d_regul								
d_sp			−y	−y				
exch_rate_cv	y	−y		y		−y		
yoy_exch_rate		y	−y			y		−y
d_distance								

*y indicates statistically significant (at 5% level) positive association and –y indicates significant (at 5% level) negative association

2.5.3 Composite Index for FDI Flow: To AE from AE

Infrastructure as well as depth of market as proxy by passenger air transport is found to be positively associated with FDI flow to AE from AE. Higher skilled labour force in AE reflected in higher salary as % of total expenses, positively associated with FDI flow from AE. Higher ICT as well as manufacturing import are observed to be negatively associated with FDI flow to AE from AE. Market size and political stability are found to be positively associated with FDI flow. PCI based on selected determinants which produce highest association with FDI is as follows

$$\begin{aligned}\mathrm{PCI}_t = (&0.0749 * \widehat{Y}'_{\mathrm{d\_Sal},t} + 0.1775 * \widehat{Y}'_{\mathrm{d\_mfg\_imp},t} \\ &+ 0.1058 * \widehat{Y}'_{\mathrm{d\_real\_int},t} + 0.3557 * \widehat{Y}'_{\mathrm{host\_gdp},t})\end{aligned}$$

where $\widehat{Y}'_{\mathrm{host\_gdp},t}$ is Panel (RE) regression estimate of Y_t when it is regressed only on host GDP indicator and 0.3597 is its correlation of $\widehat{Y}'_{\mathrm{host\_gdp},t}$ and Y_t; similarly other components.

SCI based on residuals of all determinants when they are regressed on PCI and those residuals which are found to be significantly associated with FDI is as follows

$$\begin{aligned}\mathrm{SCI}_t = {} & 0.0940 * \widehat{Y}''_{\mathrm{d\_real\_int},t} + 0.0299 * \widehat{Y}''_{\mathrm{d\_imp\_and\_exp},t} + 0.0336 * \widehat{Y}''_{d\mathrm{Sal},t} \\ & + 0.0137 * \widehat{Y}''_{\mathrm{d\_Law},t} - 0.1353 * \widehat{Y}''_{\mathrm{d\_Fisc\_def},t} - 0.1565 * \widehat{Y}''_{\mathrm{d\_Co2},t} \\ & - 0.1710 * \widehat{Y}''_{\mathrm{d\_ICT\_imp},t} - 0.1842 * \widehat{Y}''_{\mathrm{d\_popu\_less65},t} - 0.1071 * \widehat{Y}''_{\mathrm{d\_Host\_GDP},t} \\ & - 0.1953 * \widehat{Y}''_{\mathrm{d\_Distance},t}\end{aligned}$$

where $\widehat{Y}''_{\mathrm{d\_real\_int},t}$ is OLS estimate of FDI when it is regressed only on $\widehat{Z}_{\mathrm{d\_real\_int},t}$ which is residual obtained when d_real_int is regressed on PCI and 0.0940 is its correlation of $\widehat{Y}''_{\mathrm{d\_real\_int},t}$ with FDI. PCI and SCI are independent (no correlation between them). CI (final composite index) is the estimated value of Y_t when it is regressed on PCI and SCI. PCA is the estimated value of Y_t when it is regressed on the selected principal components (PC), where PCs are obtained based on principal component analysis of the selected determinants. CI is observed to have highest association with FDI. Correlation coefficients of PCA and multistage indices constructed with FDI from AE to AE group is given in Table 2.3.

Table 2.3 FDI flow from AE to AE: correlation coefficient: PCA and multistage indices with FDI

To AE from AE	FDI	PCI	SCI	CI	PCA
FDI	1				
PCI	0.41	1			
SCI	0.35	0	1		
CI	0.54	0.76	0.65	1	
PCA	0.25	0.57	−0.30	0.24	1

2.5.4 Composite Index for FDI Flow: To DE from AE

Although, pooled OLS indicates significant association of some of the indicators with the inward FDI, however, panel regression (Random/Fixed effect) model shows no such association. To determine association of indicators with FDI we use results of random/fixed effect model, as in case of pooled OLS country and time effect may distort the true association of indicators with FDI.

Fiscal deficit, manufacturing activity (Co2), ICT exports, Inflation are observed to be negatively associated with FDI flow to DE from AE. Infrastructure in terms of ATM, real interest rate (capital benefit of MNEs), Trademark application (increasing instinctual capabilities and legal infrastructure) and political stability are found to be positively associated with FDI flow to DE from AE. PCI based on selected determinants which produce highest association with FDI is as follows

$$\mathrm{PCI}_t = \Big(-0.314 * \widehat{Y}'_{\mathrm{d\_Co2},t} - 0.2414 * \widehat{Y}'_{\mathrm{d\_ICT\_Exp},t} - 0.1242 * \widehat{Y}'_{\mathrm{d\_Infl},t} - 0.1153 * \widehat{Y}'_{\mathrm{d\_popuabv65},t} + 0.4049 * \widehat{Y}'_{\mathrm{d\_real\_int},t} + 0.1643 * \widehat{Y}'_{\mathrm{d\_Trademark},t} + 0.1129 * \widehat{Y}'_{d_{\mathrm{Pol_{stab}}},t} - 0.129 * \widehat{Y}'_{\mathrm{d\_Law},t}\Big)$$

where $\widehat{Y}'_{\mathrm{d\_Co2},t}$ is OLS estimate of Y_t when it is regressed only on d_Co2 indicator and 0.314 is the corresponding correlation with Y_t (FDI). SCI based on residuals of all determinants when they are regressed on PCI and those residuals which are found to be significantly associated with FDI is as follows

$$\mathrm{SCI}_t = \widehat{Y}''_{\mathrm{d\_edu\_exp},t} * 0.0078 - \widehat{Y}''_{d_{\mathrm{ATM}},t} * 0.0563 - \widehat{Y}''_{\mathrm{d\_Fisc\_def},t} * 0.0931 + \widehat{Y}''_{d_{\mathrm{Elec}},t} * 0.1410 + \widehat{Y}''_{d_{\mathrm{Infl}},t} * 0.0958 + \widehat{Y}''_{d_{\mathrm{real_{int}}},t} * 0.1324 + \widehat{Y}''_{d_{\mathrm{RD}},t} * 0.0450 + \widehat{Y}''_{d_{\mathrm{Trademark}},t} * 0.0475 + \widehat{Y}''_{\mathrm{host_{gdp}},t} * 0.1574 - \widehat{Y}''_{d_{\mathrm{Law}},t} * 0.1232 - \widehat{Y}''_{d_{\mathrm{distance}},t} * 0.3320$$

where $\widehat{Y}'_{\mathrm{d\_ATM},t}$ is OLS estimate of FDI when it is regressed only on $\widehat{Z}_{\mathrm{d\_ATM},t}$ which is residual obtained when d_ATM is regressed on PCI and 0.0563 is its correlation of $\widehat{Y}''_{\mathrm{d\_ATM},t}$ with FDI. CI is the final composite index is the weighted average of PCI and SCI, where weights are corresponding correlation with FDI (CI can also be computed as estimated value of FDI when it is regressed on PCI and SCI).

PCA is the estimated value of Y_t when it is regressed on the selected principal components (PC), where PCs are obtained based on principal component analysis of the selected determinants. CI is observed to have highest association with FDI. Correlation coefficients of PCA and multistage indices constructed with FDI from DE to AE group is given in Table 2.4.

Table 2.4 FDI flow to DE from AE: correlation coefficient: PCA and multistage indices with FDI

To DE from AE	FDI	PCI	SCI	CI	PCA
FDI	1.00				
PCI	0.60	1.00			
SCI	0.38	0.00	1.00		
CI	0.71	0.85	0.54	1.00	
PCA	0.49	0.88	−0.12	0.67	1.00

2.5.5 *Composite Index for FDI Flow: To AE from DE*

Political stability, rule of law, depreciation of host currency, merchandise trade, current account balance are observed to be positively associated whereas real interest rate and exchange rate volatility are found to be negatively associated with FDI flow to AE from DE. PCI based on selected determinants which produce highest association with FDI is as follows

$$\mathrm{PCI}_t = \left(0.4113 * \widehat{Y}'_{\mathrm{d\_Cur\_Act},t} + 0.2763 * \widehat{Y}'_{\mathrm{exch\_rate\_yoy},t} - 0.3023 * \widehat{Y}'_{\mathrm{exch\_rate\_CV},t}\right)$$

SCI based on residuals of all determinants when they are regressed on PCI and those residuals which are found to be significantly associated with FDI is as follows

$$\begin{aligned}\mathrm{SCI}_t = &-0.1823 * \widehat{Y}''_{\mathrm{d\_edu\_exp},t} - 0.2955 * \widehat{Y}''_{d_{\mathrm{Sal}},t} - 0.0796 * \widehat{Y}''_{d_{\mathrm{Infl}},t} - 0.0824 * \widehat{Y}''_{d_{\mathrm{Mfg_{imp}}},t} \\ &- 0.1084 * \widehat{Y}''_{d_{\mathrm{real_{int}}},t} + 0.0887 * \widehat{Y}''_{\mathrm{d\_imp\_and\_exp},t} + 0.1046 * \widehat{Y}''_{d_{\mathrm{host_{gdp}}},t} - 0.0547 * \widehat{Y}''_{d_{\mathrm{pol_{stab}}},t} \\ &- 0.1205 * \widehat{Y}''_{d_{\mathrm{cont_{corruption}}},t} - 0.127 * \widehat{Y}''_{d_{\mathrm{yoy_{exch_{rate}}}},t} + 0.1266 * \widehat{Y}''_{\mathrm{d\_distance},t}\end{aligned}$$

CI is the final composite index is the estimated value of FDI when regressed on PCI and SCI. PCA is the estimated value of Y_t when it is regressed on the selected principal components (PC), where PCs are obtained based on principal component analysis of the selected determinants. CI is observed to have highest association with FDI. PCA is estimated value of FDI when it is regressed on important principal components (with eigenvalue more than 1) of selected significant determinants. Correlation coefficients of PCA and multistage indices constructed with FDI from AE to DE group is given in Table 2.5.

Table 2.5 FDI flow to AE from DE: correlation coefficient: PCA and multistage indices with FDI

To AE from DE	FDI	PCI	SCI	CI	PCA
FDI	1.00				
PCI	0.48	1.00			
SCI	0.32	0.00	1.00		
CI	0.58	0.83	0.56	1.00	
PCA	0.51	0.91	0.15	0.83	1.00

2.5.6 Composite Index for FDI Flow: To DE from DE

Determinants of FDI flow to DE from DE are quite different. Low manufacturing activities (CO_2 emission), low skilled workers (Salary as % of total expense), current account deficit, infrastructure deficiency (electricity consumption), lower intellectual progress (Trademark application), higher corruption and appreciation of host currency lead to higher FDI flow to DE from DE. PCI based on selected determinants which produce highest association with FDI is as follows

$$\mathrm{PCI}_t = (-0.3643 * \widehat{Y}'_{\mathrm{d\_ICT\_imp},t} + 0.3569 * \widehat{Y}'_{\mathrm{d\_March\_Trade},t} - 0.0786 * \widehat{Y}'_{\mathrm{d\_Trademark},t} + 0.2698 * \widehat{Y}'_{\mathrm{d\_imp\&Exp},t} - 0.1987 * \widehat{Y}'_{\mathrm{yoy}_{\mathrm{exch}_{\mathrm{rate}}},t} - 0.1697 * \widehat{Y}'_{\mathrm{d\_Elec},t}))$$

SCI based on residuals of all determinants when they are regressed on PCI and those residuals which are found to be significantly associated with FDI is as follows

$$\mathrm{SCI}_t = \widehat{Y}''_{d_{\mathrm{cont}_{\mathrm{corruption}}},t}$$

CI is the final composite index is the estimated value of FDI when regressed on PCI and SCI. PCA is the estimated value of Y_t when it is regressed on the selected principal components (PC), where PCs are obtained based on principal component analysis of the selected determinants. CI is observed to have highest association with FDI. Correlation coefficients of PCA and multistage indices constructed with FDI from DE to DE group is given in Table 2.6.

2.5.7 Composite Index (CI)—Uses and Interpretation

FDI flow to a country partly depends on prevailing macroeconomic situation and collective information of macroeconomic determinants to FDI flow is reflected in the constructed composite index CI. Therefore, correlation or any other measure of association of any macroeconomic indicator with this synthetic CI may reflect the intensity of influence of individual macroeconomic on FDI flow. Moreover, CI can be used to rank the countries within the broad groups of FDI flow (a) to AE from AE (b) to AE from DE (c) to DE from AE and (d) to DE from DE and to understand

Table 2.6 FDI flow from DE to DE: correlation coefficient: PCA and multistage indices with FDI

To DE from DE	FDI	PCI	SCI	CI	PCA
FDI	1.00				
PCI	0.52	1.00			
SCI	0.24	0.00	1.00		
CI	0.58	0.91	0.42	1.00	
PCA	0.52	0.89	0.24	0.91	1.00

macroeconomic enabler in the host country to attract FDI. CI also helps to understand country-specific relative macroeconomic enabling situation for FDI, for example, a country in AE whether it is more favourable to MNEs from AE than DE. Rank of a country within broad groups (e.g. AE to AE, AE to DE etc.), in terms of macroeconomic situation to attract FDI is given in Table 2.7 and correlation of determinants with the composite index is given in Table 2.8. During the sample

Table 2.7 Country's rank within broad groups—in terms of macroeconomic situation to attract FDI

Country: rank	FDI to AE from AE	Score
1	USA	0.73
2	France	0.47
3	Italy	0.45
4	Switzerland	0.45
5	Spain	0.43
6	Austria	0.42
7	Germany	0.41
8	UK	0.40
9	Sweden	0.37
10	Canada	0.36
11	Japan	0.34
12	Australia	0.28
Country: rank	FDI to AE from DE	Score
1	USA	0.79
2	UK	0.74
3	Spain	0.73
4	Canada	0.71
5	Japan	0.71
6	Australia	0.70
7	Austria	0.64
8	France	0.62
9	Germany	0.62
Country: rank	FDI to DE from AE	Score
1	Brazil	0.59
2	Russia	0.44
3	Mexico	0.43
4	China	0.42
5	SA	0.39
6	India	0.36
7	Thailand	0.35
8	Korea	0.31
Country: rank	FDI to DE from DE	Score
1	Brazil	0.52
2	India	0.43

(continued)

Table 2.7 (continued)

Country: rank	FDI to DE from DE	Score
3	SA	0.37
4	Korea	0.30
5	China	0.27
6	Russia	0.27
7	Mexico	0.22
8	Thailand	0.16

Table 2.8 Correlation coefficient of individual determinant with the composite index

	Correlation with CI			
	To AE from AE	To AE from DE	To DE from AE	To DE from DE
d_edu_exp	0.1021	0.0664	0.3112	0.1839
d_air	0.0892	0.2083	0.2604	−0.235
d_atm	0.0159	−0.1212	−0.3107	−0.1428
d_fisc_def	−0.0467	0.3263	−0.2973	0.6506
d_co2	0.1195	0.0181	−0.4533	−0.4472
d_sal	0.1503	−0.0291	0.0334	−0.466
d_cur_act	−0.0382	−0.6838	0.0146	−0.6424
d_elec	0.1228	−0.0201	−0.2168	−0.2777
d_gdp	−0.0775	−0.0161	0.0112	0.0756
d_ict_exp	0.0738	0.0101	−0.5766	−0.6474
d_ict_imp	0.0714	0.1928	−0.4235	−0.4933
d_infl	0.1044	−0.0198	0.374	0.56
d_mfg_imp	−0.0023	−0.0316	−0.4191	−0.6043
d_march_trade	−0.0243	−0.3926	0.0174	−0.7348
d_popu65	−0.2711	−0.6298	−0.2425	−0.4829
d_real_int	0.1069	0.1289	0.5074	0.7361
d_rd	−0.1483	−0.4313	−0.3498	−0.2983
d_time_exp	−0.1192	−0.144	0.1594	0.1711
d_trade	−0.0206	−0.4018	−0.0215	−0.7632
d_trademark	0.354	0.1036	−0.1114	−0.0007
d_imp_and_exp	0.0645	0.1734	0.2207	0.3496
d_pop_less_65yr	−0.141	0.2771	−0.4029	0.3552
host_gdp_a_vg2010	0.7407	0.4483	0.2609	0.2336
d_pol_stab	−0.1042	−0.2933	0.0476	0.1324
d_cont_corruption	−0.1434	−0.1334	0.021	0.0388
d_law	−0.0297	−0.0685	−0.1876	0.0139
d_regul	−0.1155	−0.1322	−0.2267	−0.3215
d_sp	−0.0087	0.1445	−0.314	−0.6776
exch_rate_cv	0.3282	−0.6248	0.0341	0.4202
yoy_exch_rate	−0.1749	0.3017	−0.0984	−0.2213
d_distance	−0.1151	−0.0673	−0.0741	0.5512

period (2010–2012) it is observed that USA has most desirable macroeconomic situation for FDI flow from both AE and DE, whereas, Brazil has most desirable macrosituation among DE in attracting FDI flow from both AE and DE.

2.5.8 Summary of Empirical Analysis

Important macroeconomic determinants are as follows: Note: (+) indicates positive and (−) indicates negative influence of (net Host–home) macroindicators on FDI inflow.

FDI inflow to AE from AE: Host GDP size (+); exchange rate volatility (+); Exchange rate depreciation (−); working-age population (+); Salary as % of total expense (+); trademark application (+); Manufacturing activity (+).

FDI inflow to AE from DE: Current account deficit (+); fiscal deficit (+); Market size: GDP (+); working-age population (+); merchandise trade (−); exchange rate volatility (−); exchange rate depreciation (+); Political stability and rule of law (−); R&D (−).

FDI inflow to DE from AE: Expenditure on education (+); Fiscal deficit (−); Manufacturing activities (−); Manufacturing import (−); ICT trade (−); real interest rate (+); working-age population (+).

FDI inflow to DE from DE: Fiscal deficit (+); Current account deficit (+); Manufacturing activity (−); Salary (−); ICT trade (−); Manufacturing import (−); Merchandised trade (−); Real interest rate (+).

2.6 Summary and Conclusions

Usually, firm analyses various macroparameters in foreign (host) countries vis-à-vis home country before choosing a country for its overseas investment. Pull factors or host country-specific factors, i.e. macroeconomic characteristics specific to host country which attracts FDI, together with various push factors or home country factors significantly influence the direction and intensity of FDI flow to host country. Moreover, these factors may have differential effect (direction, intensity, level of significance) on FDI flow depending on source (Advance Economies AE/Developing Economies DE) and destination (AE/DE). Also these factors are highly correlated which lead to multicollinearity issues.

Based on various macroindicators as well as bilateral FDI flow of 22 countries (both AE and DE) for the period 2010–2012, the paper investigate strength of association of macroeconomic determinants (push and pull factors) with the FDI flow for four sets of homogenous group of countries, i.e. FDI flow (a) to AE from AE (b) to AE from DE (c) to DE from AE and (d) to DE from DE.

Selected determinants for FDI are found to be highly interrelated which lead to multicollinearity issue and interpretation of the results in the multiple regression equation setups becomes confusing. To circumvent multicollinearity issue, this paper uses a new method which involve construction of primary composite index (PCI) and secondary composite index (SCI) using certain linear combinations of the determinants with optimum weight structures in such a way that PCI and SCI are uncorrelated and together can explain variation in the dependent variable better than widely used principal component analysis to resolve multicollinearity issue.

Determinants of FDI flow are very different for different set of countries, not only on intensity or level of significance but also sometimes the association is in the opposite direction. Fiscal deficit, manufacturing activities, ICT exports, Inflation of host country (net of home country) are observed to be negatively associated with FDI inflow to DE from AE. Infrastructure in terms of ATM, real interest rate, Trademark application (increasing intellectual capabilities and legal infrastructure) and political stability are found to be positively associated with FDI inflow to DE from AE.

In case of FDI inflow to AE from AE, Infrastructure as well as depth of market as proxy by passenger air transport are found to be positively associated. Also higher skilled labour force in host AE as reflected in higher salary as % of total expenses attracts FDI flow from AE. Higher ICT as well as manufacturing import are observed to be negatively associated with FDI inflow. Market size and political stability of host country (net of home country) are found to be positively associated with FDI inflow to AE from AE.

However, political stability, rule of law, depreciation of host currency, merchandise trade, current account balance are observed to be positively associated whereas real interest rate and exchange rate volatility are found to be negatively associated with FDI flow to AE from DE.

Determinants of FDI flow to DE from DE are quite different. Low manufacturing activities (as proxies by low CO_2 emission), low skilled workers (Salary as % of total expense), current account deficit, infrastructure deficiency (electricity consumption), lower intellectual progress (Trademark application), higher corruption at host country (net of home country) and appreciation of host currency lead to higher FDI flow to DE from DE.

FDI flow to a country partly depends on prevailing macroeconomic situation and collective macroeconomic determinants to FDI flow is reflected sufficiently in the constructed composite index CI. Therefore, correlation or any other measure of association of any macroeconomic indicator with the synthetic CI may reflect the intensity of influence of individual macroeconomic on FDI flow. Moreover, CI can be used to rank the countries within the broad groups of FDI flow to AE from AE, to AE from DE, to DE from AE or FDI flow to DE from DE to understand differences in macroeconomic enabler in the host country to attract FDI. CI also helps into understand relative macroeconomic situation of a country, for example, a country in AE grouping may be perceived differently by MNE's of AE origin and DE origin. During the reference period (2010–2012) among the selected countries, it is observed that USA within AE has most desirable macroeconomic situation for FDI flow from both AE and DE, whereas, Brazil has most desirable macroeconomic condition among DE in attracting FDI flow from both AE and DE. To sum up, the results indicate differences in the role played by macroeconomic variables in explaining the determinants of FDI flows from AE to AE, AE to DE, DE to AE and DE to DE.

Appendix 1

Variables and Their Definitions

i. d_RD: difference of Researchers in R&D (per million people) at host and home
ii. d_Trademark: difference of Trademark applications: total at host and home
iii. home_ict_imp: ICT goods imports (% total goods imports) by home country
iv. home_ict_exp: ICT goods exports (% of total goods exports) by home country
v. ict_exportimport: sum of ICT goods exports (% of total goods exports) by host and ICT goods imports (% total goods imports) by home country
vi. ict_importexport: sum of ICT goods imports (% total goods imports) by Host and ICT goods exports (% of total goods exports) by Home and
vii. d_edu_exp: difference of Adjusted savings: education expenditure (% of GNI) as technology and human capital factors of FDI inflow (host–home) at host and home
viii. d_Co2: CO_2 emission (metric tons per capita) difference between host and home
ix. d_mfg_imp: difference of Manufactures imports (% of merchandise imports) of host and home.
x. d_elec: difference of Electric power consumption (kWh per capita) at host and home
xi. d_Air: difference of Air transport, passengers carried/population at host and home
xii. d_ATM: difference of Automated teller machines (ATMs) (per 100,000 adults) of host and home
xiii. yoy_exch_rate: appreciation/depreciation of bilateral level of the exchange rate; Exch rate (annual freq) = 1 unit of host currency = 'x' unit of home currency; yoy exch rate = $(x_t/x_{t-1}) * 100 - 100$
xiv. exch_rate_cv: coefficient of variation of exchange rates exch = std dev $(x_t \ldots x_{t-12})$/average $(x_t \ldots x_{t-12})$
xv. d_popuabove65: difference (Host–home) of Population ages below 65 (% of total)
xvi. d_real_int: difference of Real interest rate (%) at host and home
xvii. d_sal: difference of compensation of employees (% of expense) at host and home
xviii. d_GDP: difference of GDP growth (annual %) at host and home
xix. d_infl: difference of Inflation in term of GDP deflator (annual %) at host and home
xx. d_sp: difference o fS&P Global Equity Indices (annual % change) at host and home

xxi. host_gdp_avg2010: log of host GDP
xxii. d_distance: geographical distance between capital of two country
xxiii. d_custom: difference of Customs and other import duties (% of tax revenue) at host and home
xxiv. d_imp_and_exp: sum of Cost to import (US$ per container) at host and Cost to exports (US$ per container) by home country
xxv. host_home_pol_stability: difference (host–home) of Political Stability and Absence of Violence/Terrorism: Estimate,
xxvi. d_cont_corruption: difference (host–home) of control of corruption estimate.
xxvii. d_law: difference (host–home) of rule of law
xxviii. d_regul: difference (host–home) of regulatory quality
xxix. d_fisc_def: difference (host–home) of Central government debt, total (% of GDP)
xxx. d_cur_act: difference (host–home) of Current account balance (% of GDP)

Appendix 2

Multicollinearity

Multicollinearity refers to high inter-dependence among the explanatory variables in a regression set up. Particularly when the economic indicators are considered, multicollinearity is natural outcome of economic interaction. Such high correlation among the regressors creates the problem of near singularity of the residual variance-covariance matrix and thereby inflates the parameter estimates leading to unrealistic interpretation. For instance, the parameter estimates $\widehat{\beta}$ in the following regression set up is given by

$$\beta = (X'X)^{-1}X' \underbrace{Y}$$

where

$$(1)\ Y_t = \beta_0 + \beta_1 X_{1t} + \beta_2 X_{2t} + \cdots + \beta_n X_{nt} + \in_t$$
$$\Rightarrow (2)\ Y_t = \beta X_t + \in_t$$

Thus the presence of strong dependence among variables is not desirable for robust estimation of model parameters. Now considering (1), we get

$$(1)\ Y_t = \beta_0 + \beta_1 X_{1t} + \beta_2 X_{2t} + \cdots + \beta_n X_{nt} + \in_t$$

$$\Rightarrow \mathrm{Var}\left(\widehat{\beta}_i\right) = \underbrace{\left[\frac{\sigma^2}{\sum_{t=1}^{T}\left(X_{it} - \overline{X}_i\right)^2}\right]} \times \underbrace{\left[\frac{1}{1 - R_i^2}\right]}$$

Here the variance of OLS estimate of β_i is proportional to R_i^2 where R_i^2 is the R-square value of x_i when v is regressed over other regressor. The first part of the variance expression depends upon error variance and sample variance of X_i and the second part is proportional to R_i^2. Thus higher R_i^2 is likely to inflate the variance of $\widehat{\beta}_i$. This concept has been extended to define VIF for *i*th variable which can be used for detecting multicollinearity. Higher value of VIF indicates presence of multicollinearity among the regressor. VIF is defined as

$$\mathrm{VIF}_i = \frac{1}{(1 - R_i^2)}$$

In case the variable x_k for some $k \in [1, n]$ is highly correlated with other regressor, then R_k^2 is likely to be higher and so will be $\frac{1}{\left(1-R_k^2\right)}$. Generally, for a variable VIF value exceeding 4 indicates high multicollinearity and requires further investigation.

Appendix 3

Principal Component Analysis (PCA)

PCA is a powerful data analysing tool often used to identify patterns in data, and highlight their similarities and differences, especially, in data of high dimension where graphical representation of data is not available. Once patterns in the data are found, data can be compressed by reducing the number of dimensions, without loss of much information. PCA transform the variance-covariance matrix in term of eigenvector and eigenvector with the highest eigenvalue is the principle component of the data set. PCA give us the original data solely in terms of the eigenvectors. Once eigenvectors are found from the covariance matrix, the next step is to order them by eigenvalue, highest to lowest so that one can decide to ignore the components of lesser significance and the final data set will have fewer dimensions than the original.

The space spanned by the observed variables can be widely sparse in nature which can be measured by the variance-covariance matrix of the observed data. Due to inter-dependence among the variables, the covariance terms are expected to be non-zero. PCA tries to transform the original variables into a new set of orthogonal variables such the variability of the observed data can be explained by the transformed data. In vector space, this is equivalent to transform the observed data (X) into new set of variables (Y) such that

$$(1)\ P: R^N \rightarrow R^N \ni Y = P.X$$

Geometrically P is a rotation of X into space of Y in such a manner that Y is orthogonal, i.e. $Y_i' * Y_j = 0$ for $i \neq j$. Thus given orthogonality of P, the row vectors of P (i.e. P_i, for i = 1(1)N) is the basis of space spanned by X. Now

$$\begin{aligned} S_Y &= \left(\frac{1}{N-1}\right) YY^T = \left(\frac{1}{N-1}\right)(PX)(PX)^T \\ &= \left(\frac{1}{N-1}\right) PXX^T P^T = \left(\frac{1}{N-1}\right) PAP^T = \left(\frac{1}{N-1}\right) PEDE^T P^T \\ &= \left(\frac{1}{N-1}\right)[PE]D[PE]^T = \left(\frac{1}{N-1}\right) ZDZ^T \end{aligned}$$

We select P in such a manner that P_i, is the eigenvector of XX^T. Now

$$S_Y = \left(\frac{1}{N-1}\right)\left(PP^{-1}\right)D\left(PP^{-1}\right)^{-1} = \left(\frac{1}{N-1}\right)D$$

Thus the eigenvectors are principal components and the proportion of variability explained by each principal component is determined by the eigenvalue share of corresponding eigenvector. The application of PCA can be many folds from dimension reduction to orthogonal transformation.

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Chapter 3
India in the International Production Network: The Role of Outward FDI

Khanindra Ch. Das

Abstract Outward FDI from India has expanded manifold since the liberalization of policy regime. The phenomenon is expected to improve India's involvement in international production network. The paper examines the role of outward FDI in the manufacturing sector on production-network-related trade over the period 2008–2014. The impact of bilateral outward FDI on exports of parts and components to FDI-host countries is investigated using within-transformed fixed effects, and fixed-effects Poisson quasi-maximum likelihood method. The results reveal a positive and significant impact of outward FDI on production-network-related trade, suggesting to the crucial role that manufacturing outward FDI can play in expanding the outreach of Indian manufacturing in the global economy. Towards this end, promotion of outward FDI in the manufacturing sector needs to be accompanied by policy coordination with respect to inward FDI and trade facilitation in order to integrate manufacturing facilities in India with production hubs in the international production network for deriving benefits of global value chains.

Keywords Parts and components · Production network · Global value chain · Outward FDI · India

3.1 Introduction

Developing countries have started contributing significantly to outward FDI especially after the global financial crisis. The volume of outward FDI has doubled from 234.52 billion USD in 2009 to 468.15 billion USD in 2014 (UNCTAD 2015).

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K.Ch. Das (✉)
School of Management, Bennett University, Plot No. 8-11, TechZone II,
Greater Noida 201310, UP, India
e-mail: kchdas@gmail.com

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In terms of share in world outward FDI, the figure has gone up from 21% in 2009 to 35% in 2014. The phenomenon is spearheaded by a number of developing countries from Asia and Latin America.

The rising volume of outward FDI from developing countries has been attributed to several factors. These include macroeconomic and institutional (Tolentino 2010; Buckley et al. 2007; Goh and Wong 2011; Kolstad and Wiig 2012; Das 2013; Stoian 2013), financial (Gubbi et al. 2010; Sasidharan and Padmaja 2016), home and host country-specific (Sethi 2009; Buckley et al. 2012; Anwar and Mughal 2013; Duanmu 2014), industry and firm-specific factors (Nayyar 2008; Kumar and Chadha 2009; Wang et al. 2012; Amighini and Franco 2013). The firm-specific factors contributing to outward FDI of developing country firms have been looked at from multiple perspectives. While economic factors such as the firm heterogeneity in terms of productivity differences[1] are found to be important in explaining internationalization (Demirbas et al. 2013; Wei et al. 2014; Goldar 2016; Thomas and Narayanan 2016; Hsu 2016), there are alternative factors providing firms the strength to undertake outward FDI. For instance, the prediction provided by firm heterogeneity literature can be reversed due to low-cost foreign production (Head and Ries 2003) and service quality risk (Bhattacharya et al. 2012). Further, in the environment of globalization, resource availability (Tan and Meyer 2010; Gaur et al. 2014; Wei et al. 2014; Jain et al. 2015; Tan and Mathews 2015; Buckley et al. 2016) as well as the internationalization strategy adopted by developing country firms can result in outward FDI decisions (Wang et al. 2012; Tan and Mathews 2015).

However, the literature examining the impact of outward FDI on home developing country has been sparse. In particular, in the context of outward FDI from emerging economies, an examination of production-network-related trade generated by outward FDI has been missing to a large extent. There are related studies that examine the impact of outward FDI on trade linkages (Kim and Kang 1996; Kim 2000; Pradhan 2007; Goh et al. 2013; Das 2015). Nevertheless, specific treatment of production-network-related trade is limited. Therefore, the impact of outward FDI on production-network-related exports to FDI-host countries warrants attention.

India has nimbly begun to encourage outward foreign direct investment (FDI), along with inward FDI, with the expectation of strengthening Indian industry and firm competitiveness. As a result, India is one of the leading contributors to the phenomenon of outward FDI from developing countries. The investments are primarily led by private sector firms. The rise in outward FDI from India has been studied from several vantage points. These include internationalization of Indian firms (Nayyar 2008; Kumar 2008; Athukorala 2009; Hansen 2010; Verma and Brennan 2011; Paul and Gupta 2014), determinants and motivations behind

[1]Greenaway and Kneller (2007) provide a review of literature on firm heterogeneity and the globalization strategies. The literature has grown rapidly following Melitz (2003), Helpman et al. (2004), Tomiura (2007).

overseas investment (Pradhan 2004, 2010; Kumar 2007; Balasubramanyam and Forsans 2010; Hattari and Rajan 2010; Tiwari and Herstatt 2010; Narayanan and Bhat 2011; Buckley et al. 2012; Nunnenkamp et al. 2012; Das and Banik 2015; Amann and Virmani 2015), and to a limited extent the choice of entry mode (Kathuria 2010; Nunnenkamp and Andres 2014), and the impact of outward FDI (Pradhan 2007; Pradhan and Singh 2009; Das 2015).

The current study is undertaken to contribute to the latter issue as regards the impact of outward FDI. Whereas previous studies examined impact on exports in a limited way, this study examines the impact of Indian outward FDI on production-network-related exports in the manufacturing sector. This way the study contributes to the limited body of literature on the impact of outward FDI on production-network-related exports to FDI-host countries.

Outward FDI in the manufacturing sector forms a significant portion of total outward FDI made by Indian firms albeit it is lesser than the services sector. Given that the contribution of manufacturing sector to India's GDP is on a downward trend,[2] the integration of Indian firms into international production network can play a key role in strengthening the sector. It may be noted that India's participation in international production network has remained lower than developing Asia (Athukorala 2011). The phenomenon of outward FDI in the manufacturing sector is expected to raise the level of India's participation in international production network.

Therefore, it is important to examine the role of outward FDI and other factors that may promote India's participation in international production network. This paper thus examines the impact of India's manufacturing outward FDI on production-network-related manufacturing exports by India to the FDI-host countries. The role of bilateral trade costs has also been examined as it tends to obstruct participation in international production network.

There are various ways of representing production-network-related trade. The lack of uniformity in its measurement in empirical studies could be attributed not only to different trade classification and the level of disaggregation used but also to the nature of production-network-related trade that has been measured. Nevertheless, such trade is predominant in a few manufacturing industries (and countries) including machinery and electronics than the rest. In crude terms, production-network-related exports can be represented by the exports of parts and components (Ando and Kimura 2005; Athukorala 2010). However, more advanced measures are available and capable of capturing the nature and intensity of production-network-related and intra-industry trade in a finer way. For instance, it is possible to measure the nature of specialization (horizontal or vertical) of countries involved in production network (Ando 2006) and the inward and outward processing activities (Amighini 2012). In this chapter, the production-network-related export has been measured using the classification developed by Athukorala (2010). Though the measure is crude, in the sense that it deals with mere parts and components and not

[2]The manufacturing sector contributed 15% to India's GDP in the year 2013–14.

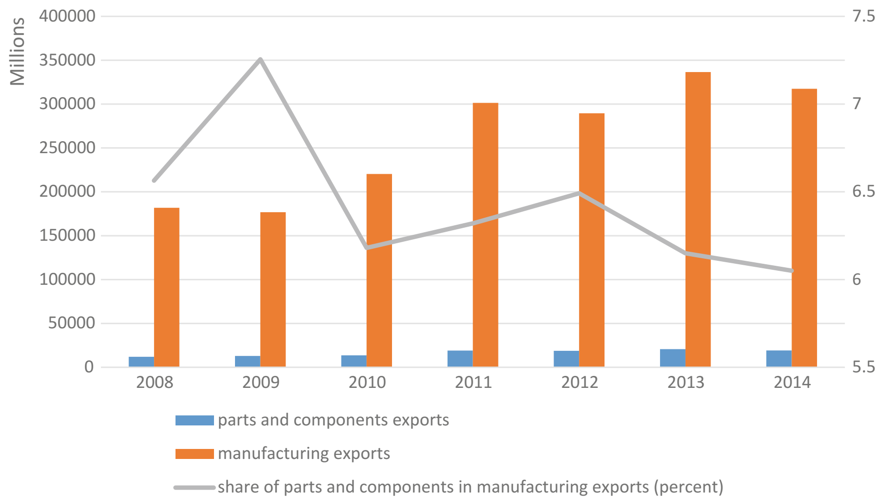

Fig. 3.1 India's exports of parts and components (US dollar million). *Source* Author's compilation from UN Comtrade (using SITC Rev. 3 data)

with the nature of such exports, but it goes beyond the machinery parts and components. In other words, the classification can capture production-network-related exports in a wide spectrum of manufacturing industries.

It may be observed that the pace of increase in exports of parts and components from India has been slower than the total manufacturing exports. **This has resulted in relatively dismal** share of parts and components in the overall manufacturing exports (Fig. 3.1).

With the development of world input–output table, the quantification of international fragmentation of production in terms of domestic and foreign value-added content of the product has become possible (see Dietzenbacher et al. 2013; Timmer et al. 2014, 2015). The foreign value-added content of a product is an indicator of the international fragmentation of production (Timmer et al. 2014). Figure 3.2 presents an example of the transport equipment manufacturing industry. It may be noted that there is an increase in the foreign value-added content of transport equipment manufacturing in India compared to 1990s. The foreign value-added share of the transport equipment manufacturing in India has been around 14% in 2010s, which is lower compared to countries with higher involvement in global value chains (e.g. in 2008 foreign value-added share of the same industry in Germany was 34%, see Timmer et al. 2014). However, India is in a position to catch up with comparable developing countries (see Fig. 3.2 for comparison with Indonesia).

Similar to the exports of parts of components, the manufacturing outward FDI has grown at a slower pace in comparison to the aggregate volume. Nevertheless, the manufacturing outward FDI constitutes a significant proportion of the total outward FDI (Fig. 3.3), and its level has remained steady.

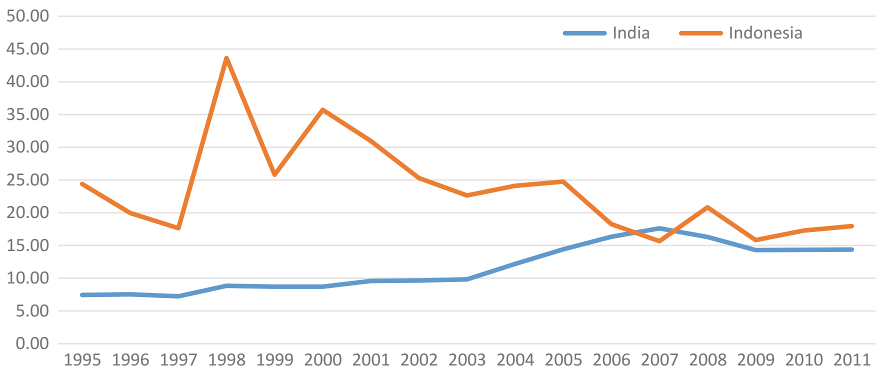

Fig. 3.2 Foreign value-added of transport equipment manufacturing (% of final output value). *Source* Author's calculation based on world input–output database (November 2013 release)

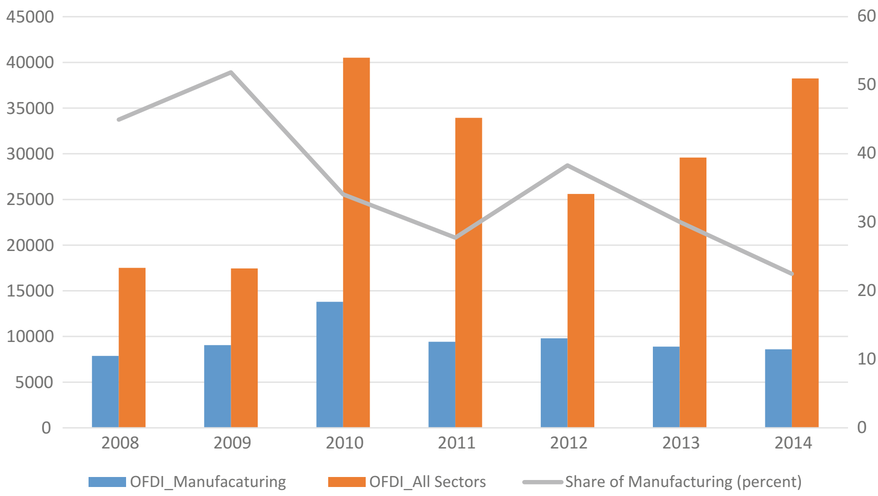

Fig. 3.3 Outward FDI by Indian firms (US dollar million). *Source* Author's compilation from RBI (using firm-level outward FDI data)

Another noteworthy feature of India's outward FDI, especially after the liberalization of policy regime,[3] has been the diversification of investment to several destinations both in developed and developing countries (Table 3.1). The manufacturing outward FDI was not adversely affected despite the global financial crisis of 2008–09 (Table 3.1). However, manufacturing exports became sluggish especially during 2009 (Fig. 3.1).

[3]The ceiling of investment by Indian entities (under the automatic route for overseas investment) was raised to 400% of the net worth of the investing company in 2007–08 (RBI 2010).

Table 3.1 Direction of India's outward FDI in manufacturing sector by destination (US $ millions)

A. Developed countries							
	2008	2009	2010	2011	2012	2013	2014
Cyprus	313.87	2110.2	180.20	182.55	180.09	236.67	193.18
Netherlands	440.47	656.06	1317.93	964.00	1316.28	1346.10	794.96
USA	492.32	423.98	903.48	704.88	2299.39	1621.97	839.55
UK	50.80	198.16	161.42	195.70	138.91	373.22	142.36
Switzerland	223.38	172.67	211.06	797.66	372.90	676.15	694.02
Denmark	281.88	77.00	148.71	92.08	117.10	1.54	–
Australia	6.45	58.45	32.16	35.04	29.01	56.43	19.26
Italy	47.55	38.10	33.45	13.97	16.75	17.69	10.87
Germany	44.67	20.72	50.88	70.13	57.20	110.88	53.33
Canada	44.25	20.02	6.05	1.02	0.56	7.04	5.86
Spain	31.87	17.41	22.33	44.48	42.64	35.47	34.51
France	11.72	9.25	32.68	20.37	12.05	43.31	77.74
B. Developing countries							
	2008	2009	2010	2011	2012	2013	2014
Singapore	1881.75	3311.07	726.63	819.76	755.91	1105.64	710.06
Mauritius	1109.31	533.71	7931.72	2616.20	2900.78	955.42	3447.78
Russia	545.70	470.99	186.62	117.64	18.57	19.62	27.02
UAE	538.73	428.55	954.83	533.50	702.96	802.82	820.95
South Africa	12.54	82.51	2.96	18.13	58.49	7.11	6.71
Thailand	118.25	53.64	4.40	34.03	4.64	53.71	4.08
China	23.30	27.99	16.87	22.80	16.05	23.70	31.29
Panama	30.09	25.61	42.88	8.03	4.27	33.36	23.41
Tanzania	0.11	20.85	1.38	12.96	0.38	6.66	2.80
Chile	–	16.71	41.91	15.30	8.58	5.20	6.46
Sri Lanka	150.69	5.04	174.30	42.68	19.11	7.37	9.87
Indonesia	23.12	4.73	5.41	23.46	20.35	16.30	82.26
Malaysia	51.14	0.62	64.78	376.73	102.73	1.94	58.95
Total manufacturing	7878.45	9055.58	13,803.74	9420.46	9808.67	8894.08	8600.83

Source Author's compilation from RBI

With this background, and given the importance of integration into international production network for boosting Indian manufacturing sector, this paper examines India's production-network-related trade of manufactured goods in relation to outward FDI and trade cost. The empirical analysis pertains to the period 2008–2014, chosen primarily based on data availability, using panel data models (within-transformed fixed effects, and fixed-effects Poisson quasi-maximum likelihood that accounts for zero trade values). The data sources include UN Comtrade, UN ESCAP, Reserve Bank of India (RBI), Ministry of Commerce and Industry (Government of India), UN Service Trade and World Trade Organization.

The findings of the analysis suggest **to the significant positive impact of** manufacturing outward FDI on exports of parts and components to FDI-host countries. The results hold after controlling for inward FDI in India from the partner country, services exports to partner country and preferential trade agreements (PTA). On the other hand, the results indicate to a negative impact of bilateral trade costs on the production-network-related exports.

The results can have pertinent policy implication. In particular, to improve India's participation in international production network significantly, there is need to further encourage outward FDI in the manufacturing sector in selected countries and regions having such potential. On the other hand, in line with the existing wisdom, trade facilitation to reduce trade costs could also strengthen India's participation in international production network. Policy coordination with respect to FDI, both inward and outward, and trade facilitation shall be important in shaping India's integration with international production network.

3.2 Empirical Examination

Empirical analysis has been carried out using panel data model[4] of the following form[5]

$$PC_{jt} = g\left(\pi_t + \chi_{jt} + \mu_j + \eta_1 \mathrm{OFDI}_{jt} + \eta_2 TC_{jt} + \eta_3 X_{jt}\right) + \varepsilon_{jt} \qquad (3.1)$$

The estimation has been done using (a) within-transformed (linear) fixed effects and (b) fixed-effects Poisson (quasi-maximum likelihood) regression that accounts for zero trade values.

In the model, PC_{jt} stands for exports of parts and components from India to host country j at time t. OFDI_{jt} is India's outward FDI in the host country j, TC_{jt} is bilateral trade cost and X_{jt} stands for additional control variables that include inward FDI, services exports. Further, the role of PTA is also examined in view of the prevalence of regionalism along with multilateral trading system. In fact, the complementary nature of PTAs to the multilateral trading system has been recognized (Low 2014).

[4]The specification uses dummy variables to account for multilateral resistance terms and gravity forces. This approach has strong links with the gold standard gravity model (Anderson and Yotov 2012; Cheng and Wall 2005).

[5]The subscript for exporter (i) is suppressed as the analysis pertains to exports from one country (India).

3.3 Data Sources and Variables

The exports of parts and components have been collected from UN Comtrade database. In order t**o arrive at a measure of production-network-related exports from India**, the values of various parts and components' exports of 5-digit SITC Rev. 3 commodities are aggregated at the country-level following Athukorala (2010) classification (**see Appendix** for the list of parts and components). The trade costs have been obtained from the ESCAP-World Bank Trade Cost Database and the bilateral outward FDI from RBI (i.e. compiled by aggregating firm-level data).

It is worth mentioning that the analysis uses a comprehensive measure of bilateral trade costs. The measure is based on Novy (2013) and captures costs associated with both exporting and importing goods between trading partners. Trade costs (ESCAP-World Bank Trade Cost Database) are provided in *ad valorem* equivalent form (see Arvis et al. 2012 for further methodological details). For instance, a country's trade costs value of (say) 142.87 with a partner country suggests that, on average, trading goods with the concerned partner country involves additional costs of approximately 143% of the value of the goods as compared to trading goods within borders of the two trading countries.

The variables used in the analysis are (a) natural log of exports of parts and components from India to partner country *j* (lpc), (b) exports of parts and components from India to partner country *j* (pc), (c) trade costs in the manufacturing sector (tc), India's manufacturing outward FDI through equity mode in destination country *j* (eq), India's manufacturing outward FDI (equity plus loan mode) in host country *j* (eq_loan), India's manufacturing outward FDI (equity, loan and guarantee mode) in destination country *j* (total). Additional control variables include inward FDI received in India from partner country *j* (ifdi), role of services proxied by India's exports of services to partner country *j* (ser_exp) and PTA with the partner country as beneficiary (pta_b).[6] Data sources for inward FDI and services exports are the Ministry of Commerce and Industry (Government of India) and UN Service Trade database, respectively. The pta_b dummy is constructed using information from PTA database, WTO. Production-network-related exports of parts and components (pc) are measured in millions of US dollar. Similarly, outward FDI (eq, eq_loan, total), inward FDI (ifdi) and service exports are measured in millions of US dollar. The descriptive statistics of the variables are provided in Table 3.2.

[6]India has been beneficiary of PTAs provided by Australia, European Union, Japan, New Zealand, Norway, Belarus, Kazakhstan, Russian Federation, Switzerland, Turkey, and the USA. Historically, India did not use PTAs as a trade policy instrument until the early 2000s (Mikic 2011).

Table 3.2 Descriptive statistics

	Mean	SD	Max	Min	Observations
pc	226.35	367.17	3087.67	0.074	402
lpc	4.42	1.64	8.04	0.071	402
tc	139.47	63.10	657.66	37.231	402
eq	44.99	188.68	2031.15	0	402
eqloan	65.88	216.77	2067.73	0	402
total	141.60	556.27	7931.72	0.0003	402
ifdi	478.37	1564.24	11,207.90	0	313
ser_exp	1471.78	3480.74	19,343.00	1.891	123
pta_b	0.34	0.48	1.00	0	402

Source Author's calculation

3.4 Results and Discussion

The baseline results of empirical analysis are reported in Table 3.3. Results presented in panel A are based on within-transformed fixed effects and provide estimate of semi-elasticities, whereas those in panel B pertain to fixed-effects Poisson quasi-maximum likelihood (that account for zero trade values within country pairs) and give the direction of impact. As expected, the trade cost variable has negative impact on India's production-network-related exports of parts and components. The coefficient is significant in all the regression models. Higher the trade costs, lesser the exports of parts and components. The most interesting part of the results is the positive and significant impact of India's outward FDI on exports of parts and components to FDI-host countries, especially for total outward FDI.

Further, robustness check exercise was carried out to control for inward FDI (ifdi) from partner countries, bilateral services exports and PTA. These results, which are in consonance with the baseline, confirm a positive impact of outward FDI on India's exports of parts and components to FDI-host countries. As shown in Table 3.4, under both the estimation techniques, all the three measures of outward FDI yield positive and significant impact on production-network-related exports to FDI-host countries. It may also be noted that trade cost remains significant, with the negative sign associated with it, despite reduction in country coverage in the sample due to inclusion of additional control variables.

The inward FDI turned out to be significant as well in the maximum likelihood estimation. Further, PTAs are found to have exerted positive impact on production-network-related exports from India. However, services exports did not exert significant impact on exports of parts and components in most of the estimations. The variable (ser_exp) suffers from non-availability of data for a number of countries, which reduces the country coverage and number of data points in the analysis. Overall, the robustness check confirms the findings of baseline analysis and brings an improvement to the results qualitatively.

Table 3.3 Baseline results

	A. Within-transformed fixed effects			B. Fixed-effects Poisson (quasi-ML)		
	lpc	lpc	lpc	pc	pc	pc
tc	−0.005** (0.002)	−0.005** (0.002)	−0.005** (0.002)	−0.015*** (0.004)	−0.015*** (0.004)	−0.015*** (0.004)
eq	−0.0001 (0.0001)			0.0001 (0.0001)		
eq_loan		−0.0001 (0.0001)			0.0002 (0.0002)	
total			0.00005* (0.00002)			0.0002*** (0.00005)
Constant	5.09*** (0.318)	5.09*** (0.318)	5.08*** (0.317)	–	–	–
Observations	402	402	402	385	385	385
No. of countries	89	89	89	72	72	72
F test	2.32*	2.31*	3.05**			
Wald test				1276.05***	1351.56***	1570.31***
R square	0.49	0.49	0.49			
Log likelihood				−4557.81	−4520.08	−4414.92

Robust standard errors are in the parentheses. Coefficients of dummies are not reported. Results are similar with the inclusion of zero trade values in the estimation, in which case the log values of the dependent variable in the within-transformed model are generated after adding 1 to parts and components exports to overcome zero trade values

Country coverage: Algeria, Argentina, Australia, Austria, Bahamas, Bahrain, Bangladesh, Belgium, Benin, Bhutan, Botswana, Brazil, Cambodia, Canada, Central African Republic, Chad, Chile, China, Colombia, Congo Dem. Rep., Cyprus, Czech Republic, Denmark, Dominican Republic, Egypt, Ethiopia, Finland, France, Gabon, Georgia, Germany, Ghana, Guatemala, Honduras, Hong Kong SAR, Hungary, Indonesia, Iran, Ireland, Israel, Italy, Japan, Jordan, Kazakhstan, Kenya, Korea, Kyrgyz Republic, Luxembourg, Malaysia, Mauritius, Mexico, Morocco, Mozambique, Namibia, Nepal, Netherlands, New Zealand, Nigeria, Oman, Panama, Peru, Philippines, Poland, Portugal, Qatar, Romania, Russian Federation, Rwanda, Saudi Arabia, Senegal, Singapore, Slovak Republic, Slovenia, South Africa, Spain, Sri Lanka, Switzerland, Syria, Tanzania, Thailand, Turkey, Ukraine, UAE, UK, USA, Uzbekistan, Venezuela, Viet Nam, Yemen

***<0.01, **<0.05, *<0.10

Although positive impact of outward FDI on India's exports is documented elsewhere (Pradhan 2007; Das 2015), there has been dearth of evidence as regards the impact of outward FDI on production-network-related exports of parts and components. The results of this analysis therefore provide fresh evidence as regards the impact of India's outward FDI on production-network-related exports.

Table 3.4 Robustness check: control for additional explanatory variables

	A. Within-transformed fixed effects			B. Fixed effects Poisson (quasi-ML)		
	lpc	lpc	lpc	pc	pc	pc
tc	−0.009***	−0.009***	−0.009***	−0.006*	−0.006*	−0.006*
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
eq	0.0002**			0.0004***		
	(0.0001)			(0.00003)		
eq_loan		0.0002*			0.0004***	
		(0.0001)			(0.00003)	
total			0.0002**			0.0002***
			(0.0001)			(0.00003)
ifdi	4.92e−06	0.00001	0.00001	0.00001*	0.00002***	0.00005***
	(0.00002)	(0.00001)	(0.00002)	(8.66e−06)	(7.18e−06)	(9.14e−06)
ser_exp	0.00002	0.00001	−3.15e−06	8.76e−06	−8.54e−06	−0.00002*
	(0.00002)	(0.00002)	(0.00003)	(0.00001)	(0.00001)	(0.00001)
pta_b	0.891***	0.8767***	0.858***	0.954***	0.950***	0.898***
	(0.076)	(0.080)	(0.086)	(0.042)	(0.042)	(0.050)
Constant	4.952***	4.974***	5.08***	–	–	–
	(0.409)	(0.419)	(0.391)			
Time dummy	Yes	Yes	Yes	Yes	Yes	Yes
Observations	121	121	121	116	116	116
No. of countries	27	27	27	22	22	22
F test	–	–	–			
Wald test				1881.20***	1884.88***	1872.58***
R square	0.41	0.41	0.42			
Log likelihood				−595.58	−593.31	−602.81

Robust standard errors are in the parentheses. Coefficients of dummies are not reported. Results are similar with the inclusion of zero trade values in the estimation, in which case the log values of the dependent variable in the within-transformed model are generated after adding 1 to parts and components exports to overcome zero trade values

Country coverage: Australia, Austria, Belgium, Canada, Chile, Cyprus, Czech Republic, Denmark, Finland, France, Hong Kong SAR, Hungary, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Poland, Portugal, Romania, Russian Federation, Singapore, Slovak Republic, Spain, UK, USA

***<0.01, **<0.05, *<0.10

3.5 Conclusion

The expansion of outward FDI is an interesting development despite India being a net importer of capital. Although there are grounds for apprehension on many counts due to outward FDI, the phenomenon is expected to enhance India's participation in the international production network and global value chains. The complementary impact of outward FDI on exports of parts and components is evident from the empirical analysis. The results suggest that outward FDI in the manufacturing sector is crucial for expanding the outreach of Indian manufacturing in the global economy. Since international production network requires lesser border costs, in terms of time and money, trade facilitation to reduce trade costs may crucially aid in deriving the complementary benefits from manufacturing outward FDI. Policy initiative towards this end is expected to produce encouraging outcome both in the context of outward FDI and inward FDI.

It may be worth noting that the 'Make in India' initiative offers several avenues, especially for foreign firms, to invest in Indian manufacturing sector. However, without enhanced integration of Indian manufacturing facilities with the global value chain, the initiative may not produce desired results. Therefore, additional focus needs to be given towards integrating manufacturing facilities in India with production hubs in the international production network. Towards this end, steps must be taken to ensure free movement of parts and components and emphasis be given on value addition in the Indian production facilities and exports. This way the initiative shall be more meaningful and appealing for domestic as well as the multinational firms. Policy coordination with respect to outward FDI, inward FDI and trade facilitation shall be crucial in enhancing the integration of India's industrial sector with international production network.

Indian firms have an important role to play in enhancing integration of Indian manufacturing with global value chains. Firms will need to capitalize on both 'Make in India' and the liberal outward FDI regime. The former can help in improving domestic manufacturing activities, whereas the latter can establish the linkages, through outward FDI, with production hubs in the global value chain.

Appendix

List of Parts and Components (SITC—Rev. 3)

58291, 59850, 61210, 62142, 62143, 62144, 62145, 62921, 62929, 62999, 65621, 65720, 65751, 65771, 65773, 65791, 65792, 66382, 66471, 66472, 66481, 66591, 66599, 69551, 69552, 69553, 69554, 69555, 69559, 69561, 69562, 69563, 69564, 69680, 69915, 69933, 69941, 71191, 71192, 71280, 71311, 71319, 71321, 71322, 71323, 71332, 71333, 71381, 71391, 71392, 71441, 71449, 71481, 71489, 71491, 71499, 71610, 71620, 71631, 71651, 71690, 71819, 71878, 71899, 72119, 72129, 72139, 72198, 72199, 72391, 72392, 72393, 72399, 72439, 72449, 72461, 72467, 72468, 72488, 72491, 72492, 72591, 72599, 72635, 72689, 72691, 72699, 72719, 72729, 72819, 72839, 72851, 72852, 72853, 72855, 73511, 73513, 73515, 73591, 73595, 73719, 73729, 73739, 73749, 74128, 74135, 74139, 74149, 74155, 74159, 74172, 74190, 74220, 74291, 74295, 74363, 74364, 74380, 74391, 74395, 74419, 74443, 74491, 74492, 74493, 74494, 74519, 74529, 74539, 74568, 74593, 74597, 74610, 74620, 74630, 74640, 74650, 75680, 74691, 74699, 74710, 74720, 74730, 74740, 74780, 74790, 74810, 74821, 74822, 74839, 74840, 74850, 74860, 74890, 74920, 74991, 74999, 75230, 75260, 75270, 75290, 75910, 75990, 75991, 75993, 75995, 75997, 76211, 76212, 76281, 76282, 76289, 76432, 76481, 76491, 76492, 76493, 76499, 77111, 77119, 77125, 77129, 77220, 77231, 77232, 77233, 77235, 77238, 77241, 77242, 77243, 77244, 77245, 77249, 77251, 77252, 77253, 77254, 77255, 77257, 77258, 77259, 77261, 77262, 77281, 77282, 77311, 77312, 77313, 77314, 77315, 77317, 77318, 77322, 77323, 77324, 77326, 77328, 77329, 77423, 77429, 77549, 77579, 77589, 77611, 77612, 77621, 77623, 77625, 77627, 77629, 77631, 77632, 77633, 77635, 77637, 77639, 77641, 77643, 77645, 77649, 77681, 77688, 77689, 77812, 77817, 77819, 77821, 77822, 77823, 77824, 77829, 77831, 77833, 77834, 77835, 77848, 77861, 77862, 77863, 77864, 77865, 77866, 77867, 77868, 77869, 77871, 77879, 77881, 77882, 77883, 77885, 77886, 77889, 78410, 78421, 78425, 78431, 78432, 78433, 78434, 78435, 78436, 78439, 78535, 78536, 78537, 78689, 79199, 79291, 79293, 79295, 79297, 81211, 81215, 81219, 81380, 81391, 81392, 81399, 82111, 82112, 82119, 82180, 84552, 84841, 84842, 84848, 87119, 87139, 87149, 87199, 87319, 87325, 87329, 87412, 87414, 87424, 87426, 87439, 87454, 87456, 87461, 87463, 87469, 87479, 87490, 88112, 88113, 88114, 88115, 88123, 88124, 88134, 88136, 88422, 88431, 88432, 88433, 88439, 88571, 88591, 88597, 88598, 88599, 89121, 89195, 89281, 89395, 89423, 89860, 89865, 89867, 89879, 89890, 89935, 89949, 89983, 89985, 89986, 89992

Note: The classification, which was developed after converting HS 6-digit level to SITC 5-digit classification using the UN HS-SITC concordance, is sourced from Athukorala (2010).

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Chapter 4
Foreign Direct Investment and Business Cycle Co-movement: *Evidence from Asian Countries*

Unmesh Patnaik and Santosh K. Sahu

Abstract Regardless of the stage of development of economy, foreign direct investment and trade are prominent channels of business cycle co-movements. In view of sustainability concerns, carbon emissions have been in focus for shaping international policy on trade and FDI. We analyze the linkages between FDI, trade and carbon emissions relative to the business cycle co-movements using a panel comprising of 25 pairs of Asian economies. Adopting econometric techniques such as the three-stage least squares and Bayesian inferences, the results indicate that both FDI and trade are important channels of international business cycle transmission. It emerges that correlation of manufacturing sector emission between countries is negatively related to business cycle co-movement and trade, but positively related to FDI. Therefore, FDI is horizontal and tends to complement trade. We conclude reduction in CO_2 emissions from manufacturing sector acts as the stabilizing agent on the business cycle co-movement, while FDI induces pollution in these economies.

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U. Patnaik
Centre for Climate Change and Sustainability Studies, School of Habitat Studies, Tata Institute of Social Sciences, Mumbai 400088, India
e-mail: unmeshpatnaik@gmail.com

S.K. Sahu (✉)
Madras School of Economics, Behind Government Data Center, Gandhi Mandapam Road, Kottur, Chennai 600025, India
e-mail: santosh@mse.ac.in

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4.1 Introduction

One of the externalities of globalization is the interdependence of business cycles across countries. As countries attempt to integrate by removing barriers to flow of goods and services, the role of national boundaries essentially remains limited to representing underlying economic policies and institutions. Both trade and Foreign Direct Investment (FDI)[1] are prominent channels through which international business cycle co-movements are transmitted between countries. Therefore, it is conceivable that countries engaging in intense bilateral trade will tend to exhibit intensive synchronization of business cycles as concluded by Frankel and Rose (1998). However, other factors such as similarity/dissimilarity in the industrialization pattern and financial integration could confound the level of correlation. Although there is no consensus in literature on the relationship between business cycles and FDI, recent research support the assertion that correlation does exist between the two: with positive correlation being credited to the spread of trade, higher financial integration and industrial structure and negative correlation being attributed to lack of spillover effects. The primary channels through which FDI is linked with business cycle co-movement are: (i) technology diffusion, (ii) international rent sharing, (iii) domestic conditions in industry and (iv) degree of capital mobility between the host and source economies. The correlation could turn out to be positive or negative subject to the dominant force that derives the business cycle. If the demand channels lead, trade integration increases correlation. However, if industry-specific factors are responsible for cyclical output, the harmonization would be negative due to specialization and inter-industry trade as in the context of developing countries. While the empirical literature on the effects of FDI is mostly based on firm-level data, the issues of investigation relate to supply-side effects on host economies in long run with the focus being on the transfer of technology, management techniques and business models. On the macroeconomic front, FDI is seen as a promoter of growth in developing economies while benefiting the more developed ones in terms of lesser costs of production. The primary advantages for the home countries are access to new markets and increased cost efficiency. In the perspective of host country, FDI is not as liquid and tradable as for the portfolio investment and, hence, considered more stable.

Over the years and especially after the 1980s, FDI on a global scale has recorded substantial increase with the Asian region being no exception. Both gross trade in volume and value-added witnessed an annual average growth rate of 8 and 10%, respectively, during 1990–2012, twice the average pace outside Asia. Not only have Asian economies traded more with one another, they have also traded differently, becoming more vertically integrated as a tight-knit supply-chain network across the region (Duval et al. 2014). The aftermath of Global Financial Crisis (2008–2009)

[1]FDI is a cross border investment made by a resident in one economy (source economy) to acquire a lasting interest in an enterprise operating in another economy which is the host economy (OECD 2008).

witnessed emergence of Asian economies as dominant players in global business, driving global economic growth. For East Asian countries, Zhang (2001) concludes that FDI is more likely to promote economic growth when host countries implement liberalized trade regime, improve human capital conditions, encourage export-oriented FDI and maintain macroeconomic stability. The data presented in Zhang (2001) suggest a negative change in the share of manufacturing FDI for the East Asian economies, generating an increase in the service sector FDI. The FDI report 2016 presents a negative change in FDI for most sectors except for the real estate category. Further, coal, oil and natural gas reclaimed top spot for FDI by capital investment and the top three sectors in FDI are Software, IT & Services; Business Services; and Financial Services (fDi Intelligence 2016). Therefore, the sectoral changes in FDI for the Asian economies suggest a shift from the traditional manufacturing towards services. However, in the manufacturing sector, FDI is more prominent in the energy-intensive sectors that are possibly emission generating. Therefore, the research question is "*what are the implications of the intensive growth on business cycle co-movement between these economies in relation to the emission from the manufacturing sector*?"

Previous research addressing business cycle co-movement, international trade and emissions is very broad. Despite many contributions, an important issue that is unanswered is the evaluation and measurement of the real and absolute impact of business cycles, international trade and FDI, on emissions. In this paper, we argue that apart from the existing indicators of business cycle co-movements; negative externalities of production such as emission, in general, and carbon dioxide (CO_2) emissions from the manufacturing industries in particular could be deployed for explaining the linkages between business cycle co-movement, trade and FDI. The relationship is plausible as better environmental performance reduces competitiveness through enhanced costs on one hand while also improving product quality through improved competitiveness and cost abatement. In particular, the latter stress that increases in competitiveness is more likely to occur over time, due to the positive effects of technological development and innovation.

Using dyadic data at aggregate level, we examine *the extent to which synchronized business cycles can be related to the rapid expansion of FDI and the internationalization of.* As an improvement to the earlier studies that links business cycle, FDI and trade with industrial similarities, we examine correlation of CO_2 emission from manufacturing sector between the dyadic sets. This link is driven from the arguments of *Pollution Haven Hypothesis* (PHH),[2] *Factor Endowment Hypothesis* (FEH) and the *Capital-Labour Hypothesis* (KLH). The treatment of CO_2 emission as an important variable in this case also goes in line of the recent experiences of FDI movement from manufacturing to the service sector. We argue a stronger relationship of CO_2 emission with FDI and trade that acts as a stabilizing agent with the business cycle co-movement. Our assumption is based on the

[2]Besides other factors, production misallocation takes place mainly from developed to developing economies as a result of strong environmental regulations in developed countries.

empirical evidence of data in hand coupled with the theoretical issues identified in earlier literature. We analyze the existence of this experience from 2007 to 2014 for Asian plus economies. The remainder of the paper is structured as follows: while Sect. 4.2 briefly outlines the channels of business cycle co-movement with empirical model specifications, Sect. 4.3 describes the data and presents the empirical results. Section 4.4 summarizes the concluding observation of this study.

4.2 Channels of Business Cycle Co-movement

Research on business cycle co-movement as a characterization of international economic interdependence has been based on two broad strands. While one is confined to international trade in goods and services that includes concerns related to specialization patterns and internationalization of production through FDI, the second focuses on trade in financial assets, such as equities and bonds. Since the mid-nineties, higher synchronization in business cycles is observed by Peersman (2002), likewise Lane and Milesi-Ferretti (2008) detecting more cross-border holdings of portfolio assets and Berben and Jansen (2002) reporting higher correlations among stock and bond markets of the major countries. All of these emphasize the importance of financial markets for transmission of shocks across countries.

Shocks emanating in specific countries could spread to other nations due to economic relations leading to intensive output co-movement, indirectly. Evidence of such phenomena was visible during the 2001 downturn as economic growth rates across industrialized economies fell to its lowest level in over thirty years. Budd and Slaughter (2000) provide evidence of cross-border profit sharing between the American and Canadian firms demonstrating the stated behaviour, whereas FDIs are observed to be horizontal (Brainard 1997; Carr et al. 2001). Frankel and Rose (1998) observed highly correlated business cycles for countries that trade closely; however, no such evidence is found either by Crosby (2003) or Inklaar et al. (2008). A detailed and representative evaluation of business cycle synchronization[3] of 1990s is found in Boone and Maurel (1998).

The other channel in understanding business cycle co-movement pertains to economic resemblance. Krugman (1993) demonstrates that economic dissimilarity results in the higher asymmetry of shock impacts leading to weaker business cycle synchronization. However, financial assimilation either through business linkages, or FDI or other joint ventures, increases the business cycle synchronisation (Imbs 2004; Hsu et al. 2011). Baxter and Kouparitsas (2005) observe evidences akin to the above (simultaneity of business cycle trade). However, Gruben et al. (2002) and

[3]The writings of Mundel (1961) and Kenen (1969) pioneered the research of economic shocks impacts to countries under the partial loss of economic policy autonomy. The follow-up discussions resulted in criteria guaranteeing the absence of dangerous asymmetric shocks or minimization of their impact on involved economies.

Inklaar et al. (2008) arrive at contrasting results and conclude the trade effect to be of much smaller intensity. Similarly, for US multinationals engaging in FDI in other developed economies, Badinger and Egger (2010) found vertical antecedents of FDI more important than horizontal with Yeaple (2003), Braconier et al. (2002) and Petroulas (2007) also concluding on similar lines. Likewise, Anderton and Tewolde (2011) conclude that global production chains operating through vertical FDI were crucial for the trade collapse in 2008–2009. Since FDI operates as one of the channels for international technology transfer and business practices, it tends to make economies more alike in structure (Keller 2004; Haskel et al. 2007).

At a micro(firm) level, Alfaro and Charlton (2009) find half of FDI to be vertical, with the outcome being specialized inputs for parent firms through intra-industry subsidiaries. For the case of Germany, Wagner (2016) finds a distinction between intra and inter-good traders, finding the latter to be larger, profitable and productive while also being human capital and R&D intensive. Dissimilarity in industrial structures (defined in terms of value added from the industries) has been another important transmission channel in the existing literature with evidences being mixed on this front. While Imbs (2004) finds industrial dissimilarity (or specialization) patterns to have significant effects on business cycle co-movements, Otto et al. (2001) and Baxter and Kouparitsas (2005) do not find such evidence. Again, Hsu et al. (2011) based on a panel of 77 advanced economies establish the importance of FDI vis-a-vis trade and monetary. Given the mixed results of the earlier studies, the relationship between business cycle co-movement, FDI and trade still requires introspection in general and for the emerging Asian economies in particular. The linkage of business cycle co-movements with trade and other-specific indicators is hypothesized in Chart 4.1.

Here, it is argued that business cycle co-movements can either be positively or negatively correlated. Along with variables used in theliterature, we introduce emissions as one of the explanation of the co-movement. In Chart 4.1, if business cycle co-movement is positively correlated between a dyadic set of country (positive part of the *X*-axis), it will depict similarity in economies, and thereby, FDI will be horizontal in nature along with trade. In this case, trade and FDI are complementary in nature. This case of complementarities will generate higher emission in general and form the manufacturing industries in particular, whereas in case of negative business cycle correlation (negative scale of the *X*-axis), FDI is considered to be vertical and working as a substitute for trade and hence non-increasing with regard to emissions. We examine evidences for these possibilities with other controlled variables drawn from the literature for our data set.

Indications regarding these also originate from the analogous literature grounded on '*environmental inequality*' and '*emission responsibility*'. Here, the focus has been on the assessment of misbalances in emissions embodied in trade of exports and imports of specific countries. In particular, two conflicting propositions have been presented in Aller et al. (2015), the first being the PHH and the second corresponding to the FEH and the KLH. The latter suggesting that countries should specialize in activities for which they have an important competitive advantage. Hereby, as developed countries possess a higher disposability of capital, they

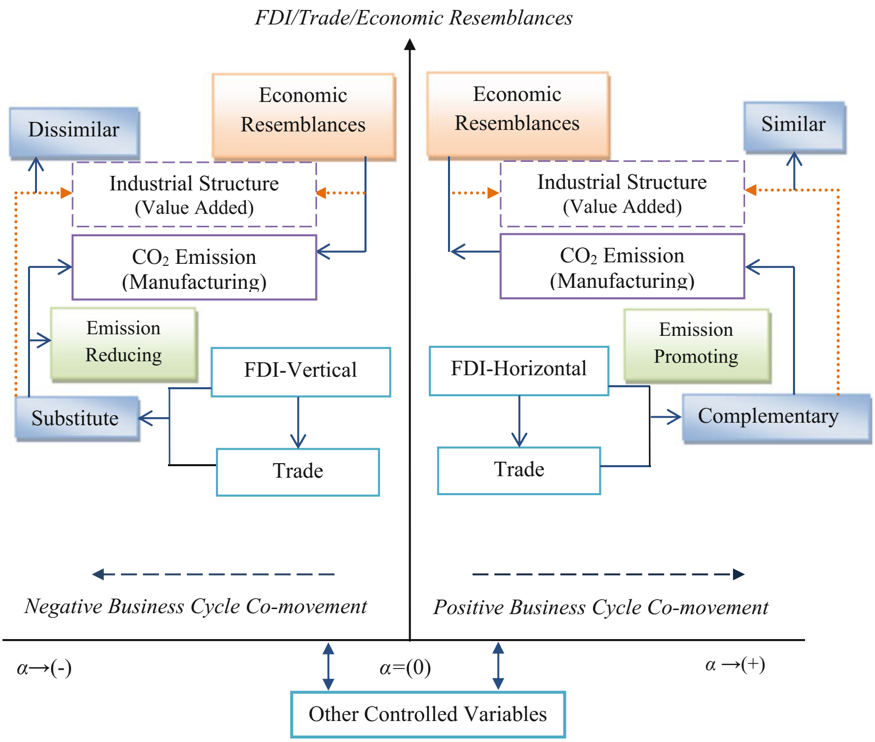

Chart 4.1 Channels of business cycle co-movement (authors' representation)

should specialize in the production of manufactured goods, which is highly pollution-intensive (Aller et al. 2015). For instance at a global level, Khan and Yoshino (2004) using trade data over 17 years, 128 nations and 34 manufacturing industries find support to PHH. They show that increases in national income are generally followed by a lowering in export of dirty goods relative to clean ones. In particular, this interrelation between income, displacement of production and the subsequent environmental impact has also received much attention in this body of literature, under the concept of the '*Environmental Kuznets Curve*' (EKC).[4]

Again, in response to challenges due to environmental degradation, numerous studies have emerged examining the economic factors influencing emissions, including international trade (Jayadevappa and Chhatre 2000). Regarding the relationship between international trade and emissions, much attention has been

[4]More precisely, the hypothesis of the environmental Kuznets curve suggests that countries may increase their emissions as a result of increasing their income but only until they reach a certain technological level, after which emissions would be reduced because of an increase in the environmental efficiency of production. Such hypothesis, suggesting an inverted-U relation between income and emissions, has been investigated by many authors.

devoted to the volumes of pollutants generated to produce goods that later have been exported and imported, i.e. emissions involved or '*embodied*' in traded goods (Wiebe et al. 2012). Increases in pollution driven by economic factors such as population, consumption per capita, consumption patterns or technological structure have also been accounted for (Arto and Dietzenbacher 2014), along with specific attention to the international trade (Antweiler et al. 2001). Kleemann and Abdulai (2013) conclude that the association between international trade, economic development and environmental degradation has often been the centre of debate, and diverse approaches adopted in the examination have resulted in conflicting results.

Within this literature, few studies have addressed emissions embodied globally, due to international trade, like Wiebe et al. (2012) on the measurement of CO_2 global emissions. Others are more country specific, like Machado et al. (2001) analyzing the energy and carbon embodied in Brazilian trade, or Liu et al. (2015) accounting for the emissions embodied in the value added by the Chinese sectors. Another stream addressed is bilateral relationships between countries and their environmental implications. For instance, Wu et al. (2016) and Zhao et al. (2016) focused on emissions embodied in China–Japan trade and Jayanthakumaran and Liu (2016) on China–Australia. We attempt to illustrate the impact of emission in terms of externalities to the environment and the responses to business cycle co-movement, FDI and trade in Chart 4.2. Here, environment sustainability is accounted for through the theories PHH and EKC. If emission and business cycle correlation are both positive (quadrant 1 of Chart 4.2), will imply negative externalities to the environment as emissions increase between the countries, whereas in the opposite environment, where correlation is negative for both the economies, it will have positive implications to the environment. In this case, business cycle co-movement, FDI and trade are argued to be sub-sets of emission co-movements.

To validate our argument of business cycle correlation with emission, in general, CO_2 emission from the manufacturing sector for the dyadic series of data for Asian plus economies is presented in the appendix. Figure 4.5 in appendix shows the relationship between the business cycle correlations with CO_2 emission from the origin country perspective. The correlation across these two for the countries is fluctuating and also overlapping for some economies. However, from the destination country point of view (Fig. 4.6), the business cycle correlation is higher than that of the CO_2 emission for most of these economies. This gives an impression that business cycle correlations are more important from the destination countries in terms of FDI and trade than the origin country context. To examine the association between these channels, we use simultaneous equation model of 3-SLS type, and the Bayesian Inference. While 3-SLS allows formulating system of equations related to business cycle co-movement, trade, FDI and correlation of emission from manufacturing sector; the results of the Bayesian inference can be used to validate the results of the 3-SLS estimation. Besides, it also attempts to understand the probability of business cycle convergence with the set of other macrovariables with prior information.

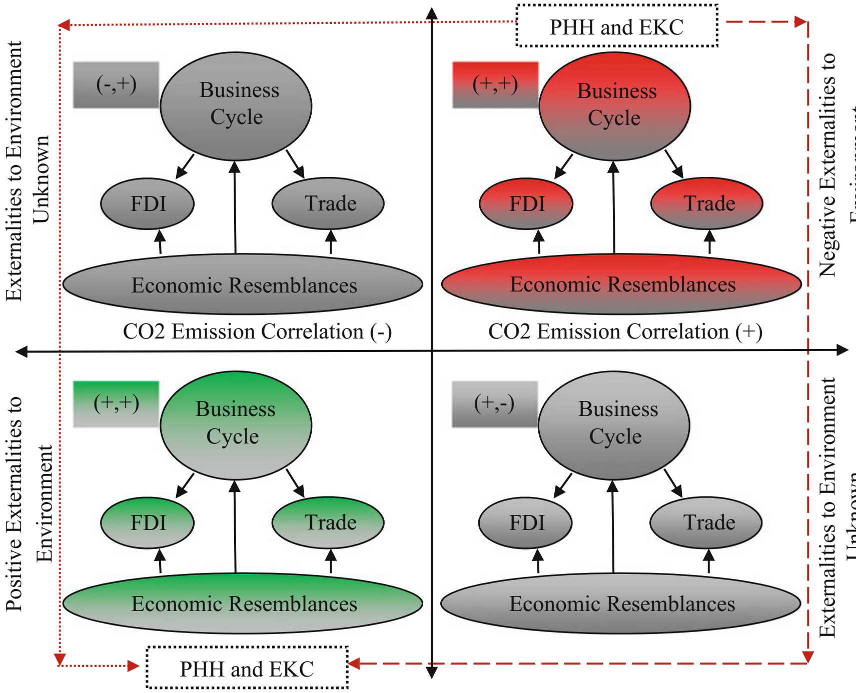

Chart 4.2 Externalities to the environment and channels of business cycle co-movement

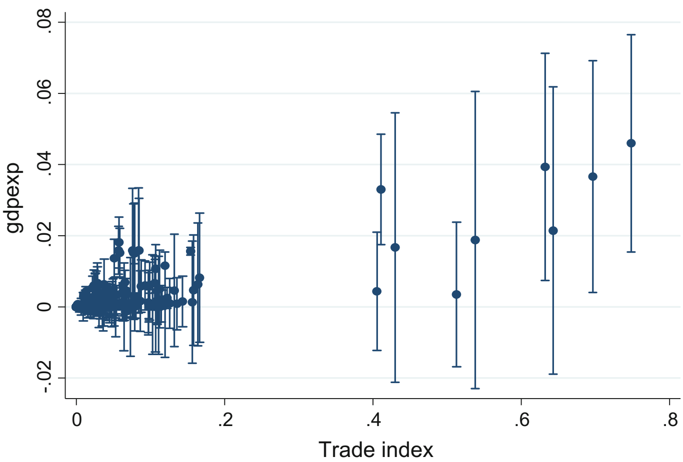

Fig. 4.1 Standard error bar chart (trade and ratio of export to GDP)

4.2.1 A Simultaneous Equation Model of BC Correlation, FDI, Trade and Emission

Natural logarithm of real GDP de-trended with a Hodrick and Prescott (1997) filter is used to compile the business cycle synchronization/co-movement (correlation). This measure has become standard and also used in earlier studies such as Clack and van Wincoop (2001) and many others for cross-border business cycle studies. To investigate the relationships among business cycle correlation (ρ_{HP}), FDI, aggregate trade intensity (Trade), trade intensity due to imports ($\mathrm{Trade}_{\mathrm{IMP}}$) and CO_2 emission from manufacturing sector (EMSNM), we use the following system of equations for country pairs (i, j):

$$\rho_{\mathrm{HP}_{i,j,t}} = \alpha_0 + \alpha_1 \mathrm{FDI}_{i,j,t} + \alpha_2 \mathrm{Trade}_{i,j,t} + \alpha_3 \mathrm{EMSNM}_{i,j,t} + \alpha_4 Z_{1,i,j,t} + \varepsilon_{1,ij,t}, \quad (4.1)$$

$$\mathrm{FDI}_{i,j,t} = \beta_0 + \beta_1 \mathrm{Trade}_{i,j,t} + \beta_2 \mathrm{EMSNM}_{i,j,t} + \beta_3 Z_{2i,j,t} + \varepsilon_{2,ij,t}, \quad (4.2)$$

$$\mathrm{Trade}_{i,j,t} = \gamma_0 + \gamma_1 \mathrm{FDI}_{i,j,t} + \gamma_2 \mathrm{EMSNM}_{i,j,t} + \gamma_3 Z_{3,i,j,t} + \varepsilon_{3,ij,t} \quad (4.3)$$

$$\mathrm{EMSNM}_{i,j,t} = \lambda_0 + \lambda_1 \mathrm{FDI}_{i,j,t} + \lambda_2 \mathrm{Trade}_{i,j,t} + \lambda_3 Z_{4,i,j,t} + \varepsilon_{4,ij,t} \quad (4.4)$$

where, for all the equation from (4.1)–(4.4), i, j, and t are index country pairs (i, j) in period t, and ε is the disturbance term. Vectors Z_1, Z_2, Z_3 and Z_4 contain exogenous variables that are employed in the system, for identification. The disturbance term is specified as the sum of a time-invariant pair-specific term and an idiosyncratic random error (e): $\varepsilon_{k,i,j,t} = \mu_{k,i,j} + e_{k,i,j,t,}$ for k refers to dependent variables and $\mu_{1,i,j}, \mu_{2,i,j}, \mu_{3,i,j},$ and $\mu_{4,i,j}$ enter the model to capture the individual effects that are specific to country pairs (i, j) in the all four equations, respectively.

Equation (4.1)[5] illustrates the major determinants of output synchronization (business cycle co-movement) that are FDI, trade, correlation of manufacturing emission and monetary policy. The empirical estimate further uses both aggregate trade index and trade through imports to validate the argument of direct link between trade dependencies in general and through import in particular. To be consistent with our intuition that FDI and business cycle co-movements have a positive relationship, it should be the case that $a_1 > 0$. As for the sign of a_2, we expect it to be positive, whereas $a_3 < 0$ based on the related literature from PHH hypothesis. The exogenous variable $Z_{1,i,j,t}$ includes a measure for the similarity of monetary policies of two countries. $Z_{1,i,j,t}$ controls for the possibility of a common shock to both economies from an external source, while FDI, trade and

[5]From the related literature, we also estimate industrial dissimilarity in relationship with business cycle co-movement and find conflicting results for the Asian economies. This makes our hypothesis stronger that correlation of CO_2 emissions from manufacturing industries are more important determinants, as compared to industrial dissimilarity computed from value added.

manufacturing CO_2 emissions in Eq. (4.1) account the channels of transmitting shocks from one country to another.

Equations (4.2) and (4.3) are for bilateral FDI and bilateral trade, respectively, with and without import dependency of trade. The FDI equation is the key equation for business cycle co-movements. Our hypothesis is β_1 to be positive. The vector of the exogenous variables, $Z_{2,i,j,t}$, includes a measure of monetary policy, legal origin and common language. In Eq. (4.3) for trade flows, the relationship between trade and FDI depends on the nature of FDI. $\gamma_1 > 0$ indicates that FDI is mostly vertical, since this type of FDI is conducted according to relative factor prices and could boost trade. Conversely, if type of FDI is horizontal, then we argue $\gamma_1 < 0$. Identical relationship is also estimated for the import dependency of trade. The exogenous variables in $Z_{3,i,j,t}$ include common language, distance, land adjacency and log of the ratio of the two countries' GDPs.

Equation (4.4) expresses similarity or dissimilarity of emissions originating from manufacturing sector.[6] If FDI and/or trade cause higher pollution in the recipient economy, we shall observe $\lambda_1 > 0$. On the other hand, if FDI and/or trade result in promotion of environment-friendly technology, they will reduce emissions, $\lambda_1 < 0$. The exogenous variables in this case represented in $Z_{4,i,j,t}$ are log of the ratio of the two countries GDP and log of the product of two countries GDP. As an improvement in the earlier studies, inclusion of correlation of manufacturing CO_2 emission will facilitate validating the PHH, in general, and for technology adoptions and positive spillovers of FDI in particular. The emission component in Eq. (4.4) is computed as the correlation of CO_2 emission in physical units, between the dyadic countries. The measure of the bilateral trade intensity, $\text{Trade}_{i,j,t}$ is defined as:

$$\text{Trade}_{i,j,t} = \frac{x_{i,j,t} + m_{i,j,t} + x_{j,i,t} + m_{j,i,t}}{x_{i,t} + m_{i,t} + x_{j,t} + m_{j,t}} \tag{4.5}$$

where, $x_{i,j,t}$ is the value of exports from country i to country j at time t. $m_{i,j,t}$ is the value of imports from i to country j at time t. $x_{i,t}$ is the value of country i's exports to all countries at time t, and $m_{i,t}$ is the value of country i's imports from all countries at time t. Previously, this was used by Baxter and Kouparitsas (2005) and Hsu et al. (2011) to measure bilateral trade intensity. On the modification of the trade impact only through imports, we have also created trade import index similar to that of Eq. (4.5) that takes only imports between countries. Since, there are no standard measures of bilateral FDI intensity, we construct this index as described in Hsu et al. (2011):

[6]Emissions (in terms of CO_2) are non-decreasing when developing and lesser developed countries tend to increase their industrial output, as a negative externality of production. Minimizing emissions can be achieved either through technology transfer or technological advancement at domestic level.

$$\mathrm{FDI}_{i,j,t} = \frac{\mathrm{fdi}_{i,j,t} + \mathrm{fdi}_{j,i,t}}{\mathrm{fdi}_{i,t} + \mathrm{fdi}_{j,t}} \tag{4.6}$$

where, $\mathrm{fdi}_{i,j,t}$ denotes the total FDI (both inward and outward) from country i to country j in time t, and $f_{i,t}$ is the aggregate FDI for country i. The data sources for all variables are presented in Table 4.3.

4.2.2 Convergence of Business Cycle Co-movement

Bayesian analysis answers questions about unknown parameters of statistical models by using probability statements.[7] In estimating the relationships between the variables of choice as described in Sect. 2.1, we estimate the following two-level mixed model.

$$\rho_{\mathrm{HP}_{i,j,t}} = \beta_0 + \beta_1 \mathrm{FDI}_{i,j,t} + \beta_2 \mathrm{Trade}_{i,j,t} + \beta_3 \mathrm{DS}_{i,j,t} + \beta_4 \mathrm{MP}_{1,i,j,t} + u_j + \varepsilon_{i,j,t} \tag{4.7}$$

where, u_j is the random effect for business cycle j, j = 1, ..., 1100, and the counter i = 1, ..., 9 identifies the independent variables. We first use mixed regression model to estimate this formulation, by using maximum likelihood for comparison purposes. Subsequently, the Bayesian model is estimated using the following functional form:

$$\begin{aligned}\rho_{\mathrm{HP}_{i,j,t}} &= \beta_0 + \beta_1 \mathrm{FDI}_{i,j,t} + \beta_2 \mathrm{Trade}_{i,j,t} + \beta_3 \mathrm{EMSNM}_{i,j,t} + \beta_4 \mathrm{MP}_{1,i,j,t} + u_j + \varepsilon_{i,j,t} \\ &= \beta_1 \mathrm{FDI}_{i,j,t} + \beta_2 \mathrm{Trade}_{i,j,t} + \beta_3 \mathrm{EMSN}_{i,j,t} + \beta_4 \mathrm{MP}_{1,i,j,t} + \tau_j + \varepsilon_{i,j,t,}\end{aligned} \tag{4.8}$$

and

$$\begin{aligned}&\varepsilon_{i,j,t} \sim i.i.d.N(0, \sigma_0^2)\\ &\tau_j \sim i.i.d.N(\beta_0, \sigma_{id}^2)\\ &\beta_0^n \sim N(0, 100)\\ &\sigma_0^2 \sim \mathrm{InvGamma}(0.001, 0.001)\\ &\sigma_{id}^2 \sim \mathrm{InvGamma}(0.001, 0.001)\end{aligned}$$

[7]The approach rests on the assumption that all model parameters are random quantities and thus can incorporate prior knowledge. This is in contrast with the traditional, also called *frequentist*, statistical inference where all parameters are considered unknown but fixed quantities. Grounded in the Bayes rule, the approach provides formalism for combining prior information with evidence from the data at hand. The Bayes rule is used to form the so called *posterior distribution* of model parameters. The *posterior distribution* results from updating the prior knowledge about model parameters with evidence from the observed data.

The parameters of interest in the analysis are the coefficients and their variance. While normal priors are used for regression coefficients, group levels are identified by the country and inverse-gamma priors for the variance parameters. The chosen priors are fairly non-informative, so we would expect results to be similar to the *frequentist* ones. To estimate this model, we include random effects for business cycle co-movement in the model. This is achieved by adding factor levels of the country identifiers to the equation by using the factor-variable specification i.i.d.[8]

4.3 Results and Discussion

We use secondary data from a panel of Asian+ countries constructed from multiple data sources. The time frame for this analysis is 2007–2014. The broad categories for which data are drawn include: (i) business cycles, (ii) bilateral trade, (iii) bilateral FDI, (iv) carbon emissions from manufacturing and (v) control variables.

4.3.1 Descriptive Analysis

The first set of results is with respect to the bilateral association between the Asian economies. The sample size for analysis is 1100 observations depicting combination of pairs of countries. Table 4.4 in the appendix, reports the unconditional correlation and the summary statistics for all the endogenous variables considered in the system of equations. It is observed that all endogenous variables are positively correlated with the business cycle synchronization except for the manufacturing CO_2 emissions. The standard error corrected bar chart for trade index and GDP of exporting countries presented in Fig. 4.1, depicting the import/export/trade dependency of the Asian economics. This figure depicts that based on the trade index in aggregate we can clearly see clusters of Asian economies behaving similar to their export potential, whereas there are countable economies that have dominant role in higher trade index and export potentials.

Figure 4.2 depicts the variability plot of business cycle correlation and CO_2 emission correlation in panel A; whereas panel B shows the variability of business cycle correlation with the CO_2 emission from the manufacturing alone. These two

[8]This specification, by default, will omit one of the id categories as a base category. In addition to the regression coefficients and variance components, random-effects parameters are estimated using Metropolis–Hastings algorithm. Checking the convergence is an essential step of any Markov Chain Monte Carlo (MCMC) simulation. Bayesian inference based on an MCMC sample is only valid, if the Markov chain has converged and the sample is drawn from the desired posterior distribution. An MCMC is said to have converged if it reached its stationary distribution. In the Bayesian context, the stationary distribution is the true posterior distribution of model parameters.

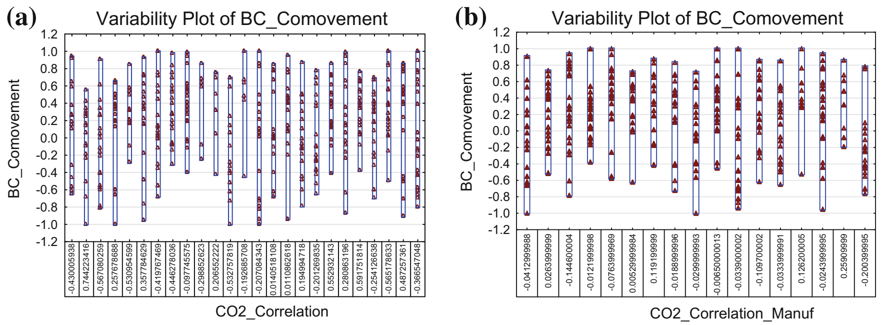

Fig. 4.2 Variability plot of business cycle co-movement, CO_2 emission correlation and CO_2 emission correlation from manufacturing

sub-graphs also validate out argument on relationship between business cycle co-movement as presented in Charts 4.1 and 4.2 earlier. Before proceeding to the simultaneous equations set up, single equation estimations between pairs of countries are presented in Table 4.5 in the appendix. Here, column 1 reports results for aggregate trade whereas; column 2 presents the estimates with trade dependency of imports. The coefficient signs and the level of significance do not change across the two sets of results, except for the relationship between trade and geographical distance. The results suggest higher bilateral trade between two countries, are associated with more correlated business cycles. FDI does not turn out to be significant across both the specifications, and so also is the case for closeness of monetary policy. Trade between economies is positively influenced by exogenous factors like similarity in language, land and GDP. In this case common language positively influences trade while distance and GDP are negatively related. Since, the ordinary least squares technique is likely to suffer from *endogeneity* problems, we employ 3-SLS framework in the subsequent analysis with a pooled data structure.

4.3.2 Results from Simultaneous Equation Estimation with Pooled Data

The results from the estimation of simultaneous equation model are presented in Table 4.1. It is observed that results are more parsimonious compared to single equation estimations. The significance of the estimated parameters have improved and so also has the effects. It can be concluded that trade is more between economies depicting higher synchronization of business cycles, in line with trade theories. Moreover, trade is higher between countries situated geographically close. Accounting for trade imports in the second specification, does not change the nature of trade i.e. countries having positive business cycle correlation engage in bilateral

Table 4.1 Estimates for 3SLS with pooled data

Variables	Model (1)		Model (2)	
	Coefficients	(S.E)	Coefficients	(S.E)
Outcome	ρ_{HP}			
FDI	0.143***	(0.039)	−0.005	(0.057)
$Trade_{IMP}$	0.001***	(0.0006)	–	–
Trade	–	–	4.213***	(1.365)
EMSNM	−11.445***	(1.688)	−11.395***	(1.867)
MP	0.035	(0.035)	0.033	(0.035)
Outcome	*FDI*			
$Trade_{IMP}$	0.005*	(0.002)	–	–
Trade	–	–	18.289***	(4.259)
EMSNM	41.574***	(6.861)	36.109***	(6.887)
MP	0.019	(0.036)	0.017	(0.034)
Legal origin	0.953	(0.704)	1.819***	(0.664)
Language	−0.205	(0.335)	−0.907***	(0.329)
Outcome	*Trade*			
FDI	0.127***	(0.031)	–	–
EMSNM	−0.332	(0.468)	–	–
Language	0.015	(0.014)	–	–
Distance	−0.012***	(0.005)	–	–
LAND	−0.002	(0.006)	–	–
GDP_G	0.343***	(0.129)	–	–
Outcome	$Trade_{IMP}$			
FDI	–	–	305.132***	(128.769)
EMSNM	–	–	−3338.466*	(1801.262)
Language	–	–	−4.111	(53.319)
Distance	–	–	−27.261	(18.448)
LAND	–	–	−26.892	(40.038)
GDP_G	–	–	697.707	(497.142)
Outcome	*EMSNM*			
FDI	0.046***	(0.013)	0.054***	(0.014)
$Trade_{IMP}$	−0.0002	(0.0001)	–	–
Trade	–	–	−0.119	(0.159)
GDP_G	0.085*	(0.051)	0.145***	(0.059)
GDP_{PROD}	0.00003	(0.00007)	−0.0005***	(0.0002)
N	1100	–	948	–

Note ***$p < 0.01$ and *$p < 0.10$; standard errors in parentheses

imports between similar economies and through FDI. Here, trade import is higher, if the correlation of manufacturing CO_2 emission is lesser. Additionally, FDI is also more between countries that have higher trade dependency, either in aggregate or from imports supporting the assertion of trade theories, while legal origin is not a barrier for engaging in trade through FDI channels. However, common official language happens to be negatively related to FDI. Theories related to FDI and spillover explains the benefits of trade and FDI in terms of technology trade and up-gradation. However, the shifts in FDI behavior to the services sector for the Asian economy might not explain the similar spillover from trade and FDI.

For example, Bu and Wagner (2016) in the context of Chinese firms FDI is jointly determined through heterogeneity in capabilities and firm size, resembling simultaneity of a race to bottom and top as well. Specifically, firms with environmental capabilities invest more in stringently regulated regions and firms with weaknesses are less likely to target such regions. Therefore, bringing in bilateral correlation between manufacturing CO_2 emissions for country pairs as a measure for the nature of industrialization, leads us to the conclusion that business cycle co-movement is positively related to FDI (both inward and outward), however negatively related to emission from manufacturing sector. In our case for the Asian economies, FDI is of the horizontal type and hence, tends to complement trade. While FDI is a major component of bilateral trade, and occurs between dissimilar economies, it is positively related to CO_2 emission from manufacturing sector. Hence while FDI intensifies pollution, co-movements in business cycle encourage environmental sustainability with reduction in emission playing the stabilizing agent for the co-movement of business cycle. Therefore, correlation in the level of emission emerges as a better indicator explaining the co-movement of business cycle, and FDI as compared to dissimilarity in industrial structures through value added. It emerges that, countries with similarity in business cycle correlation do engage in more of trade, but not necessarily through the FDI route, and may be through traditional channels of exports and imports.

4.3.3 Results from Bayesian Inferences

It is important to notice the differences and similarity of using different methodologies in understanding a similar problem, as adopted in this paper. The use of Bayesian econometrics has arisen due to the discussion on the use of *p* value.[9] Here, we follow a standard procedure of estimating mixed effects regression of different models and arrive at the informative prior from these. The results of the mixed effects regression is presented in Table 4.6 in the appendix. Figures 4.3 and 4.4 show the trace plot and, histogram in the upper part while autocorrelation plot, and

[9]If the interpretation of *p* value in case of classical inference is argumentative, it is better to use the other method that is the Bayesian inference where unlike the Classical inference, the former explains estimated parameters (β_s) as stochastic variable; data are used as evidence to update state of the mind, i.e. transform prior into posterior distribution using the likelihood; uses subjective concept of probability. One uses Bayes' theorem to obtain the posterior distribution of β and the model comparison is carried out by using posterior odds ratio. Estimates related to the Bayesian inference can be arrived at either with informative prior or no informative prior (StataCorp. 2015).

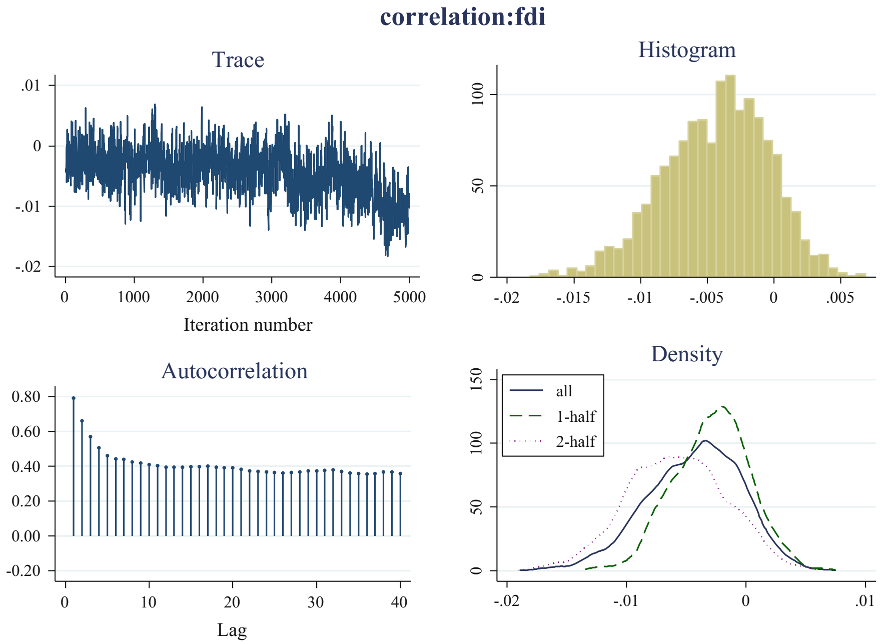

Fig. 4.3 Diagonestic test for business cycle and FDI

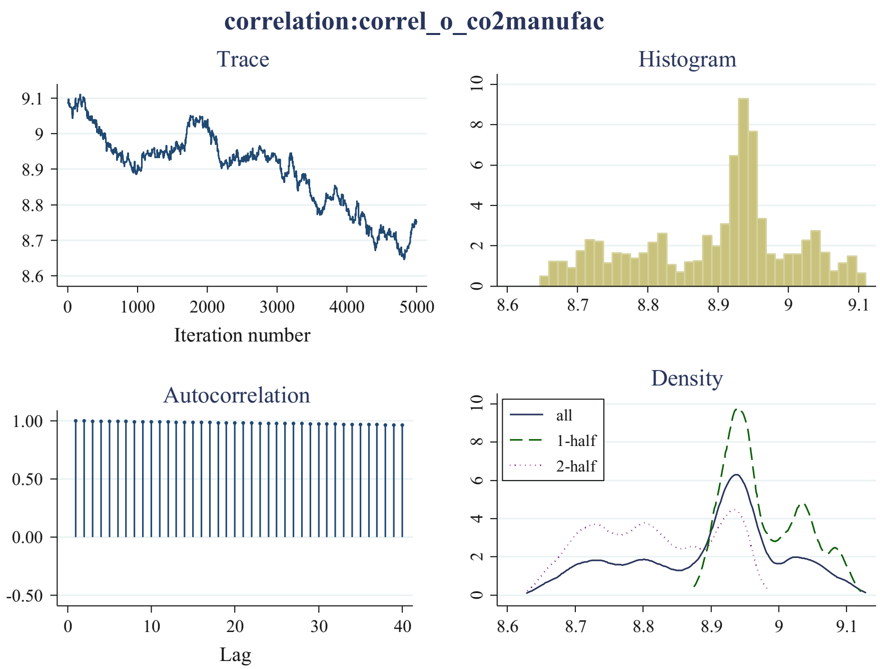

Fig. 4.4 Diagonestic test for business cycle and CO_2 emission from manufacturing sector

kernel density estimate overlaid with densities in the lower part, estimated using the first and the second halves of the MCMC sample. Both the trace plot and the autocorrelation plot demonstrate high autocorrelation. The results related to hypothesis testing are presented in Table 4.7 in appendix. Improvement in the results can be carried out through blocking of parameters.[10] From the mixed effects regressions we use multiple priors, hence the efficiencies are in question. For example, countries in our sample may and will differ in terms of business cycle co-movement, FDI, CO_2 emission from manufacturing industries, and monetary policy etc. The differences are not only in terms of the dyadic nature of the sample, but also in terms of individual sample distributions and time period. Therefore, the preferred way to increase efficiency is to estimate models with blocking of parameters. The results are presented in Table 4.2.

For the MH algorithm, an acceptance rate of 0.29 in observed in Table 4.2 for model 3 revealing that 29% out of 10,000 proposal parameter values were accepted by the algorithm.[11] While the acceptance rate in the present case is within the acceptance region, it has improved the acceptance rate to 0.41, by blocking the parameters in model 4. In this case convergence is arrived for the specified model that goes in line to support the results arrived with the 3SLS model.[12] Finally, in Table 4.2, the mean column reports the estimates of posterior means, which are means of the marginal posterior distributions of the parameters. The posterior mean estimates are pretty close to the mixed effects estimates obtained in Table 4.6 presented in the appendix. This is expected, as MCMCs have converged, because we used a non-informative prior (i.e. not providing any additional information about parameters beyond that contained in the data). Third column of Table 4.2, reports estimates of posterior standard deviations, which are standard deviations of the marginal posterior distribution.

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[10]In the original MH algorithm, the update steps of generating proposals and applying the acceptance-rejection rule are performed for all model parameters simultaneously. For high-dimensional models, this may result in a poor mixing—the Markov chain may stay in the tails of the posterior distribution for long periods of time and traverse the posterior domain very slowly. Suboptimal mixing is manifested by either very high or very low acceptance rates. Adaptive MH algorithms are also prone to this problem, especially when model parameters have very different scales. An effective solution to this problem is called blocking—model parameters are separated into two or more subsets or blocks and MH updates are applied to each block separately in the order that the blocks are specified (StataCorp. 2015).

[11]For the MH algorithm, this number rarely exceeds 50% and is typically below 30%. A low acceptance rate (for example, below 10%) may indicate convergence problems. In general, MH tends to have lower efficiencies compared with other MCMC methods. For example, efficiencies of 10% and higher are considered good. Efficiencies below 1% may be a source of concern (StataCorp. 2015).

[12]A similar exercise is carried out in explaining industrial dissimilarity, where the acceptance rate of the model is lower as compared to the emission case. Hence, this also proves that in the current period industrial similarity should be represented with emissions structures as compared to industrial value added.

Table 4.2 Random-walk metropolis-hastings sampling

	Bayesian normal regression (Model 3)					Bayesian normal regression [block] (Model 4)				
Correlation	Mean	Std. Dev.	MCSE	Lower	Upper	Mean	Std. Dev.	MCSE	Lower	Upper
FDI	0.0041	0.0067	0.0016	−0.008	0.017	0.0018	0.0006	0.0002	0.001	0.003
Trade	−0.1881	0.0833	0.0328	−0.306	−0.039	0.0053	0.0172	0.0027	−0.029	0.038
EMSNM	8.8964	0.1100	0.0426	8.676	9.084	9.0671	0.0149	0.0055	9.040	9.093
Monetary policy	−0.6763	0.0203	0.0041	−0.714	−0.635	−0.6569	0.0018	0.0005	−0.661	−0.654
Constant	0.1387	0.0090	0.0008	0.121	0.156	0.1424	0.0011	0.0004	0.140	0.144
var_0	0.0732	0.0041	0.0009	0.066	0.082	0.0003	0.0000	0.0000	0.000	0.000
var_concatt	0.6305	0.0248	0.0062	0.589	0.681	0.5961	0.0256	0.0008	0.549	0.648
	Efficiency summaries (Model 3)			Efficiency summaries (Model 4)			Summaries			
	ESS	Corr. time	Efficiency	ESS	Corr. time	Efficiency	Model		(3)	(4)
FDI	16.8400	296.8800	0.0034	9.280	538.880	0.002	Burn-in		2500	3000
Trade	6.4400	775.9900	0.0013	40.420	123.710	0.008	MCMC sample size		5000	5000
EMSNM	6.6800	749.0600	0.0013	7.410	674.800	0.002	Number of observation		948	948
Monetary policy	24.7000	202.3900	0.0049	13.280	376.630	0.003	Acceptance rate		0.290	0.413
Constant	141.0700	35.4400	0.0282	8.010	623.920	0.002	Efficiency: min		0.001	0.001
var_0	19.4200	257.4000	0.0039	26.860	186.180	0.005	Efficiency: avg		0.002	0.002
var_concatt	15.9100	314.2400	0.0032	1122.820	4.450	0.225	Efficiency: max		0.073	0.230

Note There is a high autocorrelation after 500 lags

These values describe the variability in the posterior distribution of the parameter and are comparable to mixed effects standard deviations. The precision of the posterior mean estimates is described by their Monte Carlo Standard Errors (MCSE).[13] The last two columns provide credible intervals for the parameters. Unlike confidence intervals, these intervals have a straightforward probabilistic interpretation. For example, in Table 4.2, the probability that the coefficient for business cycle correlation is between −0.008 and 0.017, for FDI is about 0.95. The lower bound of the interval is smaller than 0, so we conclude that there is no effect of FDI on the business cycle correlation. However, after blocking of parameters, in case of model 4, FDI seems to have effect of business cycle correlation as the lower bound of the interval is positive (0.001). The results in Table 4.2, model 4 also explains that CO_2 emission from manufacturing industries have effects on business cycle co-movement along with FDI. Through the Bayesian exercise it can be confirmed that trade and monetary policy do not necessarily have straightforward relationship with business cycle co-movement, but restricted based on the nature of economy, time period and their individual distributions. However, CO_2 emissions from manufacturing industries explain the business cycle co-movement. Hence, unlike existing literature on business cycle co-movement that excludes emission as one of the explanatory indicators, it has major role to play in explaining business cycle co-movement, particularly for better policy perspectives.

Most recently, Azzimonti (2016) explains the politics of FDI expropriation. The finding suggests investment risk is negatively related to FDI and government stability. Hence, FDI partly related to the economic endowments or proximity of countries and also related to the political instability as a potential explanation for the lack of capital flows from rich countries to poor countries that indicate directly to the business cycle co-movement between countries. Equivalently, our results indicate that FDI generates pollutions, or the direction of FDI related to manufacturing happens in economies that have laxity in environmental policies, particularly related to carbon and other taxes. The conclusion of Imbs (2004) coincides with the present findings that trade-induced specialization has virtually no effect on business cycles synchronization. We found trade and FDI to be complementary to each other while emission is negatively related to FDI. This result is an improvement over Ren et al. (2014) that indicated growing trade and larger FDI inflows to aggravate CO_2 emission. Our empirical investigation of relation between trade, FDI and pollution, is akin to Shapiro (2016), which quantified how international trade affects CO_2 emissions and analyzed the welfare consequences of regulating the CO_2 emissions from shipping.

[13]Monte Carlo standard error (MCSE), is the standard error of the posterior mean estimate, measures the simulation accuracy.

4.4 Conclusion and Discussion

In a departure from the previous studies that estimate single equations, we adopt simultaneous equations method, combined with a Bayesian approach and subsequently, a matching technique. In examining the business cycle co-movement with macroeconomic variables, we introduce manufacturing CO_2 emission as one of the major indicators that links FDI, trade and co-movement of business cycle. We find that bringing in bilateral correlation between emissions of countries as a measure for the nature of industrialization; FDI is positively related to co-movements in business cycles when there is trade dependency through an import. It emerges that, countries with similarity in business cycle correlation do engage in more of trade, but not necessarily through the FDI route. This supports the assertion of capital fight through FDI between diverse nations, but needs to be further checked for the sector, in which it is parked. We observe FDI as polluting whereas, business cycle co-movement and trade makes are not so, from an environmental angle. This may be due to the laxity in pollution control measures for the countries attracting higher FDI.

The results indicate that FDI helps in both ways i.e. in terms of *bulk manufacturing* such as the Chinese case, and *knowledge transfer* such as for developing countries or *exporting pollution* in case of the lesser developed and developing economies. In such a scenario, correlation of CO_2 emission from the manufacturing sector serves as a better indicator explaining business cycle co-movement. From the recent experiences on the nature of FDI and trade between countries, we also observe that FDI (both inward and outward) have marginally shifted from manufacturing to services and allied sectors. Hence, the importance of emission from manufacturing sector is another important channel of business cycle co-movement. In the background of recent literature on environment, growth and FDI, this explanatory study connects link between manufacturing emission and business cycle co-movement. The results are encouraging enough to be referred to in context of designing suitable climate negotiation policies in view of manufacturing sector emissions emerging as one of the major indicators of business cycle co-movement, through FDI and trade. Based on the results of this study, we propose design of carbon taxes on a regional scale based on the manufacturing sector that might increase global welfare while also addressing sustainability concerns.

Appendix

See Tables 4.3, 4.4, 4.5, 4.6 and 4.7; Figs. 4.5 and 4.6.

Table 4.3 Variable construction and data sources

Variable	Definition	Source
ρ_{HP}	Business cycle correlation detrended with Hodrick Prescot filter	World Development Indicators, World Bank
FDI	Bilateral foreign direct investment	Bilateral FDI Statistics, UNCTAD (2014)
Trade	Bilateral trade intensity	Bilateral FDI Statistics, UNCTAD (2014)
$Trade_{IMP}$	Bilateral trade import intensity	Bilateral FDI Statistics, UNCTAD (2014)
DS	Absolute dissimilarity in industrial structure	World Development Indicators, World Bank
MP	Monetary policy	International Financial Statistics, International Monetary Fund
LO	Legal origin: dummy that equals unity when both countries share the same legal origins, 0 otherwise	La Porta et al. (1998)
LANG	Language: dummy that equals unity when both countries share a common language, 0 otherwise	Andrew Rose's website at http://faculty.haas.berkeley.edu/arose
DIS	Distance: the log mile distance between the countries' capitals	CEPII gravity database
ADJ	Adjacency: dummy that equals unity when both countries are adjacent to one another, 0 otherwise	CEPPI gravity database
GDP_G	The log of the ratio of each country's real GDP	World Development Indicators, World Bank
GDP_{PROD}	The log of the product of each country's real GDP	World Development Indicators, World Bank
EMSNM	Emission: correlation of CO_2 emission from the manufacturing sector in physical units collected from the world development indicator, between dyadic countries	World Development Indicators, World Bank

Table 4.4 Summary statistics

	ρ_{HP}	FDI	Trade	$TRADE_{IMP}$	EMSNM
ρ_{HP}	1				
FDI	0.014	1			
TRADE	0.128***	−0.029	1		
$TRADE_{IMP}$	0.084***	−0.013	0.223***	1	
EMSNM	−0.025	−0.061**	−0.073***	0.202***	1
Descriptive statistics					
Mean	0.179	0.084	0.015	18.250	17.005
S.D.	0.448	1.657	0.056	53.461	10.088

Note ***$p < 0.01$ and **$p < 0.05$

Table 4.5 Single equation estimates

Variables	Coefficients (S.E)	Coefficients (S.E)		Coefficients (S.E)	Coefficients (S.E)
	1.1	1.2		2.1	2.2
Outcome	ρ_{HP}		*Outcome*	*FDI*	
FDI	0.006 (0.009)	0.006 (0.009)	$TRADE_{IMP}$	0.0005 (0.0007)	–
$TRADE_{IMP}$	0.0007*** (0.0002)	–	TRADE	–	1.037 (1.33)
TRADE	–	0.781** (0.338)	EMSNM	−1.533*** (0.626)	−1.517*** (0.624)
EMSNM	0.473*** (0.171)	0.499*** (0.171)	MP	−0.225* (0.126)	−0.225* (0.126)
MP	0.009 (0.034)	0.004 (0.033)	Legal origin	−0.392 (0.372)	−0.399 (0.371)
			Language	−0.038 (0.203)	−0.056 (0.215)
Outcome	*$TRADE_{IMP}$*	*TRADE*	*Outcome*	*EMSNM*	
	3	4		5.1	5.2
FDI	−0.299 (0.895)	−0.002*** (0.0005)	FDI	−0.004*** (0.001)	−0.004*** (0.001)
EMSNM	29.901 (25.458)	−0.004 (0.008)	$TRADE_{IMP}$	0.0001** (0.00005)	–
Language	63.828*** (12.592)	0.048*** (0.009)	TRADE	–	−0.007 (0.052)
Distance	2.393 (2.611)	−0.007*** (0.001)	GDP_G	−0.042** (0.018)	−0.046** (0.019)
LAND	−36.264*** (3.859)	−0.012*** (0.003)	GDP_{PROD}	−0.00006 (0.00003)	−0.00005 (0.00003)
GDP_G	−102.023*** (18.249)	−0.124*** (0.012)	N	1100	948

Note ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$; standard errors in parentheses

Table 4.6 Mixed effects ML regressions

Variables	Coefficients	(S.E)
FDI	0.005	(0.008)
Trade	1.060***	(0.245)
Monetary policy	0.001	(0.033)
Correlation CO_2 manufacturing	0.433***	(0.190)
Constant	0.159***	(0.015)
Random-effects parameters		
var (_cons)	0.000005	(0.000006)
var (residual)	0.197	(0.008)
Wald Chi^2	20.14***	–
Log likelihood	−668.299	–

Note Estimates are based on iterated EM, group variable and identity: concatt LR test versus linear model $chibar^2$***, number of observations: 1100

Table 4.7 Hypothesis testing

Models	FDI	Trade	Monetary policy	CO_2 Emi man correlation
3	−0.008	−0.306	−0.714	**8.676**
4	**0.001**	−0.029	−0.661	**9.040**

Note Lower bounds are presented in table

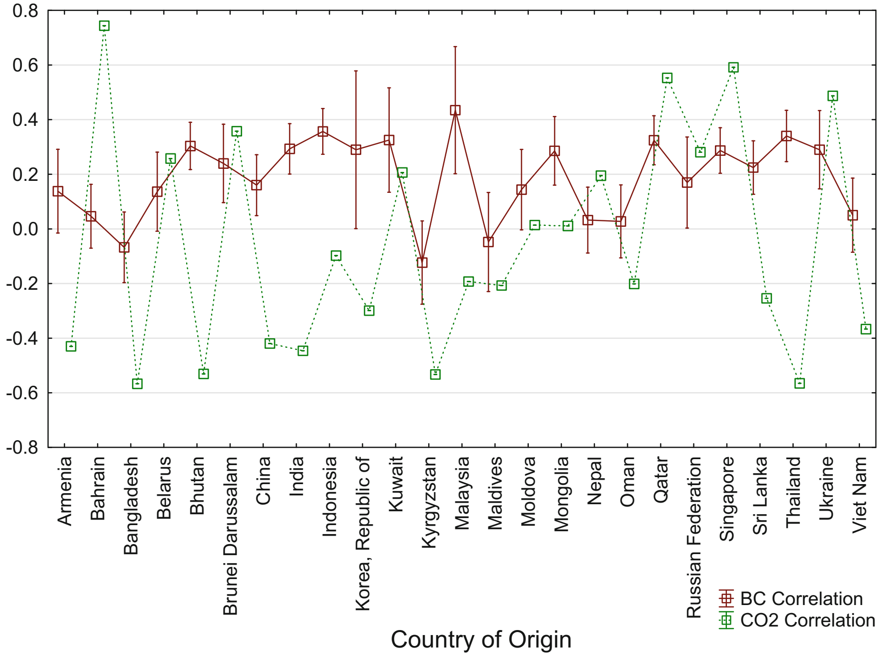

Fig. 4.5 BC co-movement and CO_2 emission: country of origin

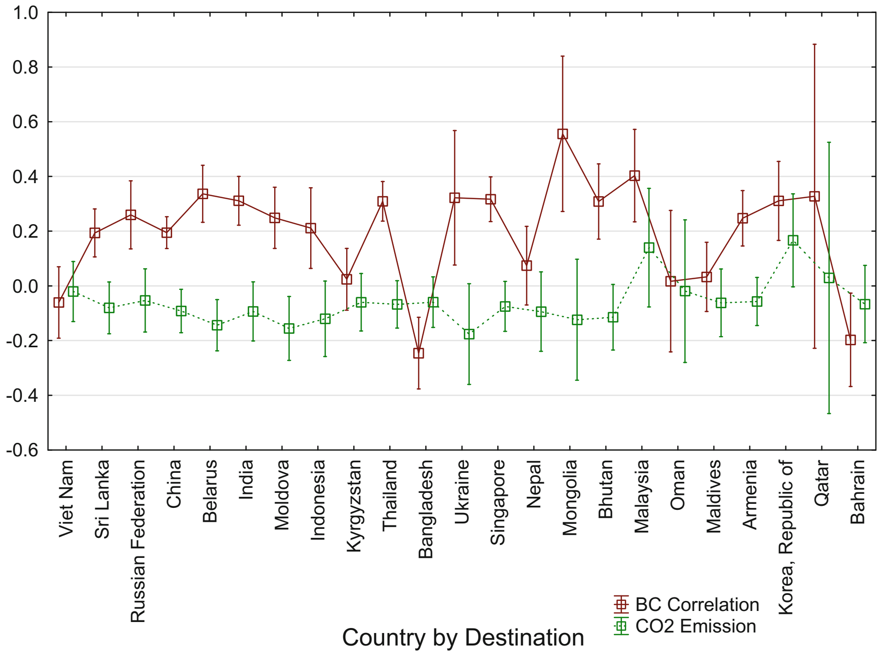

Fig. 4.6 BC co-movement and CO_2 emission: country of destination

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Part II
FDI: Consequences

Chapter 5
Firm Capabilities and Productivity Spillovers from FDI: Evidence from Indian Manufacturing Firms

Sanghita Mondal and Manoj Pant

Abstract Using a panel dataset on Indian manufacturing firms from 1994 to 2010, the present paper examines the productivity spillovers from the foreign direct investment (FDI) through various channels of horizontal and vertical linkages. In addition, the study also focuses on the influence of domestic firms' initial capabilities in absorbing FDI-induced technological benefits. Firm productivity has been measured by using the semi-parametric Levinsohn–Petrin methodology. Using the fixed-effect panel model to estimate spillover models, the initial results show that the productivity growth of Indian firms is adversely affected by various horizontal spillover channels, while the vertical linkages are found insignificant. Interestingly, the second part of the study reveals that only the domestic firms with some initial technological capabilities (proxied by initial three years' R&D activities), low technology gap with the foreign firms in the initial periods and high complementary capabilities (proxied by initial three years' average firm size) gain productivity benefits from FDI spillover channels as compared to other firms within the industry. Essentially, the study brings out the importance of domestic firms' need to encourage internal R&D activities in absorbing technological benefits from foreign presence and their economic activities in the domestic market.

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S. Mondal (✉)
P.G.D.A.V College, Univesity of Delhi, New Delhi 110065, India
e-mail: msanghita@gmail.com

M. Pant
CITD/SIS/JNU, New Delhi 110067, India

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5.1 Introduction

Since the pioneering work of Caves (1974), a substantial amount of empirical literature has focused on identifying the *spillover* effects of foreign direct investment (FDI) on the host-country firms. Studies have tried to identify the channels of spillovers and to quantify it by measuring FDI effects on productivity growth of the host-country firms. The key argument of productivity spillovers[1] is that the proprietary knowledge and technology brought by the foreign firms diffuse to the domestic firms through various channels, altering their production capacity or in other term, productivity. This has encouraged the policy makers of the developing countries to provide enough facilities to attract foreign direct investment within the countries. However, there have been limited evidences of favourable productivity spillover effects from foreign direct investment to the host-country firms.

The studies have highlighted two broad categories of FDI spillover channels, namely horizontal and vertical. The horizontal spillovers occur due to the foreign investments and activities, for example, production, R&D activities or labour training within an industry, while vertical spillovers take place across the industries through buyer–supplier linkages among foreign and domestic firms. The most debated notions of FDI spillovers concern the issue of "channels of spillovers". Several studies have pointed out that vertical spillover channels are more effective as compared to the horizontal ones.[2] The reason being, foreign firms try to protect the diffusion of technology and knowledge to their competitors while they prefer to transfer technology to their suppliers for high-quality inputs. Interestingly, the studies do not yield any clear conclusion about the most effective spillover channels or the actual spillover effects among the domestic firms. There are handful of studies showing positive productivity spillover effects (see, Kokko 1994; Liu 2002), while some other studies have shown negative spillover effects or no spillovers from foreign investments.

These mixed outcomes have raised the importance of structural factors affecting the occurrence of spillovers. Following the work of Melitz (2003) on the role of industry and firm-specific heterogeneity in influencing local and international involvement of the firms, recent studies have tried to explain the difference in dynamic spillover effects of FDI (see Merlevede and Schoors 2006). The factors include not only the host country and industry characteristics like competitive environment or openness of the industry but also firm characteristics such as technological complementary between foreign and domestic firms, financial

[1]In this study, the productivity spillover and technology spillover terms have been used interchangeably. In this context, it is necessary to distinguish between technology or productivity spillovers from technology transfer from foreign to domestic firms. In the case of technology spillover, domestic firms acquire foreign technology without fully compensating the foreign firms or not through the market transactions. When the technology flows from foreign to domestic firms through proper market transactions, we can call it technology transfer.

[2]Kugler (2006), Schoors and Tol (2002) have compared horizontal and vertical productivity spillovers from FDI and they did not find any evidence of horizontal spillovers while vertical spillovers were quite evident.

stability in capturing benefits from foreign activities within and across the industries (Crespo and Fontoura 2007). Most of the studies have shown that the firm capabilities are the crucial determinants of the benefits from FDI. Very recently, Blalock and Simon (2009) have highlighted that it is the initial level of firm capabilities which help the domestic firms to compete with the foreign firms when they start investing in the host country and also facilitate future benefits from foreign advanced technologies and business linkages.

The following study builds on the above research and investigates whether there is any productivity spillovers associated with the horizontal and vertical channels. In this line of research, a few studies were conducted to find out productivity of efficiency spillover effects from FDI on Indian manufacturing firms. Most of the studies, for example, Kathuria (2000, 2002), Sasidharan and Ramanathan (2007) found either adverse or insignificant impacts from FDI on Indian firms within and across industries. However, a few recent studies have shown positive horizontal spillover effects (see, Bhattacharya et al. 2008) from FDI. We have moved beyond these studies and decomposed the broad spillover channels into five channels, competition, imitation and labour turnover (horizontal spillover channels) and, forward and backward linkages (vertical spillover channels) to find out if any particular channel is more beneficial or detrimental for the domestic firms.

In some studies, Kathuria (2000, 2002) pointed out that the spillover effects are favourable for the domestic firms which undertake internal R&D activities. Some other studies have also shown that the motive of the foreign firms (Marin and Sasidharan 2010) and the technological gap between domestic and foreign firms (Behera et al. 2012) also act as the determining factors of productivity spillover effects from FDI. However, these studies did not consider how the initial conditions of the domestic firms influence the spillover effects. A study by Perez (1997) suggested that initial technology adaptation would depend on the initial technology gap between foreign and domestic firms which clearly states the importance of the initial firm capabilities in facing the foreign firms and building capabilities in future to compete with the foreign firms within and across industries. Thus, we extend the study and try to find out if the relationship between foreign investment and domestic firm productivity is affected by the initial firm-level capabilities as pointed out by Blalock and Simon (2009).

The study hypothesises that the domestic firms are benefitted from the linkages as compared to the production or R&D activities within the same industry as domestic firms. More importantly, we hypothesise that the firms with high initial level of capabilities in terms of absorptive capacity (R&D activities), low technology gap and bigger size generally gain higher productivity from foreign interactions as compared to other firms.

Using a long panel (unbalanced) of about 3500 firms for 17 years (1994–2010), our study brings out that Indian firms' productivity growth is adversely affected by foreign presence within an industry. Competition from the foreign firms in the domestic market seems to have the most detrimental impact on a firm's productivity growth. The study also indicates that the low R&D activities of the domestic firms impede imitation spillovers from foreign firms. In fact, the other horizontal channels also show negative impact on domestic firms' productivity growth. On the other hand, both the vertical spillover channels are found to have no impact on the productivity growth of domestic firms. The second part of the study shows that technology spillovers from FDI are highly conditional upon the initial firm capabilities. Domestic firms with high absorptive capability, low technology gap and high average size are able to gain from foreign competition in extracting benefits from foreign activities within the industries and also through linkages across industries.

The rest of the paper is organised as follows. Section 5.2 provides a brief review of the theoretical and empirical literature. The methodology and construction of the variables is illustrated in Sect. 5.3. Section 5.4 is devoted to the analyses of the productivity spillovers from FDI, and the last section concludes the paper.

5.2 Review of Literature

It has been widely acknowledged that transnational corporations (TNCs) are in general more technologically advanced and invest significantly on R&D activities as compared to pure domestic firms (Marin and Bell, 2007). Along with the major share of world R&D stocks, TNCs also possess superior managerial and organisational skills than firms belonging to the developing countries. Thus, developing countries perceive FDI from the TNCs as one of the most attractive sources of technology and skills over any other sources (e.g. licensing) of acquiring technology. Similarly, TNCs with proprietary assets like knowledge, technology, organisational skills together with their ability to exploit economies of scale also find it profitable to invest in those developing countries where they can compete over the incumbent firms in the host-country domestic market (Blomstrom and Sjoholm 1999). However, weak intellectual property rights (IPRs) in the developing countries and intangible nature of the technological knowledge leads to spillovers of technology to the domestic firms. The literature indicates several channels through which spillovers may take place among the host-country firms (for details, see, Görg and Greenaway 2004; Smeets 2008). The channels are broadly categorised into horizontal and vertical spillover channels. Moreover, literature points out that FDI spillovers are not automatic; it depends on several moderating factors such as firm capabilities, motive of the foreign firms, geographical location of the firms.

5.2.1 FDI Spillover Channels

The most significant horizontal spillovers effects arise from imitation or demonstration, labour turnover and competition from foreign firms. In *Demonstration effects*, domestic firms imitate the technology or R&D activities undertaken by the foreign firms within the industry and can upgrade their production technology (Barrios and Strobl 2002; Wang and Blomström 1992). However, the imitation depends on the complexity of technology or R&D activities undertaken by the foreign firms as well as on the technology paradigm. As mentioned by Siddharthan (2016: 32), if domestic and foreign firms belong to different technology paradigms, there can be no spillovers. Human-embodied technology is diffused to the domestic firms through *labour turnover*. Organisational and management skills, information and embodied technology diffuse to the local organisations when workers trained in the foreign entities are hired by the domestic firms or they establish new firms in the local market (Fosfuri et al. 2001). However, it is seen that hiring workers from the foreign firms sometimes increase the average wage of the industry (Poole 2013). Lastly, entry of foreign firms increases competition in the domestic market. *Competition* from the foreign firms improves the productivity and efficiency of the domestic firms by reallocating resources to the appropriate production sector (Caves 1974) and by encouraging domestic firms to improve their production process by upgrading technological capability (Wang and Blomström 1992). Even if the indigenous firms are unable to imitate technology from the foreign enterprises, competitive pressure from the foreign firms forces the domestic firms to use existing technology more efficiently which leads to productivity growth. Reduction in X-inefficiency[3] pushes the production cost down along the cost curve.[4]

However, Aitken and Harrison (1999) have shown that entrance of the foreign firms in the market may reduce the productivity of the domestic firms by reducing their domestic market share, at least in the short run. Similarly, Globerman (1979) has pointed out that foreign firms hire most of the available skilled workers from the domestic market causing a skill gap between foreign and domestic firms. Foreign firms would clearly try to minimise the diffusion of technology to its domestic competitors within industry by means like paying higher wages to their employees (to reduce labour turnover) or by patenting their technology. In similar studies, Konings (2001) for a number of transition countries, Barrios and Strobl (2002) for Spain and Kosova (2010) for Czech Republic either did not find any spillover effects or negative spillover effects on domestic firms' productivity. All these studies have mainly focused on the horizontal spillover effects arising from FDI. Interestingly, a study on 40 developed and developing countries by Xu (2000) has shown that developed countries in general are positively influenced by the FDI within industry. Keller and Yeaple (2003) for the USA, Haskel et al. (2007) for the UK found positive productivity spillovers from FDI.

These considerations led to the doubt of existence of positive horizontal spillover effects from FDI. In contrast, in vertical spillovers, FDI firms are not in direct competition with the domestic firms but have a supplier–buyer linkage so that productivity gains are mutually beneficial. The vertical spillovers occur through the

[3]X-inefficiency is the difference between the potential and observed behaviour of the firm. It occurs when potential productive efficiency is not reached due to lack of competitive pressure within the industry.

[4]Most of the studies showed that direct competition from the foreign firms are the determining factor for horizontal productivity spillover to the domestic firms (Haddad and Harrison 1993; Aitken and Harrison 1999).

backward or forward linkages with the domestic firms. *Backward productivity spillovers* take place when the foreign producers buy inputs from the upstream domestic suppliers. To maintain the international quality and standards, foreign firms generally provide necessary technological assistance to the domestic input suppliers and provide training to the local employees to improve their management and organisational skills (Blalock and Gertler 2005). Moreover, attractive business opportunities with the foreign firms induce greater competition among the upstream local firms leading to technological improvement and exploitation of economies of scale (Marin and Bell 2007). Entry of the new domestic firms in the upstream sector leads to reduction of costs even more. On the other hand, foreign firms supply high-quality intermediate inputs to the domestic final good producers through *forward linkage* that induces higher productivity. However, if the domestic firms have low bargaining power, which is the most common feature of the domestic firms in the developing countries, foreign firms may exploit the domestic firms. Moreover, if the foreign firms demand inputs with low technological content or source from abroad or "cherry-pick" the most productive domestic firm as the supplier, domestic firms may not be benefitted from the foreign technology (Schoors and Tol 2002). In the case of empirical studies on vertical spillovers, Javorcik (2004) for Luthiania, Blalock and Gertler (2008), Jabbour and Mucchielli (2007) for Spain found positive spillover effects for vertically integrated domestic firms through backward linkages. There are evidences of positive spillover through forward linkages as well (Schoors and Tol 2002; Du et al. 2012). However, in a meta analysis, Havranek and Irsova (2011) showed that backward linkages are relatively more likely than forward linkages. These mixed results on productivity spillovers fuelled the concerns about the ability of domestic firms to learn from foreign firms.

5.2.2 Firm Capabilities and Productivity Spillovers from FDI

Cohen and Levinthal (1989) have argued that while outside source of technological knowledge is critical to the internal innovation process, it is also important to have the internal capability to exploit this knowledge.[5] The study showed that prior accumulated knowledge increases the ability to assimilate new knowledge. Prior knowledge, current R&D and innovative activities develop a firm's ability to absorb technology continually. A large number of studies have shown that horizontal and vertical spillover effects are highly conditioned upon the initial and current R&D activities of the domestic firms (e.g. Blalock and Simon 2009; Damijan et al. 2003). In

[5]Most of the studies have considered the current R&D activity as the firm capability which helps in exploiting spillover effects from FDI. Among other factors, competitive environment of the industry or openness of the industry is considered as other factors which might help in gaining spillover benefits from foreign investments. In the present study, we have not discussed those factors in detail as we mainly focus on the initial-level capabilities of the domestic firms.

contrast to the view of higher technological capabilities to absorb foreign technology, Findlay (1978) proposed that the greater the distance between the foreign and domestic technology frontiers the higher would be the possibility of technology spillovers. However, mostly studies found the opposite results (Wang and Blomström 1992). Recently, Blalock and Gertler (2009) have shown that initial technological distance between the foreign and domestic firms in the form of productive capability induces higher spillovers. Among other factors, firm size is generally considered as the complementary capability of the firm as it provides competitive advantage, financial stability, greater distribution and logistics facilities, better network of suppliers, and marketing capabilities (Blalock and Simon 2009). In a study, Barrios and Strobl (2002) have shown that larger domestic firms have a higher probability of survival against foreign competition as compared to other domestic firms.

5.2.3 Indian Manufacturing Firms and Productivity Spillovers

Most of the disaggregated studies on Indian manufacturing firms have shown that FDI could not be a productivity enhancing factor (see Kathuria 2000, 2001, 2002, 2010; Patibandla and Sanyal 2005; Sasidharan and Ramanathan 2007; Marin and Sasidharan 2010). However, Siddharthan and Lal (2004), and, Behera et al. (2012) found contrasting evidences of positive technology vis-a-vis productivity spillover effects of FDI on Indian manufacturing firms.

Kathuria (2000, 2002) showed that foreign presence decreases the efficiency of the domestic firms. However, firms' internal R&D activities were found to have a strong learning effect confirming the complementary effects between foreign spillovers and absorptive capacity. These results follow the earlier result by Basant and Fikkert (1996) where they found that foreign R&D activity does not generate any positive spillover to the domestic firms if the domestic firms are not technologically advanced and undertaking some R&D activity. In another study, Kathuria (2010) could not find any systematic spillover effects of foreign presence on the productivity or productivity growth. He pointed out that foreign firms brought outdated and old technologies during 1995–2005 which did not help the domestic firms. Patibandla and Sanyal (2005) supported Kathuria's results and showed that R&D activity is a productivity enhancing factor for the firms with a low foreign ownership and low sectoral foreign presence. They argue that firms with higher foreign presence carry out their advanced innovation activity in the parent firms. However, contradicting these results, Behera et al. (2012) evidenced positive productivity spillovers from foreign investment within industry. Technology gap between foreign and domestic firms was found to be a regressive factor for productivity growth.

Moving forward, Sasidharan and Ramanathan (2007) separated the spillover channels and showed that Indian manufacturing firms are adversely affected from foreign investment within the industry. Backward and forward linkages also were not effective in gathering spillover benefits during 1994–2002 as foreign firms mostly relied on imported technology rather than sourcing domestically. In an interesting study, Marin and Sasidharan (2010) showed that technology spillovers depend highly on the heterogeneity of FDI subsidiaries rather than the simple pipeline effects. The study found that competence creating subsidiaries have a positive spillover effect on the host economy irrespective of the level of absorptive capability of the local firms. On the other hand, competence exploiting subsidiaries generate negative spillover effect only for the more advanced domestic firms, while passive firms do not show any effect on the host-country firms.

Previous studies on Indian manufacturing firms generally focus on the FDI spillover impacts within the investing industry. Moreover, the studies considered that foreign production activities as the main source of productivity spillovers, while foreign R&D activities and foreign skills also induce spillovers within investing industry. This present study tries to disaggregate these three horizontal spillover channels along with the vertical ones which occur through backward and forward linkages. Along with this, our study extends towards exploring the initial firm capabilities and their moderating effects on FDI spillovers. We hypothesise that the domestic firms with absorptive capacity, low technology gap and bigger size at the initial period of foreign intervention, gain from the foreign investments than other firms.

5.3 Data, Measurement and Empirical Strategy

5.3.1 Foreign Direct Investment in India (1991–2010)

Since liberalisation, India has been experiencing an increasing amount of inflow of actual FDI through various channels. The total FDI inflow has gone up to 34 billion in 2010 from merely 2 billion in 1991–92 (see Fig. 5.1). It is clearly seen that during the early periods of liberalisation, FDI inflows in India were moderate. As evident from Fig. 5.1, the trend break in FDI inflows occurred since 2000s, a phase that is generally attributed as the second phase of economic liberalisation. It has to be noted that during this period and especially post-2004, the policy has allowed the investors to choose automatic route in manufacturing and service sectors. This may be one of the factors explaining this considerable jump in FDI inflows. This upward trend was maintained until 2007–08 thereafter a clear deceleration.[6] Figure 5.2 clearly substantiates that the total FDI inflow has increased significantly since mid-2000s.

From a sectoral perspective (Table 5.1), FDI in India is mainly directed into services sector (with an average share of 41% in the past five years) followed by manufacturing (around 23%). However, the share of FDI in services (including all service activities) has declined over the years from almost 57% in 2006–07 to about 30% in 2010–11, while the shares of manufacturing, and “others” largely

[6]We have to note that it was during this period the global economy went into recession. Therefore, we cannot fully attribute the lack of investment inflows to the domestic economic inadequacies.

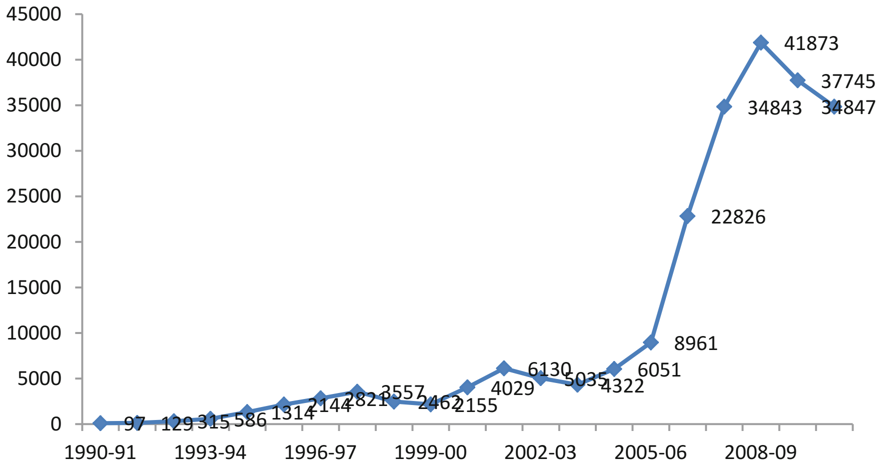

Fig. 5.1 FDI trend since liberalisation: 1990–2010 ($ Million). *Source* Handbook of Statistics on Indian Economy, Reserve Bank of India

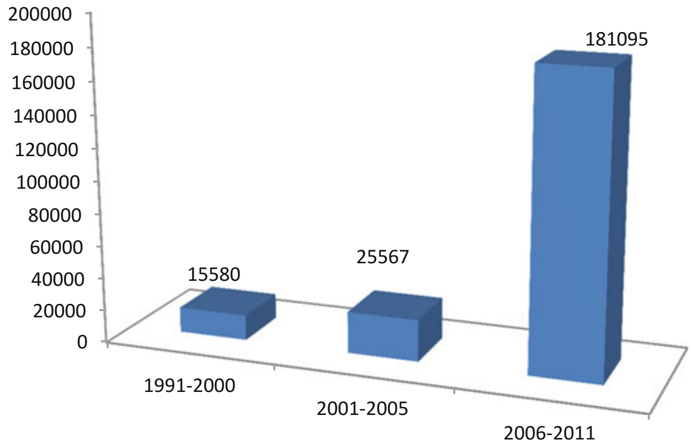

Fig. 5.2 Cumulative FDI inflow in India: 1991–2011($ Million). *Source* Handbook of Statistics on Indian Economy, Reserve Bank of India

comprising “electricity and other power generation” have increased over the same period. For instance, the share of manufacturing sector has gone up from 18% during 2006 to 32% in 2010. This suggests the growing importance of FDI in the organised manufacturing sector in recent period. Among manufacturing, some of the leading sectors that attracted FDI in the recent period are telecommunication, software and hardware, drugs and pharmaceuticals, automobiles and metallurgical industries. On the other hand, the low technology-intensive sectors such as food processing, non-conventional energy and textiles attract relatively less FDI inflows.

Table 5.1 FDI inflow in India: sectoral share (percent) and equity inflows (US$ billions)

Sectors	2006–07	2007–08	2008–09	2009–10	2010–11
Manufactures	17.6 (1.6)	19.2 (3.7)	21 (4.8)	22.9 (5.1)	32.1 (4.8)
Services	56.9 (5.3)	41.2 (8.0)	45.1 (10.2)	32.8 (7.4)	30.1 (4.5)
Construction	15.5 (1.4)	22.4 (4.3)	18.6 (4.2)	26.6 (6.0)	17.6 (2.6)
Others	9.9 (0.9)	17.2 (3.3)	15.2 (3.4)	17.7 (4.0)	20.1 (3.0)
Total	100 (9.3)	100 (19.4)	100 (22.7)	100 (22.5)	100 (14.9)

Note Figure in brackets are the equity inflows in US $ billion
Source Handbook of Statistics on Indian Economy, Reserve Bank of India

5.3.2 Data Description

The study is primarily based on the firm-level data collected from PROWESS for 1994–2010. First, we checked the growth rate of the output for each firm, and if the output growth rate for any year is found to be less than −60% or higher than 250%, we have dropped those observations (Parameswaran 2009). We have followed the same procedure for capital and labour as well. After this, we dropped all those firms with only one-year observation. In the last stage, we checked whether each firm has at least three years of continuous output data at the beginning of each firm sample. We dropped all the firms of the 2-digit industries (NIC16 and NIC31) from the sample where no foreign firms are present over the study period. After this process, we are left with an unbalanced panel sample consists of 5923 firms with 61,666 observations, where 5661 firms are domestic and 262 firms are foreign firms.[7]

From the firm-level data, we find that foreign firms are mostly concentrated in the Indian medium-high-technology (MHT) and medium-low-technology sectors (MLT).[8] In fact, these two sectors have the highest share of output (around 80% of total manufacturing output) and exports as well (almost 70% of total manufacturing exports). Interestingly, concentration of foreign firms is found to be the least in the high technology (HT) sector. It was very shocking to find out that around 32% of total Indian manufacturing firms (after cleaning the data) do not export at all over the whole study period 1994–2010, while only 6.2% of the foreign firms in India are found to be non-exporters during the study period. This might indicate that most of the foreign firms invest within India to use India as export platform for border countries. An interesting observation about the R&D activities and technology imports can be seen from the data set. Generally, it is believed that foreign firms are more R&D intensive while it is seen that only 14% of total R&D stock of Indian manufacturing sector belongs to the foreign firms. On the other hand, around 40%

[7]Following the definition of IMF, we define the foreign firms as the firm with more than or equal to 10% of foreign promoters' share holding.

[8]Electrical, Chemical, manufacturer of transport equipments, Machinery industries, etc., belong to the MLT and MHT sectors. These industries are considered to be the strong industries in India as they use semi-skilled workers and undertake moderate R&D activities.

of total imported technology belongs to them. In fact, it is seen that on average, foreign firms spend more on technology import (around 5% or more) than on R&D activities (less than 1%). This is important because it raises the question whether foreign firms undertake most of their advanced R&D activities in the parent firm and import them while they undertake basic R&D activities within India leading to no impact on the domestic R&D activities. However, on average foreign firms are found to be more technology intensive, export oriented and of bigger size.[9]

Data is also collected on input–output relationship between the industries to measure the backward and forward linkages. It is seen that foreign firms are negligibly connected to the domestic firms across industries. Moreover, forward linkages are even lesser as compared to the backward linkages among the foreign and domestic firms in the manufacturing industries.

5.3.3 *Empirical Strategy and Measurement*

5.3.3.1 Estimation of Production Function

In this study, productivity or total factor productivity (TFP) is measured directly through an econometric estimation of production function. The two important measurement issues related to the estimation of production function are endogeneity of input choices or simultaneity bias and the selection bias (Beveren 2012). Simultaneity bias arises because the input decision of the firms is often determined by the characteristics of the firm or its productivity performance. This means that input choice in the production process is not exogenous but simultaneously arises from the correlation between the input mix and unobserved productivity shocks (De Loecker 2007). The issue of selection bias arises when firm's decision to stay in the market highly depends on its productivity and expected future profitability. Thus, in the presence of endogeneity, OLS does not produce unbiased estimates.

The semi-parametric productivity measure proposed by Levinsohn and Petrin (2003) incorporates the unobservable effects on productivity from inputs and produces reliable input coefficients. To solve the endogeneity problem, L-P methodology uses intermediate inputs (raw material or energy inputs) as the proxy variable which is assumed to have a monotonic relationship with the firm-specific unobserved productivity differences. Using a Cobb–Douglas production function where we assume output is a function of capital (endogenous input), labour and raw material (free input) and power and fuel (proxy variable), we estimate TFP of the firms for the period 1994–2010. The production function can be expressed as:

$$Y_{it} = A_{it} K_{it}^{\beta_k} L_{it}^{\beta_l} M_{it}^{\beta_m} E_{it}^{\beta_e} \quad (5.1)$$

[9]A few indicators are provided in the Appendix Table 5.6.

where Y_{it} represents the output of the firm i at period t. A_{it} is the productivity level of the firm i at period t. $K_{it}, L_{it}, M_{it}, E_{it}$, respectively, represents the state variable capital, free variable labour and raw material, and the proxy variable for intermediate input, energy which is correlated with unobserved productivity. Taking natural log in Eq. (5.1), the production function can be written as:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + \beta_e e_{it} + \omega_{it} + \varepsilon_{it} \quad (5.2)$$

$y_{it}, k_{it}, l_{it}, m_{it}, e_{it}$ denote the log of output, capital stock, labour raw material and energy variable. $(\omega_{it} + \varepsilon_{it})$ represents the error terms of the estimation.

$\ln(A_{it}) = \beta_0 + \omega_{it} + \varepsilon_{it}$, where β_0 measures mean productivity level across the firms at time t. And the error terms together present the time-producer-specific deviation from that mean (Beveren 2012). Specifically, ω_{it} denotes the firm-specific productivity difference not captured by explanatory variables, and ε_{it} stands for the measurement error uncorrelated to the input choices. The major difference between ω_{it} and ε_{it} is that the former is a state variable,[10] which is observable to the firm only, and hence influences firms' input demand choices. In other words, we can say that ω_{it} is the information set on which the optimal input choices of the firm depend, and therefore, there exists a non-negative correlation between input factors and ω_{it} (Parameswaran 2009).

As we have considered that energy (e_{it}) as a proxy to take care of endogeneity bias, by assumption of LP methodology, the demand function of energy variable would be monotonically increasing function in its unobserved productivity, conditional on the state variable k_{it}. Therefore, the demand function of e_{it} can be expressed as: $e_{it} = e_t(\omega_{it}, k_{it})$. By the assumption of monotonicity, we can write this function as $\omega_{it} = \omega_t(e_{it}, k_{it})$ by inverting the energy demand function. Thus, the unobserved productivity term (ω_{it}) becomes the function of two observed inputs, e_{it} and k_{it}. Rewriting the previous equation, we get:

$$y_{it} = \beta_l l_{it} + \beta_m m_{it} + \theta_t(e_{it}, k_{it}) + \delta_{it} \quad (5.3)$$

Where, $\theta_t(e_{it}, k_{it}) = \beta_0 + \beta_k k_{it} + \beta_e e_{it} + \omega_t(e_{it}, k_{it})$ and δ_{it} are not correlated with the inputs. The estimation of production function takes place at two stages.[11]

At the first stage of the estimation, the conditional moments $E(y_{it}|e_{it}, k_{it})$, $E(l_{it}|e_{it}, k_{it})$, $E(m_{it}|e_{it}, k_{it})$ are estimated by regressing the respective variables on e_{it} and k_{it} using third-order polynomial regression with full set of interactions. Subtracting the expectation of Eq. (5.3) conditional on e_{it} and k_{it} from Eq. (5.3), we get the following equation:

[10]State variables are fixed factors which are affected by the distribution of ω_{it}, conditional on the information set available at (t−1) period and past values of ω_{it}. In the case of free variables, the input choices by the firms depend upon the current values of ω_{it} (Ollay and Pakes 1996).

[11]Detailed estimation process is given in Levinsohn and Petrin (2003).

$$y_{it} - E(y_{it}|e_{it}, k_{it}) = \beta_l(l_{it} - E(l_{it}|e_{it}, k_{it})) + \beta_m(m_{it} - E(m_{it}|e_{it}, k_{it})) + \delta_{it} \quad (5.4)$$

Following Levinsohn and Petrin (2003), we use the no intercept OLS on Eq. (5.4) to estimate the parameters $\widehat{\beta}_l$ and $\widehat{\beta}_m$. In the second stage, we use two moment conditions to identify the parameters β_k and β_e. Using the estimated coefficients of the production function, we can calculate the productivity of Indian manufacturing firms as follows

$$\ln \mathrm{TFP}_{ijt} = y_{ijt} - \widehat{\beta}_l l_{ijt} - \widehat{\beta}_k k_{ijt} - \widehat{\beta}_m m_{ijt} - \widehat{\beta}_e e_{ijt} \quad (5.5)$$

5.3.3.2 Estimation of Productivity Spillovers

To investigate the relationship between productivity growth $\left(\text{i.e.}, \mathrm{TFPG}_{ijt} = \Delta \ln \mathrm{TFP}_{ijt}\right)$ and FDI in the same industry or across the industries, the following equation is estimated.

$$\begin{aligned} \mathrm{TFPG}_{ijt} = {} & \beta_0 + \beta_1 \mathrm{Expint}_{ijt-1} + \beta_2 \mathrm{RDint}_{ijt-1} + \beta_3 \mathrm{DTint}_{ijt-1} + \beta_4 \mathrm{ETint}_{ijt-1} \\ & + \beta_5 \mathrm{Size}_{ijt} + \beta_6 \mathrm{HHI}_{jt} + \beta_7 \mathrm{Openness}_{jt-1} + \beta_8 \mathrm{SP}_{jt-1} + T + \epsilon_{ijt} \end{aligned} \quad (5.6)$$

where SP_{it-1} is a vector of horizontal and vertical spillover variables.

$$\mathrm{SP}_{jt-1} = \left(\mathrm{CompSpill}_{jt-1}, \mathrm{IMITATION}_{jt-1}, \mathrm{SKILLSpill}_{jt-1}, \mathrm{Backward}_{jt-1}, \mathrm{Forward}_{jt-1}\right) \quad (5.7)$$

The first three variables represent the horizontal spillover variables, and the last two are the linkage variables. The lag of the spillover variables is considered to capture the lagged impact of spillover variables.

Here, i represents the firm, j represents the 2-digit industry in which foreign presence is measured, t represents time. The firm-level variables included in the model are export intensity (Expint_{ijt-1}) measured as the ratio of export income to total income of the firm. This variable captures the learning effect of exports on the productivity growth of the domestic firms. It is generally said the exporting firms are exposed to the international technology which induces higher productivity. Thus, we expect positive impact of export intensity on the productivity growth of the domestic firms. The technology variables included in the study are R&D intensity (RDint_{ijt-1}), technology import intensity (DTint_{ijt-1}) and capital good import intensity as a proxy for embodied technology import intensity (ETint_{ijt-1}). Most of the studies have shown that firms with in-house R&D activities increase adaptability of the new technology as well as the innovation capability which help in diversifying products. Improvement of the existing production process reduces cost of production and raises productivity (Wei and Liu 2006). Therefore, we hypothesise that R&D intensity would have positive impact on productivity growth of the domestic firms.

Similarly, import of technology in disembodied and embodied forms is expected to have favourable impacts on the productivity growth of the importing firms. However, it is believed that decoding disembodied technology requires a certain level of R&D base and human capital which lacks in Indian manufacturing firms. In fact, previous results also do not show any impact of disembodied technology on the productivity growth of the domestic firms. On the other hand, imported capital goods are easy to use and does not require any specific technology base; thus, it is expected that embodied technology imports in the form of capital goods will give positive impacts on the productivity growth. Size (Size_{ijt}) variable enters the model because it is pointed out that larger the firm, higher would be the possibility that the firm would overcome the production difficulty or failure efficiently by diversifying product choices (Majumdar 1997) inducing higher productivity.[12]

Among the other control variables, we have incorporated two industry-level variables; concentration (HHI_{jt}) which generally shows that higher the concentration, lower is the interaction among the firms reducing the possibility of spillovers or productivity growth, and, openness (Openness_{jt-1}) of the industry in terms of actual consumption of the imported goods. The argument is that firms within the industries which efficiently uses imported goods gain higher productivity.

Five different proxies are used to measure foreign presence in the horizontal and vertical sectors following Franco and Sasidharan (2010), Blalock and Gertler (2008). The horizontal spillover channels as mentioned in the theory vary according to their economic activities, for example, competition from the foreign firms come through the market sharing between foreign and domestic firms. Thus, competition spillovers are measured by the foreign firms' domestic production in the total industry output for domestic market. Similarly, domestic firms' imitation highly depends on the foreign firms' R&D activities. Therefore, imitation spillovers are proxied by foreign firms' R&D expenditure to total industry expenditure on R&D activities. Furthermore, if foreign skills diffuse to domestic workers through labour turnover domestic firms, gain skills which in turn improve productive capability of the domestic firms. As turnover of the workers are unavailable in Indian manufacturing firms, we proxy diffusion of skills by foreign firms' wage bill to total industry wage bill. We hypothesise that foreign firms' activities encourage domestic firms to improve quality of production and in turn productivity.

The measures of horizontal variables can be represented as:

$$\text{Horizontal}_{jt} = \frac{\sum \text{Factivity}_{ijt}}{\sum \text{Industry Activity}_{jt}} \times 100 \tag{5.8}$$

Horizontal_{jt} is the horizontal spillover variables where $\sum \text{Factivity}_{ijt}$ is the total foreign activities within an industry at a time period. Foreign activity can be total

[12]Measurements and the descriptive statistics of the variables are provided in the Appendix Tables 5.7 and 5.8 respectively.

output of the foreign firms in an industry, total R&D activity of the foreign firms in an industry or total wage bill of the foreign firms in an industry. $\sum \text{Industry Activity}_{jt}$ is the respective industry activity at a particular time period. To explain, total foreign output for the domestic market to industry output for the domestic market will measure the competition spillovers (CompSpill) from foreign firms. Similarly, we can elaborate the imitation spillovers and skill spillovers.

We use two variables to measure the linkages across the industries. *Backward* is a proxy for the foreign interactions with the upstream domestic suppliers. Supply of the advanced technology by the foreign firms of the domestic suppliers to maintain the production quality is generally believed to induce higher productivity among the upstream local firms. The *Backward* variable is measured as

$$\text{Backward}_{jt} = \sum_k \alpha_{jkt}\text{FDI}_{kt} \quad \text{where } j \neq k \tag{5.9}$$

where α_{jkt} is the proportion of the industry j's output[13] used by the industry k at time t.

Forward spillovers occur from the upstream foreign firms to the downstream domestic firms. In this case, spillover occurs when the foreign firms supply advanced intermediate inputs or final products to the domestic buyers. The variable is measured as:

$$\text{Forward}_{jt} = \sum_k \beta_{kjt}\text{FDI}_{kt} \quad \text{where } j \neq k \tag{5.10}$$

β_{kjt} represents the proportion of the industry k's output going to the industry j at time t. In both the cases, FDI_{kt} represents the share of the foreign output in the total output in industry k (which is within industry foreign presence).

5.3.3.3 Firm Capabilities and Productivity Spillovers

Now we have extended our study to investigate the significance of initial firm capabilities in moderating spillover effects. The model consists interaction terms of firm capability variables and spillover variables along with the similar firm- and sector-specific variables as before. The model is represented as:

$$\begin{aligned}\text{TFPG}_{ijt} = {} & \beta_0 + \beta_1\text{Expint}_{ijt-1} + \beta_2\text{RDint}_{ijt-1} + \beta_3\text{DTint}_{ijt-1} + \beta_4\text{ETint}_{ijt-1} \\ & + \beta_5\text{Size}_{ijt} + \beta_6\text{HHI}_{jt} + \beta_7\text{Openness}_{jt-1} + \beta_8\text{SP}_{jt-1} + \beta_9\text{FC}_{ij} \times \text{SP}_{jt-1} + T + \epsilon_{ijt}\end{aligned} \tag{5.11}$$

[13]To measure vertical spillover variables, the FDI variable or the foreign presence within industry is measured by the foreign output share in total industry output (not domestic sales as discussed before). Output considers total domestic sales and export of the firms.

Among the explanatory variables, we focus on the two variables; spillover variables $\left(\mathrm{SP}_{jt-1}\right)$ and interaction terms between firm capabilities and spillover variables $\left(\mathrm{FC}_{ij} \times \mathrm{SP}_{jt-1}\right)$. FC_{ij} represents the firm capability variables.

We have used three firm capability (FC) variables; absorptive capability (RD), production capability (TECH) and complementary capability (SIZE). The interaction terms between each of the spillover variables and firm capabilities are presented by $\left(\mathrm{FC}_{ij} \times \mathrm{SP}_{jt-1}\right)$, for instance, interaction between absorptive capability and competition spillover (RDComp), interaction between production capability and competition spillover (TECHComp) and interaction between complementary capability and competition spillover (SIZEComp). Likewise, interactions of the imitation spillover variable with firm capabilities are represented as RDIMITATION, TECHIMITATION and SIZEIMITATION. Interaction variables of firm capabilities and skill spillovers are RDSKILL, TECHSKILL and SIZESKILL. These interaction terms indicate the influence of firm capabilities in accruing benefits from foreign activities within industry. Similarly, we use interaction terms between the firm capabilities and backward spillover, specifically, RDBACK, TECHBACK and SIZEBACK in the model to capture the benefits of backward linkages comes through firm capabilities. RDFOR, TECHFOR and SIZEFOR represent the interaction terms between firm capabilities and forward linkage variables.[14]

Measures of the firm capability variables are discussed below:

Production Capability (Relative Technology Gap): Following Blalock and Gertler (2009), we measure production capability as the distance of the domestic firms' initial technical competency levels to that of the foreign firms. To measure it, the whole sample is divided into two parts, pre-sample period which is the first three years of each sample firms and another including rest of the observation. Initial baseline productivity of the domestic firm is measured by the average productivity of the initial three years of each domestic firm. The distance of average TFP of the domestic firms from the median foreign productivity of the 2-digit industry over these initial 3 years was taken as the gap between foreign and domestic firms in the initial period. Then, we divide the gap by the average productivity of the foreign firms for initial 3 years to get production capability or relative technology gap between domestic and foreign firms.[15]

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[14]There is high correlation among the spillover variables. Therefore, we use separate models representing the firm capabilities and their interactions with spillover variables.

[15]For the analysis, we drop first three years for each firm as this is considered as the production capability of the firms in the pre-sample period. Due to the endogeneity of the production capability measure, the whole sample years were divided into pre-sample period and current period. The endogeneity problem arises because the production capability and the current productivity are jointly determined (Blalock and Simon 2009). As was argued by Blalock and Simon (2009), to avoid the prior production capabilities acquired from FDI. It is possible that low-productive firms gain immediately and heavily at the initial period of foreign entrance. High productivity of the later years would outweigh the initial low productivity and laggard firms would emerge as highly productive firms which are not true. Therefore, the measurement of the production capability does not consider the entire period. By separating the panel, prior technology competency of pre-sample period is calculated.

Absorptive Capability: The absorptive capacity of the domestic firms is measured using the initial R&D intensity. We take average R&D intensity[16] of the domestic firms of the initial three years to capture absorptive capacity of the domestic firms on the premise that increasing R&D expenditure in every year due to change in production capacity is not easy or costless (Blalock and Simon 2009). The initial R&D capability of the firms is used for rest of the study years.

Complementary Capability: Complementary capability is measured by the size of the firms. Due to unavailability of the employment data at the firm level, we use the ratio of output of the each domestic firm to the median output of the 2-digit industry in pre-sample period as the measure of initial size of the firms. Similar to the other firm capabilities, we use this initial size of the firms for rest of the years. We expect that higher the initial size, higher would be the productivity spillover from foreign activities in the domestic market.

A small descriptive statistics of the firm capability variables is presented in Table 5.2. It shows foreign firms had higher capability compared to domestic firms. From the first row of Table 5.2, we see that on average, domestic firms were 45% less productive than the average foreign firms in the initial periods.[17] Although, R&D intensity of the domestic and foreign firms did not differ much at the beginning, still we find that foreign firms had higher average R&D intensity than domestic firms. Very low standard deviation of R&D intensity points to the fact that most of the foreign firms were undertaking R&D activity, while heterogeneity is quite visible among domestic firms. Similarly, foreign firms were bigger in size relative to the domestic firms.

For both the equations, we use fixed-effects panel data model for the estimation. Firm fixed effects would control for the unobserved time-invariant firm characteristics. Firm capability measures are also time invariant, and thus the main effects are dropped from the fixed-effects specification (Blalock and Gertler 2009). The effects of firm capabilities enter in the model only through the interaction between spillover and firm capabilities. Moreover, we have included time dummy for years (*T*) to control time-variant effects on productivity growth of domestic firms.

[16]Average R&D intensity is measured as the ratio of average R&D expenditure of the domestic firms in the initial three years to average sales of the domestic firm.

[17]As median productivity of the foreign firms is considered as the "frontier" benchmark for the measurement of technology gap, the gap for foreign firms does not make any sense and thus we did not report it in the table.

5.4 Estimation Results

5.4.1 *FDI Spillover Effects on Productivity Growth of Domestic Firms (1994–2010)*

Spillover Variables

Table 5.3 presents the factors influencing FDI-induced productivity growth of the domestic firms estimating Eq. (5.6). The negative coefficients of most of the spillover variables suggest that Indian firms are in general adversely affected from foreign presence and their activities. The negative effects become significantly high when the foreign firms operate within same sector as of the domestic firms. The significantly negative coefficient of the *CompSpill* variable indicates that Indian firms are not able to deal with foreign competition. Indian industries are mainly dominated by low technology-intensive small- and medium-sized firms and therefore, mostly lack ability to absorb foreign competition. In this situation, foreign competition reduces the market share of the domestic firms increasing average cost of production offsetting the positive spillover benefits (if any) from technology diffusion or resource reallocation, resulting productivity loss of the domestic firms (Konings 2001).

Similarly, the other horizontal spillover variables, IMITATION and SKILLSpill, are also found to be significantly productivity-deteriorating factors among Indian manufacturing firms. These results can be attributed to three factors; *first*, foreign firms undertake very less R&D activities within the country rather it seems that they prefer to import technology which are developed in the parent firm. According to Feinberg and Majumdar (2001), the possibility of R&D spillovers highly depends on the prevailing policy environment of the domestic market. Indian policy does not compel foreign firms to commence R&D activities in the domestic market. Thus, the possibility of imitation spillovers decreases among the domestic firms. *Second*, foreign firms generally employ skilled workers from the domestic market and pay higher wages to reduce the movement of their employees. This on one hand increases the gap between the foreign and domestic human capital, and on the other hand, high wage paid by the foreign firms increases the average wage of the industry. These two together pushes the cost of production up reducing the possibility of productivity growth. *Third*, lack of domestic R&D activities and lack of human capital to absorb foreign technology reduce the possibility of the imitation and skill spillovers (Cantwell and Piscitello 2002).

Now we move to the spillover effects from vertical linkages between foreign and domestic firms. The coefficient of the backward spillover variable (Backward) is found to be positive but insignificant. Lack of statistical significance may indicate that foreign firm may source less technology-intensive intermediate inputs from the local firms or probably rely on the imported inputs or on other foreign subsidiaries

Table 5.2 Mean and standard deviation of firm capability variables for foreign and domestic firms

Firm capability variables	Domestic		Foreign	
	Mean	SD	Mean	SD
Production capability	0.455	9.365		
Absorptive capability	0.002	1.401	0.004	0.058
Complementary capability	2.489	0.059	4.912	1.427

Source Author's calculation based on firm-level data collected from PROWESS, CMIE

in the upstream market for technologically advanced inputs.[18] Similar to the *backward* variable, we do not find any statistically significant impact of *forward* linkage on productivity growth of the domestic firms.

Sectoral Variables

The general anticipation about the effects of openness (*Openness*) on productivity growth of domestic firms does not hold among Indian manufacturing firms. The insignificant negative coefficient of the *openness* variable shows that import penetration does not influence productivity growth of the domestic firms. Similarly, the other sector-specific variable, concentration (HHI), shows no effects on the productivity growth in the estimated models.

Firm-Specific variables

We find the expected results of the technology variables (RDint, ETint and DTint) on productivity growth. All these variables are positive and significant confirming the importance of firm's technological capability in enhancing productivity of the domestic firms. It can be seen that the imported disembodied technology has the lower impact on the productivity growth of the Indian firms as compared to the imported embodied technology which is very expected as capital goods are ready to use and easy to use than the codified technologies. Our analysis contradicts Kathuria (2000, 2002) as we find that exposure to the foreign market (expint) enhances productivity of the domestic firms. *Size* of the firms shows positive impact on the productivity growth of the Indian manufacturing firms. The usual notion that firms with higher size are able to handle competition and hedge risk of production clearly holds in the case of Indian manufacturing firms. In all specifications of regression, R&D activity (RDint), import of technology (DTint, ETint), export activity (expint) and size of the firms are found to be important factors for productivity.

[18]However, our finding contradicts the study by Lall (1978) which found significant positive impact of FDI backward linkage on the productivity of the Truck industry in India.

Table 5.3 Productivity spillover from FDI through horizontal and vertical channels during 1994–2010 (domestic firms): dependent variable (TFPG)

Variables		Model 1	Model 2	Model 3	Model 4	Model 5
Constant(β_0)		0.5936 (0.0446)***	0.6728 (0.0412)***	0.6478 (0.0429)***	0.6620 (0.0416)***	0.6709 (0.0418)***
expint$_{-1}$(β_1)		0.0143 (0.0017)***	0.0144 (0.0017)***	0.0144 (0.0017)***	0.0144 (0.0017)***	0.0145 (0.0017)***
RDint$_{-1}$(β_2)		0.0114 (0.0015)***	0.0113 (0.0015)***	0.0114 (0.0015)***	0.0113 (0.0015)***	0.0113 (0.0015)***
DTint$_{-1}$(β_3)		0.0043 (0.0014)**	0.0043 (0.0014)**	0.0044 (0.0014)**	0.0043 (0.0014)**	0.0043 (0.0014)**
ETint$_{-1}$(β_4)		0.0138 (0.0012)***	0.0137 (0.0012)***	0.0138 (0.0012)***	0.0138 (0.0012)***	0.0138 (0.0012)***
Size(β_5)		0.0001 (0.00006)*	0.0001 (0.00006)*	0.0001 (0.00006)*	0.0001 (0.00006)*	0.0001 (0.00006)*
HHI(β_6)		−0.3451 (0.2380)	−0.3310 (0.2350)	−0.3920 (0.2353)	−0.3242 (0.2349)	−0.3269 (0.2349)
Openness$_{-1}$(β_7)		−0.0120 (0.0087)	−0.0122 (0.0109)	−0.0151 (0.0096)	−0.0165 (0.0105)	−0.0164 (0.0105)
CompSpill$_{-1}$(β_8)		−0.7321 (0.1314)***				
		IMITATION$_{-1}$(β_8)			−0.3253 (0.1316)**	
SKILLSPill$_{-1}$(β_8)				−0.2209 (0.1104)**		
Backward$_{-1}$(β_8)					0.2377 (0.1545)	
Forward$_{-1}$(β_8)						−0.3872 (0.2587)
R-Squared	Within	0.3278	0.3279	0.3194	0.3226	0.3126
	Between	0.2164	0.2166	0.2145	0.2177	0.2157
	Overall	0.2338	0.2331	0.2278	0.2286	0.2266
F-statistics		160.85***	162.73***	159.56***	161.69***	156.69***
No. of observation		49434	49,434	49,434	49,434	49,434
No. of firm		5661	5661	5661	5661	5661

*, **, *** represents 10%, 5% and 1% level of significance. The values in the parentheses are robust standard errors

5.4.2 Firm Capabilities and Productivity Spillovers from FDI: Manufacturing Sector (1994–2010)

Horizontal Spillovers

In Table 5.4, we report the results based on the interactions between firm capabilities and spillover variables in all manufacturing firms.[19] Models 1–9 of Table 5.4 show the effects of initial domestic firm capabilities on the firm's propensity to grow from horizontal spillovers. Models 1–3 of Table 5.4 focuses on the competition spillover effects and the interaction between capabilities and competition spillover variable. Similarly, Models 4–6 represent the imitation spillover, and Models 7–9 present the skill spillover effects. For simplicity, we discuss various firm capability variables separately.

Absorptive Capability (RD): As expected, the interaction terms, RDComp (Model 1), RDIMITATION (Model 4) and RDSKILL (Model 7) show significant positive coefficients. Thus, we say that initial internal R&D activity of the domestic firms is an important component in penetrating advantages from foreign competition, foreign technological activities and foreign skills within the industry. Initial R&D firms are more innovative and could diversify products rapidly as compared to non-R&D firms in the face of the competition from foreign firms. In fact, the result shows that by quickly realising the relevance of the technologies, initial R&D domestic firms were more capable of absorbing technological advancement of the foreign firms and utilise existing resources more efficiently without incurring much extra cost and therefore, inducing higher productivity growth. Besides, the domestic firms can internalise foreign skills if they undertake higher R&D activities because in this case, workers in the domestic firms are already exposed to technological knowledge. Therefore, we find a complementary relationship between foreign competition, foreign R&D activity and foreign skills with initial internal R&D activities of the Indian firms.

Production Capability (TECH): In contrast to the technology gap hypothesis, we find that that higher initial technology gap would hinder the productivity growth through horizontal spillover channels. The estimates of the coefficients of TECHComp (Model 2), TECHIMITATION (Model 5) and TECHSKILL (Model 8) variables are negative and significant for TECHIMITATION and TECHSKILL. The TECHComp variable is insignificant and negative. Firms with large initial technology gap cannot compete in the market due to lack of technological and production capability. Similarly, firms with higher initial technical proficiency could easily imitate and employ advanced technology (TECHIMITATION) brought by the foreign firms and reduce the negative effects of foreign R&D activity

[19]For the convenience, we have reported only the spillover variables and the interaction terms in the text.

Table 5.4 Firm capability and intra-industry productivity spillovers from FDI on Indian manufacturing firms (1994–2010)

Variables		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
$Comp_{-1}$ (β_8)		−0.1878 (0.1093)	−0.1984 (0.1093)*	−0.1627 (0.1090)						
$IMITATION_{-1}$ (β_8)					−0.1067 (0.0561)*	−0.0518 (0.0338)	−0.1072 (0.1090)			
$SKILL_{-1}$ (β_8)								−0.1350 (0.1236)	−0.1827 (0.1231)	−0.1734 (0.1090)
$RDComp_{-1}$ (β_9)		0.0751 (0.0102)***								
$TECHComp_{-1}$ (β_9)			−0.0672 (0.0586)							
$SIZEComp_{-1}$ (β_9)				0.0291 (0.0016)***						
$RDIMITATION_{-1}$ (β_9)					0.0552 (0.0060)***					
$TECHIMITATION_{-1}$ (β_9)						−0.0527 (0.0286)*				
$SIZEIMITATION_{-1}$ (β_9)							0.0091 (0.0056)			
$RDSKILL_{-1}$ (β_9)								0.0679 (0.0091)***		
$TECHSKILL_{-1}$ (β_9)									−0.0002 (0.0001)**	
$SIZESKILL_{-1}$ (β_9)										0.0036 (0.0026)
R^2	Within	0.1421	0.1422	0.1423	0.1415	0.1423	0.1422	0.1422	0.1423	0.1424
	Between	0.0721	0.0719	0.0719	0.0722	0.072	0.0723	0.0728	0.072	0.0716
	Overall	0.1051	0.1048	0.1034	0.1052	0.1047	0.1046	0.1055	0.1035	0.1046
F-statistics		68.13***	64.96***	64.98***	68.21***	64.93***	67.73***	67.85***	64.62***	65.66***
No. of observation		42,607	42,607	42,607	42,607	42,607	42,607	42,607	42,607	42,607
No. of firm		5620	5620	5620	5620	5620	5620	5620	5620	5620

Note ***, **, * signify 1%, 5% and 10% level of significance, respectively. Values in the parenthesis are the heteroscedasticity corrected standard errors on domestic TFP growth.[20] The significant negative coefficient of the TECHSKILL variable indicates that domestic firms benefit from skill spillovers with a small technology gap from foreign firms.

Complementary Capability (Size): Similar to the other firm capabilities, domestic firm with initial larger size enjoys productivity gains from the foreign competition in the industry (SIZEComp). Our result shows that if foreign presence in the industry increases from 0 to nearly 1 (almost 100% foreign presence in the market), then an initial larger firm accrues almost 2.9% point higher productivity growth relative to other firms, due to increase in foreign competition. However, the other two interaction terms with horizontal spillover channels (SIZEIMITATION and SIZESKILL) are insignificant with positive signs.

Vertical Spillovers

Table 5.5 summarises the estimation results of Eq. (5.11) focusing on the vertical spillover channels (backward and forward). The Models 1–3 present the results of backward spillover channel and the interactions between backward linkage and firm capabilities. The Models 4–6 present the results of forward spillover variables.

Absorptive Capability (RD): Model 1 and Model 4 of the table show the effects of initial R&D activity of the domestic firms on the propensity of domestic firm's productivity growth from backward and forward linkages between foreign and domestic organisations. As expected, domestic firms with high R&D intensity would achieve higher productivity gains from both backward (RDBACK) and forward (RDFOR) linkages. Coefficients of both the interaction terms are positive and highly significant. Domestic firms with initial R&D activity are able to exploit technology, supplied by the downstream foreign firms more efficiently compared to other domestic firms in the upstream sector. Moreover, foreign firms prefer to build linkages with domestic firms which have R&D activity as they want to maintain the international standard of intermediate products. Direct supply of technology to the upstream domestic firms reduces the cost of technology acquisition, resulting higher productivity growth. We find that if the R&D domestic firms in the upstream sector increase R&D activity by 10%, the productivity benefit from backward linkage is almost 1.4% points relative to other firms that do not. Similarly, initial domestic

[20]The coefficient of the IMITATION variable in Model 5 is insignificant although carries a negative sign. The estimates of Model 2 showed that without the interaction terms, Comp, IMITATION and SKILL variables had significant negative impact on the productivity growth of the domestic firms. Due to the inclusion of the interaction terms in the models, these variables become insignificant. This reflects that the negative impacts of the foreign activities within sector would reduce if the domestic firms possess particular firm specific capabilities. Or, in other words, firms with higher R&D activity, low technology gap and larger size are capable of extracting benefits from intra-industry foreign activities.

R&D firms in the downstream sector can appropriately utilise technologically advanced intermediate inputs supplied by the foreign firms in the production process and thus appropriate higher productivity growth as compared to other domestic firms.

Production Capability (TECH): The coefficient of the interaction term TECHBACK (Model 2) is negative and highly significant implying that high initial technology gap hurts the upstream domestic firms. We know that technologically backward domestic firms need to invest on skill development and R&D activity if they want to absorb foreign technology. Interestingly, the other interaction variable (TECHFOR) shows a positive sign (Model 5) with marginal significance which implies that domestic firms with large initial technology gap benefits from upstream foreign linkage. The reason may be that foreign firms mainly use downstream local firms for their assembly works rather than production work. Thus, foreign firms supplied their products to the low technology- and low skill-intensive domestic firms which benefited from foreign contract and financial support rather than technological advancement.

Complementary Capability (SIZE): Similar to the previous results, we find that the larger firms, with higher complementary capabilities, benefit more from foreign vertical linkages. If we compare the coefficients of both interaction terms (SIZEBACK and SIZEFOR), it is evident that larger domestic firms can reap higher benefits from backward spillover (SIZEBACK) compared to the forward linkage (SIZEFOR). Chung et al. (2003) show that larger domestic firms in the upstream sector attract higher association from the foreign firms. Therefore, inflow of technology and knowledge from the foreign to local supplying firms would naturally lead to higher productivity benefits.[21]

Other firm and sectoral variables do not change their signs or significance much with the introduction of the interactive variables in the regression models. Therefore, we do not discuss those variables separately in this section again.

[21]Comparing the coefficients of the interaction terms between horizontal and vertical spillover channels with initial absorptive capacity and technology gap variables, we can say that firms with initial absorptive capacity and technological capabilities gain higher productivity from vertical spillover channels as compared to the intra-industry spillover channels. Upstream and downstream domestic firms obtain advanced technology, financial support, labour training, etc., directly from the foreign firms related through the vertical linkages. R&D activity, larger size and low technology gap of the domestic firms are added advantages for the domestic firms in upstream and downstream sectors for gaining more productivity compared to other firms. On the other hand, industries where foreign and domestic firms act as competitors, foreign firms attempt to reduce the leakage of knowledge to the domestic firms in different ways. Thus, to gain benefits from foreign activities within industry, domestic firms need to be highly technologically proficient. Moreover, the cost of learning is also high in the case of horizontal spillovers. Therefore, it is apparent that any firm capability would be highly beneficial for the firms in upstream and downstream sectors compared to competing sector.

Table 5.5 Firm capability and inter-industry productivity spillovers from FDI on Indian manufacturing firms (1994–2010)

Variables		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
$\text{Backward}_{-1}(\beta_8)$		−0.1958 (0.1695)	−0.2243 (0.1648)	−0.2653 (0.1672)			
$\text{Forward}_{-1}(\beta_8)$					0.4927 (0.2950)*	0.2763 (0.2228)	0.2658 (0.2717)
$\text{RDBACK}_{-1}(\beta_9)$		0.1429 (0.0220)***					
$\text{TECHBACK}_{-1}(\beta_9)$			−0.1596 (0.0316)***				
$\text{SIZEBACK}_{-1}(\beta_9)$				0.0822 (0.0452)*			
$\text{RDFOR}_{-1}(\beta_9)$					0.1494 (0.0432)***		
$\text{TECHFOR}_{-1}(\beta_9)$						0.2218 (0.1198)*	
$\text{SIZEFOR}_{-1}(\beta_9)$							0.0204 (0.0100)**
R^2	Within	0.1417	0.1422	0.1422	0.1416	0.1421	0.1422
	Between	0.0722	0.0720	0.0721	0.0724	0.0719	0.0722
	Overall	0.1052	0.1049	0.1049	0.1055	0.1031	0.1035
F-statistics		67.93***	64.59***	64.70***	67.64***	64.69***	64.68***
No. of observation		42,607	42,607	42,607	42,607	42,607	42,607
No. of firm		5620	5620	5620	5620	5620	5620

Note ***, **, * signify 1%, 5% and 10% level of significance, respectively. Values in the parenthesis are the heteroscedasticity corrected standard errors

5.5 Summary and Conclusion

In the present paper, we examined the impact of FDI spillovers on the productivity growth of Indian manufacturing firms during 1994–2010. In contrast to the earlier studies, we have focused on different channels and aspects of the FDI spillover effects. We extended our study by separating spillover channels according to FDI activities pointed out in the literature, competition spillovers (foreign firms' domestic production), imitation spillovers (foreign firms' R&D activities) and skill spillovers (through labour turnover). Moreover, we identified three firm capabilities, namely absorptive capability (initial R&D capability), production capability (relative productivity gap between domestic firms and average foreign firm in the initial periods) and complementary capability (initial size of the domestic firms) to find out their moderating effects on productivity growth from the above-mentioned spillover channels. Existing literature on productivity spillovers from FDI show that most of the developing countries are adversely affected from foreign activities within the industry. The market-stealing effect from foreign firms outweighs the benefits generated from technology advancement through imitation or resource reallocation. However, host-country firms are generally benefitted from backward linkages. Along with this, handful of empirical studies also show that host-country firms which are equipped with R&D capabilities and have human capital gain from foreign investments within and across industries. Thus, our main hypotheses were, *first*, to find out the spillover channels that generate positive or negative spillovers, and, *second*, how the initial firm-level capabilities moderate spillover effects within and across industries.

Before moving into the detailed econometric analysis, we performed a little firm-level comparison between foreign and domestic firms as it is generally believed that foreign firms are technologically advanced and have higher productivity as compared to the domestic firms. This notion came true for Indian manufacturing sector as we find out that foreign firms' average expenditure on technologies (in the present study, R&D activity, import of embodied and disembodied technology) is more than their domestic counterpart. Interestingly, most of the foreign activities are concentrated in the MLT and MHT sectors which use semi-skilled workers and also undertake moderate R&D activities. However, the disappointing fact is that the R&D stock of foreign firms in Indian manufacturing sector is very low and foreign firms spend more amount on the import of technology than in-house R&D activities. This indicates that foreign firms generally perform their technological activities in the parent firm and import it back to the investing country. During the study period, 1994–2010, inflow of FDI was quite moderate till 2002. FDI inflow increased heavily after 2002, mainly since 2004 after the automatic approval of FDI inflow. The insurgence of FDI in India and the export activities of the foreign firms (around 65% of the foreign firms are engaged into export activities) together might be a sign of India being used as export platform for foreign firms. In this case, both firms would produce for two different markets reducing the possibility of interactions and spillovers.

To measure productivity, we followed the semi-parametric estimation algorithm of Levinsohn and Petrin (2003). In the second stage of the estimation process, we carried out fixed-effect panel regression considering TFPG as the dependant variable. Apart from the spillover variables, we incorporated various sectoral- and firm-specific control variables, which are often considered as some of the major determinant factors of productivity growth at the firm level.

Our primary findings show that productivity growth is highly influenced by the export intensity of the domestic firms. External competition, knowledge of advanced technology and increased market demand associated with export activity induce higher productivity growth among the export oriented domestic firms. We also find that the technology indicator such as R&D activity, import of disembodied and embodied technology facilitates productivity growth of the domestic firms. The R&D activity induces higher innovation activity and import of technology (embodied and disembodied) increases technological capability of the domestic firms. Innovation activities and advanced technology base improve the production process and thus enhance productivity of the domestic firms. The size of the domestic firms is also found to be a marginally important in enhancing productivity. Based on *HHI* indices, in general we did not find any significant impact of concentration on productivity growth of the domestic firms.

In the case of spillover variables, we find that foreign presence and its activities within and across industries do not facilitate productivity growth of the domestic firms in aggregate manufacturing sector. It was argued in previous literature that the market-stealing effects might outweigh the technology benefit from foreign presence inducing negative productivity spillover effects. Disentangling all possible channels of spillover effects, we found that foreign competition reduces productivity growth. Similarly, we do not find any evidence of R&D spillover and skill spillover from foreign firms on Indian manufacturing firms. Foreign firms can afford skilled labour and undertake advanced innovation process compared to the domestic firms and thus are able to produce at a lower cost. Introduction of cheap products by foreign firms forces domestic firms to reduce production and to produce at a higher average cost. Similar to this, domestic firms, with relatively low R&D capability and semi-skilled workers are not able to absorb the benefits of advanced technology and skills introduced in the market. As in the case of India, we find that foreign firms are not much R&D intensive and mostly rely on imported technology, thus it is not unexpected that domestic firms will not gain from foreign R&D activity. Indian firms do not indicate any vertical productivity spillover effects from backward or forward linkages as well.

Interestingly, when we estimate the models controlling initial firm capabilities (by introducing interaction terms between firm capabilities and spillover channels), we find positive productivity spillovers for the firms with initial high level of capabilities. The econometric result of the panel data revealed that domestic firms are largely benefitted from the initial level of absorptive capability, low technology gap and complementary capability. High initial R&D capacity of the domestic firms allows them to compete with the foreign firms within industry by upgrading their technology, and, innovating and diversifying their products. Moreover, firms with higher initial R&D can imitate foreign technology rapidly and are able to use the knowledge embodied in foreign labour efficiently as compared to non-R&D firms. Similarly, domestic firms with an initial low technology gap benefit more from foreign technology and knowledge spillover generated from horizontal and vertical FDI presence. Initial size of the domestic firms is found to be an important factor to capture higher benefits only from the competitive pressure from foreign firms. Hence, these results reflect that in aggregate manufacturing sector, domestic firms could actually gain higher productivity if initially the firms possess internal capabilities.

From the above analysis, it is very clear that productivity growth from FDI is largely conditioned upon the technological competency of the domestic firms. There is a need to create synergy between internal technological capability and foreign activities. In this context, when FDI inflow has reached about $46 billion, Indian government needs to take steps to create high-quality R&D base and develop human skills by building efficient scientific infrastructure. This would also encourage foreign firms to take R&D activities within the industries. Moreover, Government needs to focus on building human capital by improving research-based educational facilities and advanced training. In short, Indian Government needs to improve and build internal capabilities for generating long-term dynamic development.

Appendix

See Tables 5.6, 5.7 and 5.8.

Table 5.6 Average size, export income and average expenditure on skill and various technology products (domestic and foreign firms) across industries

2-digit industry	Size		Export		Wage		Research and development		Import of disembodied technology		Import of embodied technology	
	Foreign	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign	Domestic
10	11.548	2.98	46.04	45.334	48.384	5.4	1.07	0.087	1.0673	0.0345	2.256	0.367
11	4.71	3.355	0.1066	10.69	15.191	7.15	0	0.0418	0.0078	0.02065	0.943	0.595
12	3.44	6.11	56.837	64.57	43.079	82.65	2.737	4.203	2.1905	0.00235	10.47	19.268
13	4.69	2.698	82.072	38.05	8.958	7.75	0.3124	0.0582	0.0278	6.04195	6.801	2.815
14	7.95	2.217	200.087	40.06	26.004	5.617	0.4745	0.0217	1.4948	0.0901	4.426	1.339
15	45.98	2.828	16.637	35.74	159.77	2.912	2.43	0.0094	3.7047	0.0077	3.234	0.924
17	5.101	2.849	12.308	10.693	8.31	5.645	0.0935	0.06616	0.00689	0.02533	1.879	1.695
18	5.282	9.76	2.3425	25.094	3.979	18.708		0.0092	0.5096	0.0299	2.015	3.686
19	53.771	129.54	741.51	2247.56	43.936	106.83	1.872	5.5743	3.9249	9.5895	52.207	48.492
20	15.581	4.617	72.203	32.352	33.245	9.74	2.663	0.4562	2.2187	0.328	4.963	1.963
21	14.582	4.359	109.137	65.169	34.655	10.35	10.309	4.8677	0.60256	0.0552	5.841	1.684
22	6.308	4.661	20.587	27.96	7.976	5.571	0.137	0.248	0.151	0.9023	3.937	2.173
23	7.55	3.603	59.754	24.69	22.013	13.967	1.9	0.3141	1.1248	0.2754	8.388	3.764
24	11.93	5.439	264.313	100.94	17.871	22.78	0.301	0.345	1.275	0.5709	13.576	7.068
25	5.736	2.7665	22.37	20.324	12.408	5.8	0.0023	0.1002	0.15446	0.0688	2.506	0.694
26	5.787	6.762	16.249	24.58	11.024	14.379	0.152	1.9223	0.2251	0.6265	1.643	3.338
27	9.295	2.82	50.244	14.33	28.398	8.139	2.125	0.1894	1.4272	0.0991	5.502	0.977
28	5.74	5.697	25.7309	24.63	19.414	20.699	0.5592	1.6337	1.2044	0.4092	2.73	1.716
29	1.21	2.94	154.002	519.56	142.263	226.975	33.106	66.3	7.3944	50.5933	84.172	114.72
30	7.14	2.4	38.628	22.31	35.614	14.935	3.394	1.7928	6.4308	0.8829	9.023	3.889
32	2.65	5.83	63.943	148.25	4.024	4.234		0.0639	0.00163	0.02369	0.197	0.721
Manufacturing	10.479	5.3	80.415	63.4	27.1102	12.479	2.414	0.979	1.7907	6.4661	7.395	3.266

Source Authors calculation based on firm-level data collected from PROWESS database of CMIE

Table 5.7 Definition of the explanatory variables with expected signs

Variables	Symbol	Definition	Expected sign
Export intensity	Expint	Ratio of FOB value of export and output of the firm	+
R&D intensity	RDint	Expenditure on R&D divided by output of the firm	+
Disembodied technology import intensity	DTint	Royalty and technical Fee payment made abroad divided by output of the firm	±
Embodied technology import intensity	ETint	Import of capital goods to output of the firm	+
size	Size	Ratio of the firm output to the median output of the industry	+
Concentration of the industry	HHI	$HHI_{jt} = \sum_{i=1}^{n} \left(\frac{y_{ijt}}{y_{jt}}\right)^2$ (Herfindahl–Hirschman Index)	−
Trade openness	Openness	Measured by import penetration of the industry ($Openness_{jt} = \frac{import_{jt}}{output_{jt} + import_{jt} - export_{jt}}$)	+
Competition spillover	CompSpill	Share of foreign output to total output in an industry	±
Demonstration spillover	IMITATION	Share of the MNE's total R&D and technology import expenditure to total R&D and technology import expenditure of the industry	+
Skill spillover	SKILL	Share of the MNES' expenditure on wages and salaries on total expenditure on wages and salaries of the sector	+
Backward spillover	Backward	$Backward_{jt} = \sum_k \alpha_{jkt} FDI_{kt}$	+
Forward spillover	Forward	$Forward_{jt} = \sum_k \beta_{kjt} FDI_{kt}$	+

Table 5.8 Descriptive statistics of the explanatory variables used in the estimation of FDI spillovers and productivity growth

Industry code	Statistics	Expint	RDint	Dtint	Etint	Size	HHI	Openness	GAP	Comp	IMITATION	SkillSpill	Backward	Forward
10	Mean	0.0840	0.0004	0.0004	0.0049	3.2542	0.0142	0.0543	−0.4809	0.1150	0.2554	0.2195	0.0227	0.0118
	Std dev	0.2105	0.0019	0.0080	0.1105	8.6212	0.0037	0.0258	6.0749	0.0193	0.1175	0.0176	0.0161	0.0024
11	Mean	0.0177	0.0001	0.0003	0.0028	3.3966	0.0757	0.0110	−0.4999	0.0291	0.0301	0.0411	0.0014	0.0005
	Std dev	0.0628	0.0011	0.0036	0.0163	7.2100	0.0159	0.0057	1.9362	0.0276	0.0389	0.0384	0.0005	0.0003
12	Mean	0.0278	0.0010	0.0004	0.0032	5.5811	0.6072	0.0232	−0.2837	0.1345	0.1597	0.1245	0.0824	0.0237
	Std dev	0.0433	0.0017	0.0012	0.0067	16.6804	0.0405	0.0070	1.0687	0.0369	0.0842	0.0405	0.0366	0.0236
13	Mean	0.1870	0.0005	0.0334	0.1014	2.7491	0.0113	0.0875	−0.1753	0.0405	0.0584	0.0258	0.0292	0.0054
	Std dev	0.3121	0.0066	2.7183	2.9919	6.0058	0.0016	0.0138	2.4883	0.0056	0.0284	0.0091	0.0029	0.0008
14	Mean	0.4099	0.0003	0.0024	0.0589	2.4053	0.0504	0.1776	−0.3986	0.0912	0.0959	0.0998	0.0615	0.0078
	Std dev	0.4053	0.0069	0.0160	0.6714	4.0052	0.0081	0.0574	3.0580	0.0600	0.0872	0.0438	0.0400	0.0023
15	Mean	0.5273	0.0002	0.0095	0.1991	3.8874	0.1296	0.1409	−0.1649	0.3058	0.2418	0.6160	0.1296	0.1214
	Std dev	0.4405	0.0007	0.2182	3.1923	8.1613	0.0420	0.0551	1.4139	0.0684	0.1148	0.0878	0.0097	0.0181
16	mean	0.0576	0.0005	0.0000	0.0063	3.1189	0.1294	0.1359	−0.0521	0.0000	0.0000	0.0000	0.0000	0.0000
	Std dev	0.1240	0.0017	0.0003	0.0416	7.3277	0.0364	0.0514	0.4970	0.0000	0.0000	0.0000	0.0000	0.0000
17	Mean	0.0205	0.0005	0.0006	0.0586	2.9506	0.0465	0.0635	−0.0564	0.0760	0.1052	0.0654	0.0373	0.0155
	Std dev	0.0664	0.0032	0.0105	2.1342	7.0262	0.0127	0.0370	0.5203	0.0084	0.1447	0.0051	0.0087	0.0047
18	Mean	0.0356	0.0000	0.0028	0.0207	8.2744	0.3705	0.0953	−0.0718	0.3464	0.3984	0.2724	0.1303	0.1191
	Std dev	0.1034	0.0000	0.0095	0.1019	30.1144	0.1810	0.0830	0.4446	0.2578	0.2808	0.2256	0.0301	0.0258
19	Mean	0.1119	0.0008	0.0034	0.1264	120.5565	0.2559	0.2371	−0.3528	0.0436	0.1051	0.0635	0.0072	0.0082
	Std dev	0.8469	0.0032	0.0263	1.8280	448.8419	0.0384	0.0919	1.4773	0.0148	0.0995	0.0178	0.0048	0.0016
20	Mean	0.1101	0.0030	0.0025	0.0344	5.4805	0.0211	0.1351	−0.1935	0.2172	0.2503	0.2250	0.0400	0.0306
	Std dev	0.2742	0.0404	0.0799	0.9714	19.4098	0.0038	0.0117	1.1396	0.0240	0.0869	0.0134	0.0061	0.0035
21	Mean	0.1388	0.0170	0.0104	0.0072	5.0502	0.0207	0.1116	−0.2492	0.1862	0.1428	0.2210	0.0349	0.0313
	Std dev	0.2169	0.1590	0.6181	0.0707	11.9290	0.0021	0.0193	1.9471	0.0215	0.0316	0.0475	0.0084	0.0047

(continued)

Table 5.8 (continued)

Industry code	Statistics	Expint	RDint	Dtint	Etint	Size	HHI	Openness	GAP	Comp	IMITATION	SkillSpill	Backward	Forward
22	Mean	0.1176	0.0027	0.0066	0.1309	4.7694	0.0331	0.1126	−0.0819	0.0816	0.0942	0.1036	0.0380	0.0196
	Std dev	0.2266	0.1118	0.2908	5.5021	15.3667	0.0041	0.0289	0.9416	0.0215	0.0488	0.0368	0.0114	0.0084
23	Mean	0.0586	0.0017	0.0067	0.0943	3.8948	0.0367	0.0489	−0.4065	0.1448	0.1752	0.1066	0.0818	0.0173
	Std dev	0.1452	0.0190	0.1902	2.3584	9.3516	0.0025	0.0102	1.3280	0.0226	0.1342	0.0272	0.0230	0.0028
24	Mean	0.0949	0.0006	0.0358	0.4970	5.7170	0.0593	0.1226	−0.3115	0.0778	0.1241	0.0312	0.0210	0.0087
	Std dev	0.4231	0.0181	2.3280	34.2068	26.8881	0.0255	0.0236	4.3968	0.0165	0.0836	0.0070	0.0055	0.0024
25	Mean	0.1032	0.0005	0.0059	0.0418	2.8332	0.0378	0.0538	−0.1196	0.0364	0.1125	0.0500	0.0133	0.0064
	Std dev	0.2671	0.0026	0.2324	1.1860	6.2369	0.0079	0.0121	2.3553	0.0188	0.1543	0.0245	0.0069	0.0009
26	Mean	0.1241	0.0072	0.0389	0.3020	6.6828	0.0870	0.1977	−0.2873	0.0694	0.0298	0.0540	0.0582	0.0101
	Std dev	0.2876	0.0264	1.0579	9.8066	24.6609	0.0284	0.0727	2.3133	0.0104	0.0199	0.0154	0.0124	0.0016
27	Mean	0.0770	0.0050	0.0919	0.3819	3.4386	0.0236	0.0980	−0.1116	0.2226	0.4200	0.2699	0.1447	0.0741
	Std dev	0.1792	0.1344	3.6535	13.8686	7.4697	0.0021	0.0283	0.7643	0.0229	0.1149	0.0218	0.0098	0.0248
28	Mean	0.0885	0.0028	0.0023	0.0844	5.7006	0.0692	0.0681	−0.0863	0.0944	0.1520	0.0970	0.0361	0.0073
	Std dev	0.1601	0.0142	0.0092	4.4057	25.1810	0.0136	0.0293	0.8226	0.0096	0.0458	0.0068	0.0253	0.0036
29	Mean	0.0623	0.0103	0.0066	6.2093	2.5732	0.1989	0.0825	0.0567	0.1073	0.1219	0.1471	0.0628	0.0101
	Std dev	0.0774	0.0242	0.0094	83.3091	3.2203	0.0247	0.0157	0.2663	0.0186	0.1459	0.0114	0.0211	0.0029
30	Mean	0.1001	0.0033	0.0042	0.0524	2.9089	0.0311	0.0979	−0.1203	0.2562	0.2907	0.2248	0.1182	0.0635
	Std dev	0.1900	0.0110	0.0358	1.4165	7.9792	0.0039	0.0209	1.4634	0.0239	0.0604	0.0283	0.0309	0.0142
32	Mean	0.7200	0.0014	0.0008	0.0249	5.7019	0.0695	0.5879	−7.2071	0.0190	0.0129	0.0428	0.0020	0.0029
	Std dev	1.2044	0.0150	0.0093	0.2741	12.2483	0.0229	0.8361	97.6654	0.0036	0.0105	0.0071	0.0004	0.0023

Source Author’s calculation based on the firm-level data collected from PROWESS, CMIE

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Chapter 6
FDI, Technology Imports and R&D in Indian Manufacturing: Revisited

Maitri Ghosh and Rudra Prosad Roy

Abstract This paper investigates into the factors determining firm-level R&D intensity in Indian manufacturing during post-reforms. In doing so, the differential impact of productivity for Multinational Enterprises vis-a-vis the domestic firms on R&D intensity has been studied. This paper further investigates into the role of imported technology in determining innovative activities of firms. System GMM estimation with firm-level data from 2001 to 2010 suggests that foreign ownership plays a key role in determining firm-level R&D in Indian manufacturing. Interestingly, highly productive foreign firms invest more in R&D activities as against their local counterparts in India. Imported foreign technology significantly reduces R&D intensity of firms which is indicative of the fact that imported foreign technology acts as a substitute of local innovative activities in Indian manufacturing during post-reforms.

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M. Ghosh (✉)
Bethune College, 181 Bidhan Sarani, Kolkata 700006, India
e-mail: maitri_ghosh@yahoo.com

R.P. Roy
Department of Economics, Jadavpur University, Kolkata 700032, India
e-mail: rudraprosadroy@gmail.com

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6.1 Introduction

This study explores the possible determining factors influencing firm-level R&D activities of Indian manufacturing during the post-reforms period. In this context, the role of foreign direct investment (FDI) and hence Multinational Enterprises (MNEs) is considered. Recognizing the fact that foreign firms are technologically advanced than their domestic counterparts, this study attempts to understand the differential impact of productivity for MNEs as against the domestic firms on firm-level R&D intensity. This paper also empirically investigates into the role of imported foreign technology in determining local R&D activities of Indian manufacturing at the firm level.

FDI inflows to the emerging market economies including India mostly occur through Multinational Enterprises (MNEs), whereby foreign firms acquire a substantial control over a host-country firm or set-up a subsidiary in a host country (Markusen 2002). The theory of the MNEs assumes advantages that these entities have over the existing local enterprises (Hymer 1976). In particular, these advantages arise from ownership, assets, knowledge and technology, risk taking behaviour and long-term financing decisions over the domestic counterparts (Caves 1996). MNEs remain internationally competitive through a combination of technological innovation, access to frontier foreign technology and a variety of complementary assets. It has been increasingly recognized that the presence of foreign firms contributes, directly or indirectly, to the performance and technological choices of host-country firms.

Initial theoretical literature on R&D activities of MNEs predominantly considered cross-border transfer of mature technologies (Vernon 1974; Dunning 2000; Lall 1979) and product adaptation. The determinants of cross-border R&D activities of the MNEs primarily occur due to the operation of centripetal factors (MNEs to keep R&D as a headquarter function) and centrifugal factors (pulling away R&D activities from the centre into peripheral locations). With operation of centrifugal forces there may be a need to adapt production processes as well as characteristics of products to meet local conditions. With the studies of Ronstadt (2002), Pearce (1999), Birkinshaw and Morrison (1995), Vernon (2000), it is established that dissemination of innovative activities by the MNEs often arises out of the technology seeking behaviour of firms. Further, Mukherjee and Sinha (2013) in a North–South trade model show that southern patent protection makes southern firms better off by increasing the southern firms' incentive to innovate and affecting the nature of competition in the world market. In sharp contrast to the conventional perception, the modern knowledge seeking R&D laboratories seek for geographically differentiated frontier technology with the motive to preserve the technological lead of the MNEs. Findlay (1978), Das (1987), Wang and Blomstrom (1992), Perez (1997) contribute to the theoretical literature, focusing on the effects of the presence of MNEs on the technology development of the host country. They emphasize on the fact that spillover benefits might increase with the technology gap between local recipient and foreign investors. Findlay (1978) formulates a dynamic model to analyse the role of MNEs in the process of technological transfer to the LDCs. Das (1987), considering technological spillovers from MNE subsidiary to the host-country firms, show higher productivity spillovers to the domestic firms resulting from higher production of the subsidiary. Firms' own capability is also crucial in making use of the knowledge that they can access (Blomstrom and Kokko 2003; Keller 1996; Rogers 2004).

The empirical literature on the issue deals with two different approaches. The first approach links technology imports, both by MNEs and domestic firms and local R&D while the second indicates diffusion of imported technology through knowledge and productivity spillovers to domestic firms from foreign firms. The nature of the relationship between technology imports and local R&D has been a matter of debate. For some (Blumenthal 1979; Lall 1993; Katrak 1985), the relation is complementary while for some others (Kumar 1987; Basant and Fikkert 1996; Kathuria and Das 2005; Chuang and Lin 1999; Fan and Hu 2007), foreign technology substitutes local innovative activities. A large number of studies including Kumar (1987), Basant and Fikkert (1996), Kathuria and Das (2005) for Indian manufacturing find substitutability between technology imports and domestic R&D. Thus, a conclusive evidence with regard to the relationship between imported technology and domestic R&D is still not available particularly for emerging market economies like India. Again, with the study of Griliches (1958), a good amount of both theoretical and empirical studies enquiring into the R&D—factor productivity relationship has emerged in the literature. The theoretical models of Griliches (1973) and Terleckyj (1974) suggest that R&D plays a key role in productivity growth. Empirical findings on the issue also indicate a positive and significant relationship between a firm's R&D investment and its productivity (Griliches and Mairesse 1984; Griliches 1986, 1988; Mansfield 1980; Zhang et al. 2003; Chuang and Lin 1999; Hanel 2000; Coe and Helpman 1995). A recent strand of literature further focus on the relationship between innovation and 'absorptive'/'learning' capacity (Cohen and Levinthal 1989) of firms. Wang and Blomstrom (1992) suggest that such learning efforts of domestic firms might occur as a result of technology transfer from foreign firms to domestic firms which has implications for local innovative activities. Hence, differences in R&D incentives for MNEs and domestic firms in the host economy are likely. The case becomes even more intriguing if a differential impact of productivity for foreign firms and domestic firms on R&D initiatives is noticed for economies like India. This paper aims at understanding this aspect of MNE–R&D relationship for Indian manufacturing.

With quantum inflow of FDI and increase in MNE operations in India since 1991, the hitherto protected domestic firms facing competition had to review their technology strategies. As technology followers, on the one hand, it was expected that there would be a huge dependence on imported technology. While on the other, it was also argued that the inward-looking policies followed by India in the first three decades after independence have enabled the manufacturing industries to develop a high capital base. Hence, firms are likely to invest in local R&D as well. However, a pertinent question that emerges in this context is whether in the liberalized regime the foreign-owned firms invest more in R&D than the domestic firms in the host economy? Again, whether the most productive foreign firms invest more in R&D than their local counterparts? Any further research on the issue of R&D activities in India must investigate into these nuances at a further disaggregate level. This study precisely aims to understand these different dimensions impacting R&D intensity of Indian manufacturing at the firm level during the post-reforms era. It explores the impact of ownership and foreign technology imports on firm-level R&D. In doing so, this study, in particular, tries to understand whether the highly productive foreign firms invest more on R&D initiatives as against the domestic firms. This is where the paper contributes to the existing literature. The rest of the paper is organized as follows. Section 6.2 puts forth some stylized facts on R&D in Indian manufacturing. Section 6.3 discusses the analytical framework, the empirical model, the database and method of estimation. Section 6.4 presents the empirical results. Finally, Sect. 6.5 summarizes the major findings of the paper.

6.2 Some Stylized Facts on R&D Expenditure in India

The comprehensive reforms process which began in the early 1990s in India was initiated in the mid-1980s with liberalization of external trade. Wide ranging changes in India's industrial policy, especially with regard to foreign capital movements, were introduced in 1991 with complementary changes in other policies as well. India's foreign investment policy measures initiated in the 1990s, which mark a departure from those of the 1980s, made the economy more open and proactive to build strategic alliances and penetrate the world market (Ahluwalia 2008). As a result, India witnessed quantum increase in FDI inflows since 1991.[1]

FDI in many emerging market economies including India is encouraged to gain international competitiveness. In this context, technology plays an important role along with FDI. The host economy gets access to world class technology with FDI inflows and foreign firms contributing, directly or indirectly, to the innovative activities of host-country firms (Lall 1993). The adoption of the WTO Agreement on the Trade-Related Intellectual Property Rights (TRIPS) since the mid-1990s has significant implications for international technology markets and international technology transfer. India's technology indicators show improvements during post-1991 reforms (Ghosh and Sinha Roy 2016). India's in-house R&D expenditure increased after 1991 along with an increase in non-residents patent applications in India during the same period, especially after 1999 (see Fig. 6.1).

Further, as Banerjee and Sinha Roy (2014) show, imports of embodied technology, capital goods in particular, increased significantly during this period. A rise in the R&D expenditure is indicative of an enhancing domestic technological

[1]Developing countries witnessed increasing foreign investment inflows since the 1980s (UNCTAD 1995).

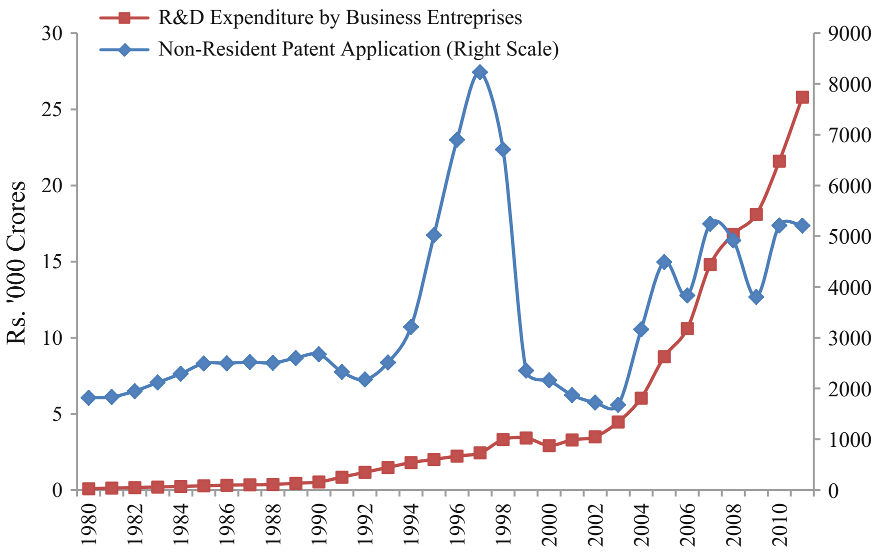

Fig. 6.1 R&D activity in India

Table 6.1 R&D expenditure as per cent of GDP

Country	Year									
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
India	0.72	0.71	0.71	0.74	0.81	0.80	0.79	0.84	0.82	0.80
China	0.95	1.06	1.13	1.22	1.32	1.38	1.38	1.46	1.68	1.73
BRICS	0.92	1.00	0.98	0.98	1.01	1.03	1.05	1.07	1.14	1.11
US	2.64	2.55	2.55	2.49	2.51	2.55	2.63	2.77	2.82	2.74
Japan	3.07	3.12	3.14	3.13	3.31	3.41	3.46	3.47	3.36	3.25
South Asia	0.58	0.58	0.59	0.63	0.69	0.70	0.71	0.73	0.71	0.69
OECD	2.17	2.14	2.15	2.12	2.15	2.19	2.23	2.31	2.36	2.33
World	1.55	1.54	1.54	1.52	1.54	1.55	1.57	1.61	1.65	1.63

Source UNESCO's database of Science, Technology and Innovation

capability, a rise in non-resident patent application in India corroborates to increasing multinational R&D activity in India. Further, such a pattern of development of technological capability in India can be explained, following Dinopolous and Segerstorm (2010), in terms of technology transfer within multinationals when IPR protection is strong in a southern country.

However, it is to be noted that R&D expenditure in India as a percentage of GDP, as reported in Table 6.1, has been low as compared to developed and other emerging market economies such as China. Table 6.1 reflects that between 2001 and 2010, R&D expenditure as a percentage of GDP has increased from 0.72 to 0.80 in India, whereas that of China has increased from 0.95 to 1.73. Although India's R&D expenditure as a percentage of GDP has always remained lower than

Table 6.2 R&D expenditure in different economic activities in 2009–10 (in Rupees Crore)

NIC 2004	Economic activity	Public	Private	Total
A + B + C	Agriculture, forestry and fishing, mining and quarrying	7047.1 {87.50} [21.54]	1006.72 {12.50} [4.96]	8053.82 {100} [15.19]
D	Manufacturing	1924.98 {17.05} [5.88]	9365.76 {82.95} [46.12]	11290.74 {100} [21.29]
E + F	Construction, electricity gas and water supply	3575.53 {96.83} [10.93]	117.12 {3.17} [0.58]	3692.65 {100} [6.96]
I	Transport and communication	776.42 {12.66} [2.37]	5354.48 {87.34} [26.37]	6130.9 {100} [11.56]
L + O	Public administration and defence and other services	19397.18 {81.30} [59.28]	4462.6 {18.70} [21.98]	23859.78 {100} [44.99]
A + B + C + D + E + F + I + L + O	Total	32721.22 {61.71} [100]	20306.67 {38.29} [100]	53027.89

Source Authors' calculation based on data obtained from Ministry of Science and Technology, Government of India
Note The first figure in a cell is the R&D expenditure measured in Rs. Crore. The second and the third figures are the sectoral share and share of the economic activity, respectively

the developed countries such as the US or Japan as well as the OECD countries, it has performed substantially well vis-à-vis its regional counterparts.

At this juncture, it would be useful if we consider the major economic activities in which expenditure has been incurred on R&D in recent years. Table 6.2 shows R&D expenditure in India across major economic activities during 2009–10. It is to be noted that in terms of source of funding, R&D expenditure can be divided into two categories, namely public and private. It is shown in Table 6.2 that R&D expenditure in the manufacturing sector accounts for only 21.29% of the total R&D expenditure in the economy. However, almost half (46.12%) of the total R&D expenditure funded by private sources goes to manufacturing sector. Again, within the manufacturing sector, 82.95% of the total spending on R&D has been funded by private sources. Such nuanced aspects make manufacturing an interesting case and call for firm- level studies to arrive at the determining factors of R&D intensity in Indian manufacturing sector.

There are further implications to the above observation if we consider the expenditure on R&D across sectors in Indian Manufacturing. Table 6.3 suggests that R&D expenditure in Indian manufacturing has increased across sectors from 2005–06 to 2009–10. This is true not only for high-tech industries but also for medium-tech and low-tech industries. The total expenditure on R&D increased from

Table 6.3 R&D expenditure across sectors in Indian manufacturing industries in 2005–06 and 2009–10

Manufacturing	NIC 2008	Technology Intensity (ISIC)	2005–06	2009–10
Drugs and pharmaceuticals	21	High-tech industry	3408.42	6475.92
Manufacture of medical, precision and optical instruments	26	High-tech industry	58.16	67.37
Manufacture of chemicals, chemical products and fertilizers	20	Medium-high-tech industry	478.6	973.71
Manufacture of electrical machinery and apparatus	27	Medium-high-tech industry	288.87	519.11
Manufacture of machinery and equipment	28	Medium-high-tech industry	458.45	1391.84
Manufacture of coke, refined petroleum products and nuclear fuel	19	Medium-low-tech industry	147.44	349.75
Manufacture of rubber and plastic products	22	Medium-low-tech industry	58.45	125.46
Manufacture of other non-metallic mineral products	23	Medium-low-tech industry	73.98	110.9
Manufacture of basic metals	24	Medium-low-tech industry	154.54	278.12
Manufacture of fabricated metal products	25	Medium-low-tech industry	66.32	84.95
Manufacture of food products and beverages	10 + 11	Low-tech industry	210.1	437.25
Manufacture of tobacco products	12	Low-tech industry	67.5	109.58
Manufacture of textiles	13	Low-tech industry	110.06	180.09
Manufacture of wearing apparel, dressing and dyeing of fur	14	Low-tech industry	20.21	30.46
Tanning and dressing of leather, luggage handbags, etc.	15	Low-tech industry	45.27	65.14
Manufacture of wood and products of wood and cork	16	Low-tech industry	7.54	12.21
Manufacture of paper and paper products	17	Low-tech industry	40.43	78.88
Total R&D expenditure (in Rs. crore)			5193.23	10377.1

Source Ministry of Science and Technology, Government of India

Rs. 5193.23 crores in 2005–06 to Rs. 10377.1 crores in 2009–10. Drug and Pharmaceuticals is the sector which is found to expend the most on R&D activities over years followed by machinery and equipment and electrical machinery and apparatus. Such an observation is expected as these industries belong to the high-technology or medium-high-technology sector. In the medium-low-technology sector, basic metals industry shows the maximum R&D expenditure. Interestingly, in the low-technology sector, the expenditure on R&D of food products has more than doubled from Rs. 210.1 crores in 2005–06 to Rs. 437.25 crores in 2009–10.

Textiles also show considerable improvements in R&D expenditure during this period.

In this paper, we have considered firms belonging to the high-tech chemicals (including drug and pharmaceuticals), machineries, and transport equipment industries as well as medium- and low-tech industries like basic metals, food and beverages, and textiles industries to understand the determining factors of firm-level R&D intensity in Indian manufacturing across sectors.

6.3 Analytical Framework

Increase in R&D activities of a firm can either be due to increased demand and/or on account of reduced average cost (Kumar and Aggarwal 2005). Among the factors that directly or indirectly determine firm-level R&D intensity can be firm-specific, sector-specific as well as induced by some exogenous policy factors (see Fig. 6.2). The firm-specific factors that this study considers are the age of the firm, size of the firm, ownership (whether the firm is domestically owned or foreign owned), import of foreign technology and Total Factor Productivity (TFP). A detailed discussion of these factors is given below.

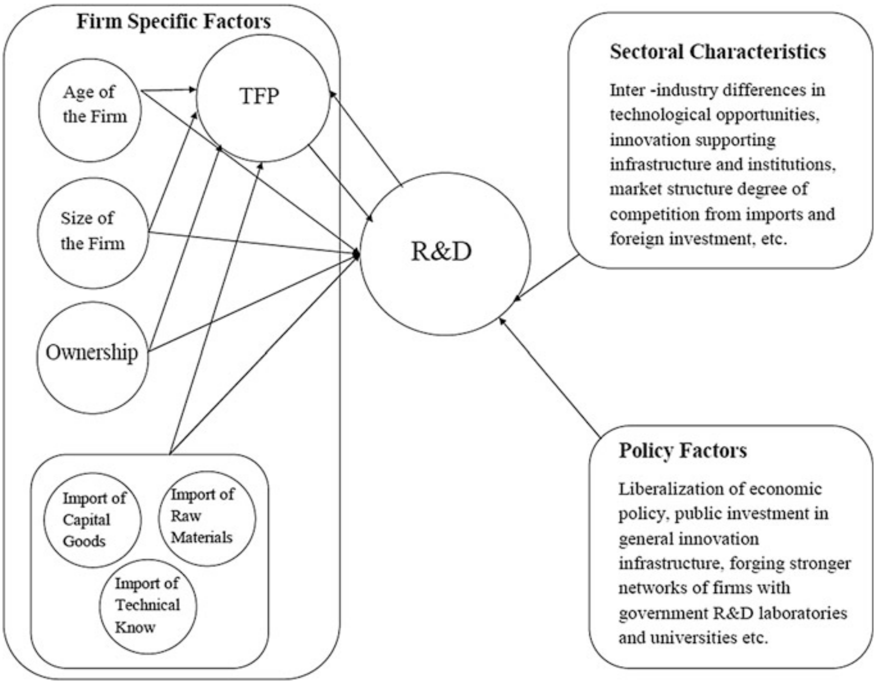

Fig. 6.2 Schematic framework of the factors determining R&D intensity of firms

6.3.1 Ownership

As far as access to frontier technology is concerned, the MNEs have easy and continuous access to the parent firm's technology (Kumar and Aggarwal 2005). Most of the innovative activities of the MNEs are carried out in their home countries (Cantwell 1989; Annique and Cuervo-Cazurra 2008). Thus, it is unlikely that these firms would invest in R&D activities in the host country. However, since mid-2000 it has been realized that India and China are emerging as the two most attractive destinations for R&D set-ups for the MNEs (Mrinalini et al. 2013). Studies by Mrinalini et al. (2014), Basant and Mani (2012) suggest that India continues to be an attractive destination for FDI in R&D. Sasidharan and Kathuria (2011) further suggests that foreign firms invest in innovative activities in high-tech sectors of Indian manufacturing. Kumar (2001) reveals that foreign firms invest in R&D activities in the host economies to adapt to local conditions particularly when high-skilled technical professionals are available in the host country. In this context, it is to be noted that India tops the list of countries in terms of access to highly skilled labour force (Pohit and Biswas 2016). Hence, it is expected that MNEs and hence foreign ownership of firms will have a significant impact on R&D intensity in Indian manufacturing. Thus, in this paper, we expect foreign firms to invest in R&D activities.

6.3.2 Imported Foreign Technology

In India, import of technology is one of the major channels of knowledge acquisition by firms. Technology can be imported in both embodied and disembodied forms. Embodied technology is imported in the form of raw materials, intermediate goods and capital goods, while imported disembodied technology includes patented knowledge, technical know-how, drawings and designs. Studies for Indian manufacturing reveal a positive relationship between imported disembodied technology and R&D (Siddharthan 1992; Aggarwal 2000) as well as imported embodied technology and R&D (Basant 1997). However, as firms operate under severe budget constraint (Kathuria and Das 2005), it is also not unlikely for them to curtail expenditure on R&D while they incur expenditure on imported foreign technology. Sasidharan and Kathuria (2011) show that imported technology has detrimental effect on R&D activities of medium-tech industries in Indian manufacturing. Fikkert (1993) also shows a negative relationship between technology imports and R&D intensity for Indian manufacturing. In our analysis, we postulate a negative relationship between the two.

6.3.3 Size

Literature suggests that one of the most important determinants of innovative activities of firms is size of a firm which arises from the Schumpeterian notion of existence of economies of scale (Cohen and Levinthal 1989). Large firms have greater financial resources and are capable of hedging the risk and uncertainty of undertaking variety of innovative activities. Studies for Indian manufacturing have shown both linear and nonlinear relationship between size of a firm and its R&D intensity. For example, while the studies by Lall (1983), Katrak (1985), Kumar and Saqib (1996) postulate a linear relationship, the recent studies by Pradhan (2002), Kumar and Aggarwal (2005), Sasidharan and Kathuria (2011) postulate a nonlinear relationship between the two. In this study, the firms vary widely according to firm size. Hence, a quadratic relationship between firm size and R&D intensity has been considered.

6.3.4 Age

Age of a firm, in the literature, shows the extent of a firm's learning experience leading to greater experimental and tacit knowledge (Bhaduri and Ray 2004). Older firms have an edge over the new entrants as a result of accumulated experience (Sasidharan and Kathuria 2011). This is particularly because of the fact that older firms, with experience, are able to bear sunk costs and can take up technology decisions enabling them to earn more return on their investment on R&D. Hence, older firms are likely to invest more on R&D as compared to newer firms which accumulate knowledge through interfirm transfer of technology (Katrak 1997). Thus, a positive relationship between age and R&D intensity of firms is expected.

6.3.5 Marketing Costs

If a firm incurs expenditure on advertisement marketing and distribution and creates service networks, it might attain cost competitiveness. These costs are, however, sunk in nature and cannot be recovered (Baldwin 1999). With the operation of MNEs in economies like India, such specific costs have become an important determining factor of firm-level exports (Ghosh and Sinha Roy 2016). Thus, in a liberalized regime, with improved marketing and distribution networks, exports of firms rise. This might lead to an increase in investment in R&D at the firm level.

6.3.6 Factor Productivity

Existing literature establishes a positive and significant impact of R&D on factor productivity of firms (Crepon et al. 1998; Griffith et al. 2006). However, these studies are based on the cross-sectional data and cannot consider the dynamic linkage between R&D and productivity of firms and the bidirectional causality between them (Raymond et al. 2015). In a liberalized regime, with FDI inflows, access to imported foreign technology has become easier. With such imported technology and technology transfers/spillovers, factor productivity of a firm might have an impact on the firm's decision to invest in R&D. In this context, the present study captures the pertinent question of whether more productive foreign firms invest more in R&D activities in Indian manufacturing as against their domestic counterparts or not.

6.4 Estimation Model

In this paper, we have estimated three models. The first model in its estimable form is as follows:

$$\begin{aligned}\ln \mathrm{R\&D}_{it} = {} & \alpha_0 + \beta_j\left(\ln \mathrm{R\&D}_{t-j}\right) + \alpha_1(\mathrm{size}_{it}) + \alpha_2\left(\mathrm{size}_{it}^2\right) + \alpha_3(\mathrm{age}_{it}) \\ & + \alpha_4(\ln \mathrm{mktcost}_{it}) + \alpha_5(\ln \mathrm{fortech}_{it}) + \alpha_6(\ln \mathrm{TFP}_{it}) + \alpha_7(\mathrm{own}_{it}) + u_{it}\end{aligned} \tag{6.1}$$

where the variables[2] are constructed as follows:

R&D	Ratio of R&D expenditure to sales.
size	Ratio of firm sales to industry sales.
age	Absolute age of the firm in number of years.[3]
mktcost	Ratio of summed up advertising expenditure, marketing expenditure and distribution expenditure to sales.
fortech	Ratio of the sum of expenditure on import of capital good, import of raw materials and import of foreign technical know-how to sales.
TFP	Total Factor Productivity measured by the semi-parametric method of Levinsohn-Petrin (2003).[4]
own	A dummy variable, taking the value 1 if the firm is foreign and 0 otherwise.

[2]See Appendix for the correlation matrix.

[3]A better estimate of 'age' in this context could be the numbers of years under present management. However, the database used for the purpose of analysis does not provide such data. Hence, the absolute age of the firm since incorporation has been considered to construct the variable.

[4]See Appendix.

In the second model of econometric estimation, two variables are created interacting ownership with TFP (own * TFP) and ownership with foreign technology purchase (own * fortech). These interaction terms are expected to have implications for the foreign-owned firms. This estimation model will provide insights whether more productive foreign firms invest more in R&D at the firm level for Indian manufacturing. The estimable model is as follows:

$$\ln \mathrm{R\&D}_{it} = \alpha_0 + \beta_{j1}\left(\mathrm{R\&D}_{t-j}\right) + \alpha_1(\mathrm{size}_{it}) + \alpha_2\left(\mathrm{size}_{it}^2\right) + \alpha_3(\mathrm{age}_{it}) + \alpha_4(\ln \mathrm{mktcost}_{it}) + \alpha_5(\ln \mathrm{fortech}_{it}) + \alpha_6(\ln \mathrm{TFP}_{it}) + \alpha_7(\mathrm{own}_{it} \times \ln \mathrm{fortech}_{\mathrm{it}}) + \alpha_8(\mathrm{own}_{\mathrm{it}} \times \ln \mathrm{TFP}_{\mathrm{it}}) + u_{\mathrm{it}} \tag{6.2}$$

Along with its direct effects on R&D intensity, imported technology might have some indirect effects through TFP. To capture this effect, a third model is estimated introducing an interaction of TFP and foreign technology purchase (TFP*fortech) as follows:

$$\ln \mathrm{R\&D}_{it} = \alpha_0 + \beta_j\left(\mathrm{R\&D}_{t-j}\right) + \alpha_1(\mathrm{size}_{it}) + \alpha_2\left(\mathrm{size}_{it}^2\right) + \alpha_3(\mathrm{age}_{it}) + \alpha_4(\ln \mathrm{mktcost}_{it}) + \alpha_5(\ln \mathrm{TFP}_{it}) + \alpha_6(\ln \mathrm{TFP}_{it} \times \ln \mathrm{fortech}_{it}) + \alpha_7(\mathrm{own}_{it}) + u_{it} \tag{6.3}$$

In the above equation,

$$\frac{\partial \ln \mathrm{R\&D}_{it}}{\partial \ln \mathrm{TFP}_{it}} = \alpha_5 + \alpha_6(\ln \mathrm{fortech}_{it})$$

Again,

$$\frac{\partial\left(\frac{\partial \ln \mathrm{R\&D}_{it}}{\partial \ln \mathrm{TFP}_{it}}\right)}{\partial \ln \mathrm{fortech}_{it}} = \alpha_6$$

Thus, α_6 measures how imported technology impacts R&D intensity indirectly via TFP. The estimation results of Eqs. (6.2) and (6.3) also check the robustness of the estimation results of Eq. (6.1).

6.5 Methodology and Data

6.5.1 Econometric Technique for Estimation

The study uses system estimator introduced by Blundell and Bond (1998). Dynamic relationship among economic variables is identified by the presence of a lagged dependent variable among regressors. In a panel data set-up, this can be discerned by the presence of autocorrelation and other individual effects that account for heterogeneity among individuals:

$$y_{it} = \delta y_{i,t-1} + x'_{it}\beta + u_{it} \quad i = 1, 2, \ldots, N; \quad t = 1, 2, \ldots, T \tag{6.4}$$

where δ is a scalar, x'_{it} is a $1 \times K$ vector of strictly exogenous regressors and β is a $K \times 1$ vector of coefficients. Here, u_{it} is assumed to follow a one-way error component as following:

$$u_{it} = \mu_i + v_{it} \tag{6.5}$$

where μ_i and v_{it} are independent of each other and IID with mean 0 and variance σ^2_μ and σ^2_v, respectively. The unavoidable correlation between $y_{i,t-j}$, i.e. the lagged dependent variables with u_i, makes OLS estimator biased and inconsistent even though v_{it} is not serially correlated. Anderson and Hsiao (1981) show that first differencing of the model can give consistent estimator. However, this might not necessarily produce efficient estimator. A generalized method of moments (GMM) procedure suggested by Arellano and Bond (1991) gives a consistent estimator.

Based on the study by Arellano and Bover (1995), Blundell and Bond (1998) have developed an estimator by assuming absence of autocorrelation in the idiosyncratic errors and no correlation between panel-level effects and the first difference of the dependent variable. Blundell and Bond (1998) by making this additional assumption increase efficiency by introducing more instruments. This method is called the system GMM dealing with a system of two equations namely the original and the transformed equations. This system GMM estimator not only improvises precision but also reduces finite sample bias even when the covariates are weakly exogenous. With large cross-sectional units observed for a small number of time periods, different GMM estimators have often been found to produce unsatisfactory results (Mairesse and Hall 1996). System GMM turns out to be a better choice in this case.

6.5.2 Data

Despite limitations, firm-level data across sectors are obtained from Prowess Database published by the Centre for Monitoring Indian Economy (CMIE) for the period 2001–2010. In this study, the firms were identified according to ownership, i.e. the “FDI firms” as against “non-FDI firms”. PROWESS provides data for foreign promoter’s equity holdings. If for a company, equity holding of the foreign promoter exceeds 25%, it is classified as a foreign-owned firm or a “FDI firm”. However, PROWESS reports data on foreign promoter’s equity holdings only for post-2001 period. However, numerous missing values of equity participation do not auger well with the empirical analyses being carried out. The database provides separate information on the ownership group of firm in the sense of whether a firm is 'Private Indian', 'Private Foreign' or a 'State-run' enterprise, etc. This information is used in the study to identify domestic and foreign ownership[5] of firms. We use a dummy variable indicating ownership taking the value one if the firm is foreign and the value zero if the firm is domestic.

The PROWESS database provides information on salaries and wages and provides no information on the number of employees. In order estimate Total Factor Productivity, labour data were required. The Annual Survey of Industries (ASI) database of the Central Statistical Organization (CSO) is used to mitigate the problem. The data on total emoluments and total persons engaged for the relevant industry were collected from the ASI database. This requires data matching. Such matching has been done at the two-digit level. Since the time period under consideration is 2001–2010, concordance between NIC 1998, NIC 2004 and NIC 2008 classification of industries at two-digit level has been done. A total of 3840 observations include both domestically owned and foreign-owned firms.[6]

6.6 Estimation Results

Estimation results of Eqs. (6.1), (6.2) and (6.3) are presented in Table 6.4 (labelled as Model 1, Model 2 and Model 3, respectively). Evidence from the estimation of Model 1 and Model 3 suggests that foreign ownership plays a positive and significant role in determining firm-level R&D intensity in Indian manufacturing. Though it is often suggested that MNEs carry out their innovative activities in their home countries (Annique and Cuervo-Cazurra 2008) rather than in their host countries, the situation has changed for countries like India in the post-liberalization era. With establishment and improvement of R&D laboratories in the host economy, foreign firms have started investing in innovative activities in the host economy (Sasidharan and Kathuria 2011). Again, since firm productivity often works through skills of workers (Yeaple 2005) and foreign firms often invest in R&D if supply of high-quality R&D personnel is available (Kumar 2001) in the host economy, India has become an important destination of FDI in R&D. The result of this study in the Indian context is in conformity with Kumar (2001) suggesting that MNEs invest in R&D activities in host economies. Further, the estimation result of Model 2 suggests that more productive foreign firms invest more in R&D activities in Indian manufacturing. This is an interesting result and the

[5]As the study explores the impact of foreign ownership on R&D intensity of firms, the 'ownership' variable does not consider the differences between public and private enterprises or proprietary and partnership enterprises.

[6]Sectorwise analysis of the relationship between R&D intensity of firms and the other variables can give a better insight as technology opportunities are likely to vary across sectors and R&D intensities would vary accordingly. However, this study considers Indian manufacturing as a whole. This is precisely because of the fact that number of foreign firms in certain sectors are too less as compared to the domestic firms and do not auger well for econometric estimation.

Table 6.4 Blundell–Bond (system GMM) estimation results

Variables↓	Model 1	Model 2	Model 3
R&D *L*1	0.6303359*** (0.0601315)	0.6572769*** (0.0609668)	0.6525242*** (0.0595499)
R&D *L*2	−0.124838* (0.0646184)	−0.1200692* (0.0657671)	−0.1192919* (0.0651938)
R&D *L*3	0.1372679** (0.0695254)	0.1510189** (0.071245)	0.1409477** (0.0700047)
Age	0.0141544 (0.0087272)	0.0139563 (0.008892)	0.0113312 (0.0086554)
Ownership	1.577941*** (0.5207738)		1.133372** (0.4629266)
Size	19.36425*** (5.668709)	14.66034*** (5.360657)	16.36112 (5.322065)
Size square	−19.38069*** (6.695841)	−15.99829** (6.655247)	−18.12652*** (6.660786)
ln TFP	−0.0711189*** (0.0239204)	−0.0891778*** (0.0251803)	−0.1170507*** (0.0404786)
ln fortech	−0.1453943** (0.0585175)	−0.0913735* (0.0538106)	
ln TFP × ln fortech			−0.022699* (0.0117403)
ln marketing cost	0.0854666 (0.1217983)	−0.0200547 (0.1155673)	−0.0007804 (0.1171515)
Ownership × ln TFP		0.1803538** (0.0770702)	
Ownership × ln fortech		−0.170985 (0.2668049)	
Constant	−2.403408*** (0.6531816)	−2.224367*** (0.6790555)	−2.13021*** (0.6419858)
Wald χ^2	229.47***	234.17***	234.91***

Note
(a) R&D intensity is the dependent variable
(b) Model is estimated considering ln TFP as endogenous
(c) *L*1, *L*2 and *L*3 are first, second and third lags, respectively
(d) Standard errors are reported in parentheses
(e) ***Implies significance at 1% level; **implies significance at 5% level; *implies significance at 10% level

reasons for the same can be varied. MNEs are often involved in research intensive production which is often linked with local innovative facilities. As Cantwell (1987) suggests that productive MNEs invest in R&D in host economies to facilitate their production and gain more from local science, technology, support and infrastructure. Again, if both the foreign and the host country have highly evolved technologically competitive markets, then MNEs often invest in local innovative activities or set up R&D centres in the host economy (Mrinalini et al. 2013). Such observations leave enough scope for further research on the issue.

In most emerging economies including India import of raw materials, capital goods and foreign technical know-how by firms is one of the major sources of acquiring knowledge from rest of the world. The existing literature in this context initiates debate on the issue of complementarity (Deolalikar and Evenson 1989; Siddharthan 1992; Aggarwal 2000) as well as substitutability (Fikkert 1993; Blumenthal 1979; Katrak 1990; Kumar and Siddharthan 1997) between R&D intensity and imported technology. This study suggests a negative and significant relationship between imported foreign technology with that of firm-level R&D intensity (see Model 1 and Model 2 in Table 6.4) implying substitutability. In a liberalized regime, with access to imported foreign technology, this is an expected result because a firm investing in foreign technology adapts it to local condition rather than investing further in innovative activities. Further, imported technology by foreign firms do not have any impact on their R&D activities. This complements our previous result that foreign firms in India invest in local R&D and hence do not depend on imported technology.

A significant path dependence of firm-level R&D intensity is evident implying that the past year's expenditure on R&D has a strong impact on the R&D expenses of the current year. This also shows the extent of a firm's learning experience (Bhaduri and Ray 2004) which facilitates innovative activities the firm. The estimation results also indicate that large-sized firms invest in R&D as size is found to be significantly affecting the R&D intensity of firms. Firm size is often considered to be a proxy for resource base, risk perception and economies of scale that crucially determines R&D activities of a firm (Kumar and Pradhan 2003). This is true for Indian manufacturing during the post-reforms. A significant nonlinearity also exists in this case. However, age of a firm and marketing costs remain insignificant in explaining firm-level R&D intensity in Indian manufacturing in all the three estimated models.

The estimation results of all the three models suggest that higher TFP of a firm significantly reduces its R&D intensity. This other-way-round relationship is an interesting finding suggesting that productive firms already have a competitive edge over other firms and they are not interested in investing further in R&D for Indian manufacturing as a whole. It is to be noted in this context and as discussed earlier that this is in contrary to the case for foreign firms. This might imply that more productive foreign firms invest more in R&D activities than their domestic counterparts in India. Again, the interaction between TFP and import of foreign technology is found to be significant and negative in sign. Therefore, import of foreign technology is found to have an indirect effect on R&D intensity of firms through TFP. The coefficient of this interaction term measures the change in effect of TFP on R&D intensity due to import of foreign technology. This is indicative of the fact that changes in factor productivity as a result of foreign technology imports at the firm level lead to a negative impact on R&D intensity of the firms in Indian manufacturing.

In sum, foreign ownership and large size of firms are important determining factors of innovative activities of firms across sectors in Indian manufacturing during post-reforms. Such activities also found to have strong path dependence.

However, imported technology and R&D intensity of firms are found to be negatively related suggesting that for Indian manufacturing, imported technology and R&D activities of firms are substitutes. Importantly, more productive foreign firms are found to invest more in R&D activities vis-a-vis the domestic firms in Indian manufacturing during post-reforms.

6.7 Conclusion

Technological upgradation and advancement is one of the major factors in achieving economic growth. Emerging economies like India have been striving hard to improve their technological conditions by both importing foreign technology as well as investing in indigenous R&D. Since technology decisions are taken at the firm level, empirical literature on the issue have given thrust on firm-level studies. Literature suggest that FDI and MNEs form one of the major channels of developing modern/new technologies in host economies. Thus, foreign ownership is likely to impact on the technology choices of firms. Again, easy access to foreign technology also might have an impact on a firm's innovative activities. This paper empirically investigates the role of these factors in determining R&D intensity of Indian manufacturing at the firm level during post-reforms. Dynamic panel data estimation for the period 2001–2010 suggests that foreign ownership, large size and previous experience of firms positively explain R&D intensity of firms in Indian manufacturing. Importantly, more productive foreign firms invest more in innovative activities in Indian manufacturing. This is an interesting result and calls for further research on the issue. Estimation results also reveal a significant substitutability between imported technology and local R&D for Indian manufacturing. Age of firms and marketing costs do not create any significant impact. However, for a firm in Indian manufacturing, a change in factor productivity due to imported technology has a detrimental effect on local R&D. Such evidence by itself creates a case for industrial policy interventions.

Appendix

See Tables 6.5 and 6.6.

Table 6.5 Classification concordance between NIC 1998, NIC 2004 and NIC 2008

Description	NIC 1998 2-digit	NIC 2004 2-digit	NIC 2008 2-digit
Chemical and chemical products	24	24	20 + 21
Basic metals	27	27	24
Food products and beverages	15	15	10 + 11
Motor vehicles, trailers and semi-trailers + other transport equipment	34 + 35	34 + 35	29 + 30
Textile products + wearing apparel, dressing and dyeing of fur	17 + 18	17 + 18	13 + 14
Machinery and equipment NEC + accounting and computing machinery	29 + 30	29 + 30	26 + 27 + 28

Table 6.6 Correlation matrix

	R&D	Age	Size	Marketing cost	TFP	Fortech
R&D	1					
Age	−0.0701**	1				
Size	−0.019	0.1886***	1			
Marketing cost	−0.0232	−0.0784**	0.1502***	1		
TFP	0.008	0.0028	0.0356	0.0823**	1	
Fortech	−0.0223	0.0166	0.0079	0.0398	−0.009	1

Note ***Implies significance at 1% level; **implies significance at 5% level; *implies significance at 10% level

Note

Estimation of Physical Capital Stock

Physical capital stock is estimated using the perpetual inventory method using data of Gross Fixed Assets (GFA) and taking 2004–05 as the base year. Since information on economic rate of depreciation of assets are not available, Gross Fixed Assets has been used instead of Net Fixed Assets. The revaluation factor for GFA is estimated as a ratio of GFA at replacement costs and GFA at historical costs. To obtain GFA at replacement cost, the GFP at capital stock needs to be revalued. GFA at replacement cost is obtained by multiplying GFA at historical cost by the revaluation factor (Srivastava 1996). To calculate the revaluation factor, the rate of growth of investment and the rate of change of price of capital stock are required. It is assumed that no firm has any capita stock in the base year (2004–05) of a vintage earlier than 1990–91 implying that the life of machinery is assumed to be fifteen years. The change in price of capital has been estimated. Wholesale Price Index (WPI) for machine and machine tools, available from the database of Reserve Bank of India, has been used as a proxy for price of capital. Finally, the rate of growth of gross fixed capital formation has been estimated with the assumption that investment has increased at a constant rate for all firms in an industry. Thus, the revaluation factor and capital stock has been estimated for all six industries separately.

Estimation of Total Factor Productivity

Total Factor Productivity in this study is calculated following Levinsohn and Petrin (2003). Recently, econometricians doing micro-econometric research have paid great attention to the problem of measuring Total Factor Productivity. Presence of correlation between unobservable productivity shocks and input levels make OLS estimator biased. Olley and Pakes (1996) suggest use of investment as a proxy for these unobservable shocks. However, this may produce inconsistent estimator especially when investments of firms are lumpy. In a semi-parametric model, using intermediate inputs instead of investment, Levinsohn and Petrin (2003) have addressed this simultaneity problem described by Marschak and Andrews (1944). Using intermediate input as proxies instead of investment has many advantages. Since intermediate inputs are not state variables, it renders a simple link between the estimation strategy and the economic theory. From a practical point of view, one may say that use of intermediate inputs as proxies avoids truncating all the zero investment firms, as investment proxy is only valid for firms reporting nonzero investment. In our study, presence of large number of zero observation on investment impelled us to use Levishon and Petrin (2003) method to estimate Total Factor Productivity considering use of energy as the proxy for unobservable productivity shocks. The brief idea of the estimation technique is as follows:

The logarithmic version of a Cobb-Douglas-type production function is as follows:

$$\ln Y_t = \beta_0 + \beta_1 \ln L_t + \beta_2 \ln K_t + \beta_3 \ln M_t + \omega_t + \eta_t \qquad (6.6)$$

where Y_t is the firm's output, commonly measured as the gross value added; L_t and M_t are labour and intermediate inputs, respectively; and K_t is the use of capital. The two components of the error namely the transmitted productivity component and the component which is uncorrelated with input choices are denoted by ω_t and η_t, respectively. OLS estimation technique ignores correlation between ω_t with other state variables resulting in inconsistent results. Demand for intermediate input m_t can be expressed as a monotonically increasing function of ω_t:

$$m_t = m_t(k_t, \omega_t) \qquad (6.7)$$

To get the function for the unobserved productivity term, the above function can be inverted as follows:

$$\omega_t = \omega_t(k_t, m_t) \tag{6.8}$$

Finally imposing an identification restriction following Olley and Pakes (1996) that productivity is governed by a first order Markov process, we have:

$$\omega_t = E[\omega_t|\omega_{t-1}] + \xi_t \tag{6.9}$$

where ξ_t is innovation to productivity that is uncorrelated with k_t but not necessarily with l_t.

Now, Eq. 6.1 can be rewritten as:

$$\begin{aligned} y_t &= \beta_0 + \beta_1 l_t + \beta_2 k_t + \omega_t + \eta_t \\ &= \beta_1 l_t + \phi_t(k_t, \omega_t) + \eta_t \end{aligned} \tag{6.10}$$

where $\phi_t(k_t, \omega_t) = \beta_0 + \beta_2 k_t + \omega_t(k_t, m_t)$. Estimation is carried out in two stages. In the first stage, replacing $\phi_t(k_t, \omega_t)$ by a third order polynomial, Eq. 6.4 is estimated using OLS technique. In the second stage, estimated value of $\phi_t(k_t, \omega_t)$ i.e. $\hat{\phi}_t$ and subsequently $\hat{\omega}_t$ are calculated. To calculate standard errors of $\hat{\beta}_1$ and $\hat{\beta}_2$ a Bootstrap approach is used. Finally, appropriate moment conditions are used to estimate $\hat{\beta}_0$ and $\hat{\beta}_3$. When all the $'\hat{\beta}'$s are estimated, the estimated values of TFP from the following equation are derived as follows:

$$\ln \mathrm{TFP}_t = \ln Y_t - \hat{\beta}_1 \ln L_t - \hat{\beta}_2 \ln K_t - \hat{\beta}_3 \ln M_t - \hat{\beta}_4 \ln E_t \tag{6.11}$$

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Part III
R&D and Innovations

Chapter 7
Innovation and Patent Protection: A Multicountry Study on the Determinants of R&D Offshoring

Giulia Valacchi

Abstract This paper looks at the role that intellectual property rights (IPR) protection plays in the decision of multinational corporations (MNCs) to locate their R&D activities abroad, a phenomenon which has been labelled in the literature as innovation offshoring. Do countries with stronger IPRs attract more offshored innovation? Do different types of innovation offshoring respond equally to IPR variations? Using a novel multicountry and multisector database gathering information on the innovation activity of more than 15,000 MNCs from all around the world, I am able to distinguish among two types of innovation offshoring: innovation carried out in nations different from the home country, where the firm undertakes production activities directly or indirectly through a subsidiary (commercial innovation), and research done in countries, where the MNC only collaborates with local firms or inventors, with no on-site production involved (external innovation). In order to better isolate the impact of property rights protection on R&D, my identification strategy takes into consideration IPR's variation across industries. I find that firms tend to locate commercial innovation in countries with strong IPR protection. This is true especially for long life-cycle industries which rely longer on patents. In contrast, short life-cycle technologies with faster obsolescence rate (e.g. high-tech products) are less responsive to IPR protection. External innovation, on the other hand, is less affected by patent protection, suggesting other motives behind its location decisions.

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G. Valacchi (✉)
Graduate Institute of Geneva, Geneva, Switzerland
e-mail: giulia.valacchi@graduateinstitute.ch

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7.1 Introduction

Innovation has been recognized as one of the driving factors for social development and growth. Increase in productivity is crucial for a world with limited resources that wants to keep improving its living standard, and minimizing input demand. R&D activity is still mostly concentrated in developed countries, even if, in recent years, it started to bloom in developing economies as well: for example China or India (UNCTAD 2005; OECD 2010). Location of inventions is crucial due to the tendency of R&D spillovers to be very localized (Jaffe et al. 1993; Coe and Helpman 1995; Helpman et al. 2008), and spreading them globally is at the top of the agenda for most policy makers in the world. Multinational corporations (MNCs), defined as firms with factories or other assets in at least one nation different from the home country, are responsible for the majority of the patenting activity across the globe: the 700 larger MNCs account for more than 70% of the world private R&D expenditures (UNCTAD 2005; OECD 2010). The attraction of MNCs' innovation investments in a country represents an open challenge for the policy maker. Patents' protection policies can help attracting R&D into a given country: IPRs aim to protect ideas incorporated into new products, and the intensity of this protection could affect a firm's decision to innovate in a given country (Boldrin and Levine 2002; Aghion et al. 2015). This paper analyses the impact of IPR in affecting MNCs decisions on where to locate their R&D. I use a newly created dataset containing information on the patenting activity of more than 15,000 multinationals undertaking research in 99 countries and 37 sectors in the years from 2005 to 2013. R&D location is identified by tracking inventors' addresses, which are publicly disclosed in patent records. My identification strategy exploits the fact that IPRs are more important for certain sectors, namely sectors with long life-cycles (e.g. metals and industrial production) than for those with short life-cycles (i.e. where products get obsolete faster) such as computer and other electronic equipment. Legal and socio-economic characteristics of a country affect patents' protection levels, but not products' life-cycle lengths, which only vary across industries. This enables me to isolate the effect of IPR protection on R&D activities. Two types of innovation offshoring are considered in this paper. Commercial innovation, on the one hand, takes place in locations, where the MNC undertakes production activities directly or indirectly through a subsidiary. External innovation, on the other hand, involves collaboration with foreign inventors, or firms, in countries, where the MNC does not hold any factory. There is a distinction between the two in the way they react to IPR intensity. I find that firms tend to locate commercial innovation in countries with strong IPR protection, particularly for long life-cycle industries that rely longer on patents. In contrast, short life-cycle technologies with faster obsolescence rate (e.g. high-tech products) are less responsive to IPR protection. External innovation, on the other hand, is overall less affected by the legal framework of the destination country. The difference between commercial and external innovation can be attributed to the fact that IPR strength matters more for commercialization rather than for innovation itself (Smarzynska Javorcik 2004). These findings are in line with the theoretical prediction of my model in Sect. 7.3. In this model, I argue that while MNCs always prefer to locate their commercial innovation in countries with strong IPR (see Proposition 1), it cannot be established, a priori, whether they prefer countries with strong or weak IPR in external R&D location choices (see Proposition 3).

This work contributes to three existing strands of the literature. First, it follows out theoretical studies on the relation between R&D and IPR (Boldrin and Levine 2002; Aghion et al. 2015). My results provide empirical evidence that MNCs prefer to perform commercial innovation in countries with strong patent protection, particularly for long life-cycle products, while they are less affected by the IPR's protection when it comes to external innovation. Second, it relates to existing work which empirically evaluates the impact of IPRs on multinational activities, such as foreign direct investments (FDI), production or trade, and technology transfers (Bilir 2014; Smarzynska Javorcik 2004; Branstetter et al. 2005, 2011). My analysis provides new insight on MNCs' innovative activity in a multicountry setting. Finally, this research is also linked to the international business literature on the globalization of R&D (Abramovsky et al. 2008; Defever 2006, 2012). Compared to this literature, I add new insights by making a distinction between commercial and external R&D.

The remainder of the paper is structured as follows. In Sect. 7.2, I deepen the literature review. Section 7.3 introduces the theoretical model. Section 7.4 describes the data sources. Section 7.5 presents the sample characteristics and the main descriptive statistics. In Sect. 7.6, I address my empirical strategy. Section 7.7 discusses the results and robustness checks of my estimation exercise. Finally, Sect. 7.8 concludes.

7.2 Related Literature

The relation between IPR stringency and innovation is currently unclear. On the one hand, it has been argued that extreme patent protection may interfere with the natural flow of information, blocking the development of other potentially useful inventions, and eventually suppressing competition (Boldrin and Levine 2002, 2008). On the other hand, it has been found that, without IPR protection, any reward for the innovators would disappear, inducing a disincentive to do research (Aghion et al. 2015). Acemoglu and Akcigit (2012) observed that IPR protection should be discriminated across actors, granting stronger protection to technology leaders and laxer shield to the followers, in order to maximize the innovation outcome. However, none of these articles looks at the across-sector variation of the impact of IPR on innovation. I use this variation for building an identification strategy to isolate the effect of IPR on R&D.

A more recent stream of the literature has developed empirical analyses about the impact of IPRs on commercial activities of multinationals such as FDI, trade and production. In her latest work, Bilir (2014) built an index of product life-cycle length that reflects sectors' innovation intensity. She measures the length of time in which a specific patent continues to receive citations from subsequent patents. Products with shorter life-cycles, such as computers or electronic equipment, tend to become obsolete faster; on the other hand, long life-cycle technologies exhibit lasting relevance to future innovations. Firms operating in longer life-cycle sectors are found to be more responsive to the strength of the host-country patent protection. These results are in line with Smarzynska Javorcik (2004), who find that weak protection deters foreign investors in technology-intensive sectors and it discourages them from undertaking local production. Similarly, Smith (2001) finds a positive correlation between sales of US affiliates and IPR protection strength in the destination country. None of these studies, however, considers specifically R&D activity that is the focus of this paper.

MNCs increasingly conduct innovation abroad, what Abramovsky et al. (2008) called innovation offshoring. They observe that R&D undertaken within a state is associated not only with companies from that nation, but also with foreign firms with subsidiaries based there (what I called commercial R&D) or foreign firms without any subsidiaries who are just collaborating with domestic companies or inventors (what I called external R&D). Innovation offshoring could be triggered by two kinds of factors (Kumar 1996; Odagiri and Yasuda 1996; Florida 1997; Belderbos 2001; von Zedtwitz and Gassmann 2002; Harrison et al. 2004; Belderbos et al. 2005). The first one is specific to the destination market, in which case the products of innovation are intended for the local factories of MNCs; this has been referred to, in the literature, as adaptive R&D. The second source of innovation offshoring involves a "techno-sourcing" motive, where the products of innovative activity are meant to be channelled back home. The relation between IPR, adaptive and techno-sourcing innovation has been extensively analysed in the theoretical literature.[1] Chen and Puttitanun (2005), among others, formalize the U-shaped relationship between the optimal strength of IPR and economic development: on the one hand, stronger protection makes investments in research, and consequently production related to its outcome, safer with longer-term returns (adaptive aspect); on the other hand, low protection allows diffusion of ideas through local imitation (techno-sourcing aspect). Kerr and Kerr (2015) empirically studied collaborative patents.[2] They find a greater likelihood for these patents to be registered when a firm enters a new foreign country for innovative work. In this case, the company prefers weak IPR protection, which allows capturing more easily the existing local knowledge. The authors' definition of collaborative patents may look similar to what I called external innovation. However, these two concepts are distinct since external R&D does not necessarily involve a domestic inventor. Following my

[1]Recently Noailly and Ryfisch (2015) conducted an analysis on the motives behind the offshoring of green patents.

[2]Collaborative patents are defined as patents where at least one inventor is located outside and one inventor inside the home country of the firm the patent belongs to, but no distinction is made for inventors based in countries where the MNC holds some productive activities and countries where it has no subsidiary at all.

definition, external innovation has no association with local production activities. This implies that it has a higher probability to be induced by technology-seeking rather than adaptive motives, and therefore, it is not driven by strong IPR protection. This paper provides a contribution to this topic, showing that, while IPR stringency is a key indicator for attracting commercial R&D, particularly for longer life-cycle products' industries, it matters less for external innovation.

Recently, Griffith and Macartney (2014) have studied the impact of employment protection legislation on innovation. This paper builds heavily on the framework of Griffith and Macartney, but it focuses on the role of IPR, rather than labour protection. Additionally, it introduces multisector analysis and the distinction between commercial and external innovation, which was not present in the original setting.

7.3 Theoretical Framework

In order to analyse R&D offshoring determinants, I frame a simple partial equilibrium model that evaluates separately commercial and external R&D. I start with the case of commercial innovation. A firm i, innovating in sector s, in a foreign country c where it exerts a production activity, wants to maximize its return from R&D, Π:

$$\Pi_{i,s,c} = \left(\pi_{i,s,c} - k_{i,s,c}\right)\mathrm{MIN}(t_s, m_c) + \sum_{z \neq i} k_{z,c,s}\left[T_{\mathrm{MAX}} - \mathrm{MIN}(t_s, m_c)\right] + \varepsilon_{i,s,c} \quad (7.1)$$

where π is a fixed profit which the company is going to realize, every year, from the sales of the R&D products in sector s, in the country c, until it becomes obsolete (at time t), or imitation occurs from competitors (at time m); m is associated with IPR protection: the stronger the IPR, the more difficult it would be for competitors to imitate the technology, and thus, the bigger is m; k_{i} is the firm's own knowledge in that industry which it is able to protect until the invention becomes obsolete or the idea is stolen by competitors, depending on what comes first; k_{i} represents value of knowledge protection to the firm: without flowing of information, the MNC protects its know-how, indirectly gaining from it (this can be attributed to the adaptive innovation rational); $\sum_{z \neq i} k_z$ is the knowledge of all the other competitors of firm i present in country c and innovating in the same sector.[3] This know-how becomes accessible only after the innovative products turn obsolete (at time t), unless a possibility for imitation arises first (at time m). In this perspective, having a laxer IPR protection system (or lower m) would be beneficial for firm i which can access its competitors' information sooner (this can be attributed to the technology-seeking

[3] All the derivations consider the scenario where a unique competitor j is present in both countries. Nonetheless, the results extend easily to the case of a multi-competitor scenario where the firm has more than just one rival in the foreign market.

rational). Following Bilir (2014), I believe that the obsolescence time t is an industry-specific characteristic, as different sectors have different life-cycle lengths. T_{MAX} is the maximum obsolescence period. $\varepsilon_{i,s,c}$ accounts for possible unobservables at firm, country and sectoral level; it justifies the fact that I observe innovation in all countries and sectors both with strong and low IPR. This component is drawn independently across country-sector pairs according to a known distribution.

Firm i can observe everything, except for the imitation factor: it does not know when imitation will occur; it only knows that, in countries with higher IPRs, there is a lower possibility of early arrival, compared to laxer countries.

Assumption 1 The imitation time m in country c is uniformly distributed: $m_c = U(0;\overline{m_c});\overline{m_c}$ is the upper limit for m in c.

Firm i can decide between locating its R&D in two countries, North (N) and South (S), which are perfectly symmetric, with the same π and k, and only differ on the level of IPR protection.

Assumption 2 North has stronger law enforcement and therefore a lower probability of imitation, while South has laxer protection, and thus, imitation can arise sooner: $\overline{m_{\mathrm{N}}} > \overline{m_{\mathrm{S}}}$.

When comparing the firm's expected returns from R&D in these two countries, I find[4]:

$$E\left(\Pi_{i,\mathrm{N},s}\right) - E\left(\Pi_{i,\mathrm{S},s}\right) = \left(\frac{1}{\overline{m_{\mathrm{S}}}} - \frac{1}{\overline{m_{\mathrm{N}}}}\right)\left[\frac{t_s^2}{2}\left(\pi_{i,s} + k_{i,s}\right) - \frac{k_{j,s}t_s^2}{2}\right] \tag{7.2}$$

Proposition 1 *For sufficiently high commercial profits* π, $E\left(\Pi_{i,\mathrm{N},s}\right) > E\left(\Pi_{i,\mathrm{S},s}\right)$ *implying that a multinational always decides to locate its commercial innovation in the country with the strongest IPR protection, no matter whether it is pursuing adaptive or technology-seeking R&D.*

In order to find which industry s the firm prefers to offshore in terms of R&D, it maximizes Eq. 7.1 over the sectoral time maturity t finding a threshold level:

$$t^* = \overline{m_C} \tag{7.3}$$

it chooses to offshore all sectors with $t_s < t^*$. It is reasonable to think that innovation offshoring for products with high t is more prone to imitation than those with shorter life-cycles, putting at risk the return from sales of the company.

Lemma 1 *Assumption 1, combined with the optimality condition in* Eq. 7.3, *entails that the country with stronger IPR protection can host innovative activity for a wider variety of sectors:* $t_{\mathrm{N}}^* > t_{\mathrm{S}}^*$.

[4]For simplicity, the two countries are assumed to be symmetric; therefore, $\pi_{i,\mathrm{N},s} = \pi_{i,\mathrm{S},s} = \pi_{i,s}, k_{i,\mathrm{N},s} = k_{i,\mathrm{S},s} = k_{i,s}$ and $k_{j,\mathrm{N},s} = k_{j,\mathrm{S},s} = k_{j,s}$. For a better understanding of the resolution mechanism, please refer to Appendix 1.

From Lemma 7.1, it follows that there is an interval of sectors $t^*_{\mathrm{N}} > t_s > t^*_{\mathrm{S}}$ for which location in North is crucial, as their R&D would be offshored to North but not to South.

Proposition 2 *Location of commercial R&D in nations with stronger IPR protection matters more for long product life-cycle sectors rather than short life-cycle ones.*

Now, I move on to the case of external R&D. As highlighted before, this is the case when the MNC does not have any production activity in the country where it decides to locate its R&D.

This translates into:

$$\pi^x_{i,s,c} = 0 \tag{7.4}$$

where the superscript x indicates all variables referring to external innovation. In this context, (7.2) reads:

$$E\left(\Pi^x_{i,\mathrm{N},s}\right) - E\left(\Pi^x_{i,\mathrm{S},s}\right) = \left(\frac{1}{\overline{m}_{\mathrm{S}}} - \frac{1}{\overline{m}_{\mathrm{N}}}\right) \frac{t_s^2\left(k^x_{i,s} - k^x_{j,s}\right)}{2} \tag{7.5}$$

Proposition 3 *It cannot be established, a priori, whether a multinational prefers to locate its external R&D in countries with stronger or weaker IPRs; this decision is influenced by the nature of the innovation itself, which can be more adaptive or more technology-sourcing oriented.*

Combining Eqs. 7.2 and 7.5, I obtain:

$$\left[E\left(\Pi_{i,\mathrm{N},s}\right) - E\left(\Pi_{i,\mathrm{S},s}\right)\right] - \left[E\left(\Pi^x_{i,\mathrm{N},s}\right) - E\left(\Pi^x_{i,\mathrm{S},s}\right)\right] = \pi_{i,s}\frac{t_s^2}{2} > 0 \tag{7.6}$$

Proposition 4 *The attraction towards stronger IPR's countries always matters more for commercial rather than for external innovation.*

In the second part of this work, theoretical results have been tested empirically using a newly created database described in the next section.

7.4 Data Sources

My dataset merges four types of information: (1) firm-level data, which are used to build the group structure of each enterprise, and to identify countries where the company is present directly or indirectly through a subsidiary; (2) patent data, which identify innovation and, more specifically, innovation location; (3) country-level data, which capture countries' characteristics; (4) sector-level data, which add industry-specific life-cycle information.

Firm-Level Characteristics: I access micro-level data on firms from Orbis of Bureau van Dijck, a commercial database which contains information on more than 120 million companies around the world,[5] and focuses on the biggest players in the market, which are also the most active ones in terms of research activity. I restrict my selection to MNCs with at least one granted[6] patent between 2005 and 2013.[7] According to my definition, a multinational consists of a group's headquarters and some subsidiaries of which, at least one, needs to be located in a different country from the parent company. The subsidiaries represent an extension of the firm itself, and they are a possible mean through which the holding company conducts its activities, including R&D investments. For this reason, I used Orbis to rebuild the ownership structure of each innovating company. Since not all subsidiaries are of the same importance to a firm, I restrict my attention to those with an ownership share of more than 25%.[8] With this approach, I am also able to identify in which countries a company is present and conducts some production activities. This helps me to distinguish between commercial and external innovation.

Innovation: Orbis provides information on patents, held by a firm, through the European Patent Office (EPO) PATSTAT dataset. It includes names and addresses of the inventors that collaborated in the creation of each patent. The inventor's address is of particular importance in my analysis since it enables me to geographically localize the invention. A major advantage of using Orbis is that it harmonizes all inventors' names in order to merge them with business-related data; therefore, information is, presumably, more precise. In order to remove equivalent patents[9] from the sample, I base my analysis on the priority date[10] rather than on the application date.[11] I select only granted patents in order to restrict the focus to higher quality innovation (OECD 2010). External innovation, for a MNC, is measured as the fraction of patents attributable to scientists' resident in a country, different from the home one, where the firm does not have any subsidiary. Similarly, to assess commercial innovation, I count the number of patents associated with inventors whose primary residence is a nation where the MNC holds at least one subsidiary.

Country Characteristics: To capture the IPR protection in each country, I use two indicators:

[5] Last update as of December 2015.

[6] Granted patents are typically a higher value measure for innovation rather than just patent application which contains also patents refused or withdrawn (Guellec and Pottelsberghe de la Potterie 2000; Zuniga et al. 2009).

[7] This is the period for which I have available data on IPR protection in each state.

[8] For a detailed explanation on the process of data extraction from Orbis and sample creation, please refer to Appendix 2.

[9] A patent family which includes all patent documents sharing exactly the same priority patent.

[10] The priority date is the first absolute date of patent filing everywhere in the world.

[11] The application date is the date of patent filing in a specific patent office.

1. The World Economic Forum (WEF) index, which is an experience-based measure built with an Executive Opinion Survey that interrogates a representative sample of business leaders in their respective nations. Each of them is called to answer the following question: "*In your country, how strong is the protection of intellectual property, including anti-counterfeiting measures? (1 = extremely weak; 7 = extremely strong)*". This index gives a fair representation of the perception of the firm about the patent protection in each state. Additionally, it presents the advantage of an extensive geographical coverage, and it is therefore appropriate for my multicountry study. However, the main drawback of this index is that data are only available starting from 2004.
2. The Ginarte and Park (1997) (GP) updated index[12]; it provides a statutory measure,[13] alternative to the WEF index, of country-level IPR protection aggregating five different categories: (1) coverage, (2) membership in international patent treaties, (3) provisions for losses, (4) enforcement and (5) duration of protection. The GP index dates back to 1960, but it is only assessed every 5 years. Therefore, linear interpolation becomes necessary in order to derive a single value for each year of the analysis, and to make the index suitable for the panel data estimation.

As a control variable, I also include information on the GDP level per capita, which I gather from the World Bank's Development Indicators.[14]

Sector Characteristics: By employing the concordance tables from Lybbert and Zolas (2014), I am able to match each patent's International Patent Classification (IPC) code with its sector/s of use. With the inclusion of Bilir's index,[15] it is possible to control for different life-cycle lengths at the sector level. This index is built using information on patent citations in the USA, which I assume should not differ systematically from the rest of the world.

It covers 37 industries from the 1987 three-digit Standard Industrial Classification (SIC). Table 7.1 shows the sectors with the longest and shortest product life-cycle lengths. Electronics and computer-related sectors are the ones that get obsolete faster, while metals and hardware products, on average, have a longer patent citation lag.

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[12]See Park (2007).

[13]For an in-depth distinction between experience-based and statutory measure of IPRs, see Park (2007).

[14]I have information about GDP per capita only available starting from 2003; therefore, even if the GP index would enable a longer period analysis, I decide to restrict it to the period (2005–2013).

[15]See Bilir (2014).

Table 7.1 Product life-cycle lengths by sector

Short life-cycle sectors	Life-cycle length (T)	Long life-cycle sectors	Life-cycle length (T)
Electronic machinery	6.73	Fabricated structural metal products	10.25
Watches, clocks and clockwork operated devices	7.37	Cutlery, hand tools and general hardware	10.41
Computer and office equipment	8.38	Screw machine products, bolts, nuts and screws	10.42
Agricultural chemicals	8.69	Metal cans and shipping containers	10.63
Electronic components and accessories	8.83	Heating equipment, except electric	10.89

The table is taken from Bilir (2014), and it shows the top and bottom five industries for products' life-cycle lengths

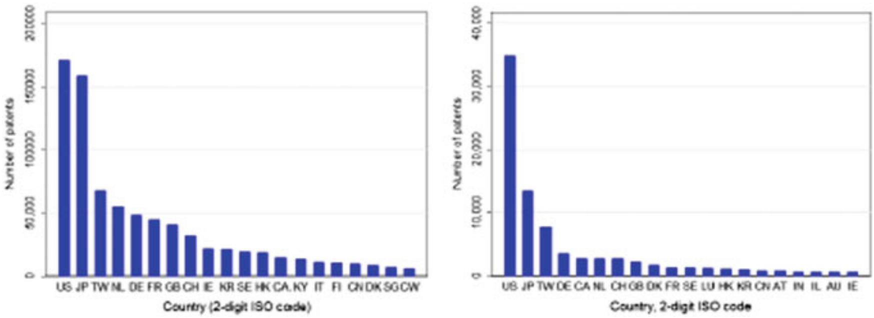
7.5 Descriptive Trends

My dataset includes around 1.2 million patents granted to almost 15,000 MNCs in 99 countries and 37 sectors across 9 years. Only 30% of this innovation can be classified as offshored: 92% of total offshored R&D takes the form of commercial R&D, while the remaining 8% is external.

Figure 7.1 shows the home countries with the top innovative firms, while Fig. 7.2 plots the destination countries for innovation by the top innovative firms. In both cases, a distinction is made between commercial (see Fig. 7.2a) and external innovation (see Fig. 7.2b). Origin countries for innovative companies do not differ significantly across the two categories of R&D, with the most active nations being the USA and Japan. Nevertheless, there are differences among MNCs which offshore their innovation: 30% of them report both commercial and external R&D, 49% of them only pursue commercial innovation, while 21% of them only undertake external innovation. In order to avoid asymmetries across firms, which I am unable to control for, I restrict the analysis only to MNCs initiating both commercial and external innovation.

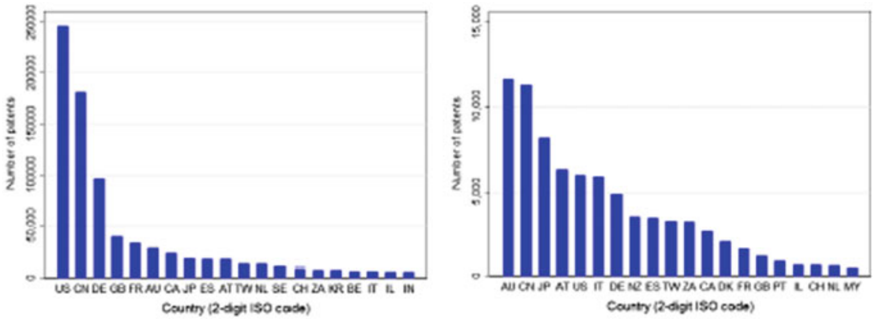
In this way, my sample shrinks to 3237 MNCs, but I believe that the two sets of firms under study are exactly the same. On the other hand, the divergence in Fig. 7.2 points to differences in the composition of the destination country group. Commercial innovation is concentrated in few bigger countries such as the USA, China or Germany, where the probability for the MNC to hold a subsidiary is larger. On the contrary, external innovation is dispersed across smaller or more remote economies,[16] where the probability of establishing a subsidiary is much lower.

[16]Among the biggest recipient countries for external innovation, there are, for example, Austria, Spain, New Zealand, Australia and South Africa.



(a) Commercial Innovation (b) External Innovation

Fig. 7.1 Top 20 home countries for innovation



(a) Commercial Innovation (b) External Innovation

Fig. 7.2 Top 20 destination countries for innovation

Figure 7.3 compares the average IPR strength of the destination country for commercial and external R&D. IPR protection is, on average, stronger in those countries where innovation is initiated along with production activities, rather than undertaken externally. This confirms the findings in Smarzynska Javorcik (2004), which stress that IPR protection matters more for commercialization purposes rather than innovation itself.

I plot, in Fig. 7.4, the average life-cycle length of patents in the commercial and the external division. Contrary to the IPR intensity in Fig. 7.3, no substantial distinction between the two categories appears here: sectors in which firms innovate more actively are substantially the same. This confirms the hypothesis that there is not a priori distinction between commercial and external innovation: the two kinds of R&D activities are initiated by the same sample of firms in similar sectors; there are no specific firms carrying out only one kind of R&D. In addition,

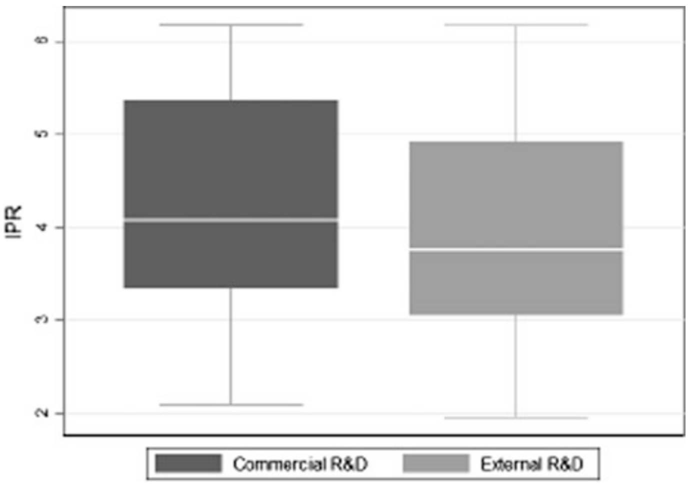


Fig. 7.3 IPR intensity in the destination country for different types of innovation

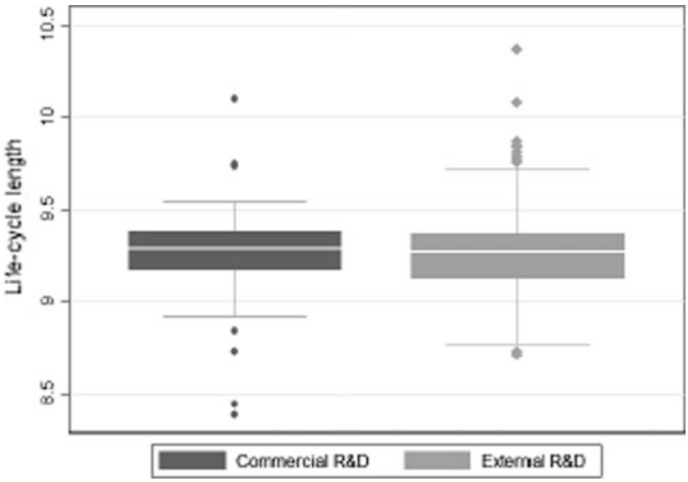


Fig. 7.4 Life-cycle lengths for different types of innovation

neither commercial innovation nor external innovation is sector specific. Any differences between the two categories should be attributed to asymmetries in the destination country's specific characteristics, particularly to different IPR intensities, which is the highlight of my analysis.

7.6 Empirical Model

Since my dataset unravels multiple dimensions (namely firm/country of origin, country of destination, sector and year), I decide, for simplicity sake, to aggregate the analysis up and remove the firm's dimension. Therefore, I omit all country of origin's specific characteristics, as well as firm-specific features from the empirical estimation. This procedure does not jeopardize the validity of the results due to the assumption that countries of origin and firms do not differ between commercial and external innovation.

Following my theoretical model prediction, I can derive the main equation to be estimated:

$$\begin{aligned} \ln\left(P_{j,k,t}\right) = \alpha + \beta_1 \mathrm{IPR}_{k,t} T_j + \beta_2 \mathrm{IPR}_{k,t} T_j^2 + \gamma_1 \ln \mathrm{GDP}_{k,t} T_j \\ + \gamma_2 \ln \mathrm{GDP}_{k,t} T_j^2 + \eta_j + \eta_{k,t} + \varepsilon_{j,k,t} \end{aligned} \tag{7.7}$$

where $P_{j,k,t}$ represents the number of patents invented in country k,[17] sector j, at time t[18]; $\mathrm{IPR}_{k,t}$ is the IPR protection ascertained in country k in year t; T_j is the life-cycle length of sector j as measured in Bilir (2014) index; and $\ln\mathrm{GDP}_{k,t}$ is the logarithm of the gross domestic product per capita in country k at time t in current US dollars. A set of fixed effects is included to make sure that I control for unobservables which may affect the innovation activity. In particular, I consider: (1) sectoral features (η_j) which are difficult to capture[19]; (2) conditions which are specific to a country in a certain year ($\eta_{jk,t}$) such as national reforms, competition levels or law enforcements. The error term $\varepsilon_{j,k,t}$ combines any omitted factor that affects the innovation activity pattern. β_1 is the coefficient attached to the interaction term between IPR protection and the life-cycle length, T; it is of particular interest as it disentangles the IPR effect across sectors with different time lengths. β_2 allows for the possibility of a non-monotonic relationship between IPR and innovation. Different orders of interaction terms between T and GDP per capita, γ_1 and γ_2, are also included to improve the identification of the β-effects. Since countries with high GDP level per capita, typically, also have a strong legal system and consequently better patent protection, I want to be sure to disentangle the impact of overall development from the more specific influence that IPR protection could have on innovation decisions.

[17]The invented patents are defined as the number of patents attributable to inventors residing in country k.

[18]If I indicate with z a specific MNC in my sample, then $P_{j,k,t} = \sum_z P_{z,j,k,t}$.

[19]Cohen and Levin (1989) talk about the differences in opportunities for technical advance across sectors which are difficult to make "empirically operational".

7.6.1 Identification Strategy

Some concerns may arise about possible endogeneity problems in the estimation exercise. First of all, intellectual property rights stringency is correlated with several economic and legal factors. Strengthening IPR typically comes along with other policies which improve the quality of the legal system.[20] This makes it very difficult to identify the real contribution of IPR in attracting innovation in a nation, as it could capture effects of different policies, such as trade or tax reforms which also favour firms' R&D activities. Introducing the interaction term between IPR and T, I am able to capture the real effect of IPR protection on innovation as T varies across sectors and stays independent of firms' sensitivity to overall institutions and development levels of a country. The index of life-cycle length, T, comes from Bilir (2014), and it is built using US patent citation data.[21] Since the index is a sector-specific measure, it does not vary across countries, and therefore, data estimated from the USA can be applied to my full sample. Nonetheless, as a robustness check (see Sect. 7.1), I run the same analysis removing all North American innovation from the sample. I find no divergence from the original findings which convinces me that T is not related to a precise country but, conversely, is a sector-specific characteristic and can be used in a multicountry study like this.

Finally, patents are not fully elastic, and it is reasonable to assume that they take some time to adjust to changes in IPR regulations. In order to avoid simultaneity issues between patenting and IPR protection, I regress the number of patents whose priority date has been registered in a year t on the moving average of the IPR measure between t and $t-1$. In Sect. 7.1, as a robustness exercise, I include different lags on all controls of Eq. 7.7.

7.6.2 Main Hypotheses

From Sect. 7.3, a number of hypotheses can be derived, which can be tested in the estimation[22]:

1. $\beta_1 > 0$: from Proposition 1, commercial innovation always prefers countries with stronger IPR protection; therefore, I expect to find a positive and statistically significant β_1;

---

[20]The decision to strengthen IPR system protection often is motivated by a compliance trigger such as joining a new transnational organization or agreement which requires the member states to undertake certain policies to reach target goals in terms of institutional quality.

[21]The author calculates the length of time during which a given patent continues to be cited by subsequent patents.

[22]Notice that there is no superscript associated with coefficients that refer to commercial innovation, while the superscript x indicates external innovation.

2. $\beta_1^x \lesseqgtr 0$: following Proposition 3, the sign of β_1^x cannot be anticipated; the sign of this coefficient can be dragged by the specific nature of the external innovation, which can be more adaptive (positive sign) or more techno-sourcing (negative sign) oriented;
3. $\beta_1 > \beta_1^x$: Proposition 4 implies that commercial innovation always values more stronger IPR's protection countries rather than external innovation; therefore, I expect to find a β_1 greater and statistically different from β_1^x.

7.7 Results

Table 7.2 reports the results of the OLS estimations for commercial and external innovation. I run a fixed effects estimation of the baseline regression in Eq. 7.7, including country-year and sector fixed effects. Judge et al. (1985) show that the OLS procedure performs best when the dependent variable is continuous (i.e. it can assume both integer and non-integer values) and normally distributed, which is the case for the patents' count adopted in this paper. Columns 1, 3, 5 and 7 use, as the main regressor, the IPR measure from the WEF, columns 2, 4, 6 and 8 use instead the GP index. Columns 1, 2, 3 and 4 regress the number of patents on both IPR and GDP per capita without including any interaction term. In this oversimplified setting, an important difference among the two types of R&D can already be noticed: the coefficients associated with IPR are positive and significant for both types of innovation, but it is much stronger for commercial rather than external innovation. However, as highlighted before, this type of estimation can suffer from endogeneity problems; therefore, I do not linger here excessively. Columns 5, 6, 7 and 8 represent the main specification of the model, respectively, for commercial and external R&D, where both the first- and second-order interaction terms between GDP and T are included. Columns 5 and 6 show that, indeed, commercial innovation concentrates in countries with stronger law enforcement: the largest impact is registered for sectors with longer life-cycle duration. These industries are systematically more responsive to IPR protection in the destination country. The second-order interaction term (IPR $\times$ T^2) is also significant confirming Bilir's prevision about the nonlinearity of the relation between IPR and T which reaches its highest effect in mid-length life-cycles sectors. IPR is positive and significant also for external R&D, as it is shown in columns 7 and 8; nevertheless, the interaction effect between IPR and life-cycle's length is more than halved, if compared to commercial innovation. This corroborates the idea that IPR stringency does not matter much for external innovation which may be driven by factors other than law enforcement. Innovation is also attracted into countries with higher GDP per capita, which are typically bigger countries with a larger demand for goods. Similarly, this feature matters more in explaining commercial rather than external R&D. This reflects the fact that external innovation does not entail commercialization purposes and it is less driven by business-related factors, such as demand for goods and invention protection.

Table 7.2 IPR protection and innovation—fixed effect estimation, commercial and external R&D

Dependent variables	Commercial innovation		External innovation		Commercial innovation		External innovation	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IPR	0.079*** (0.015)	0.166*** (0.061)	0.051*** (0.010)	0.161*** (0.041)	–	–	–	–
lnGDP	0.228*** (0.030)	0.231*** (0.033)	0.138*** (0.020)	0.207*** (0.023)	–	–	–	–
IPR·T	–	–	–	–	0.546*** (0.052)	0.927*** (0.081)	0.237*** (0.040)	0.385*** (0.051)
IPR·T^2	–	–	–	–	−0.034*** (0.003)	−0.057*** (0.005)	−0.015*** (0.002)	−0.024*** (0.003)
lnGDP·T	–	–	–	–	0.659*** (0.037)	0.642*** (0.038)	0.350*** (0.029)	0.378*** (0.030)
lnGDP·T^2	–	–	–	–	−0.040*** (0.002)	−0.039*** (0.002)	−0.022*** (0.002)	−0.023*** (0.002)
Country FE, year FE	Yes	Yes	Yes	Yes	No	No	No	No
Country-year FE	No	No	No	No	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	25,049	21,201	25,049	21,201	25,049	21,201	25,049	21,201

Country-year and sector fixed effects are included in all estimations. Dependent variable is inserted in logarithmic form. Cluster-robust standard errors are in parentheses. *, ** and ***, respectively, denote significance at 10, 5 and 1% levels. Coefficient of constant has not been reproduced

The empirical analysis confirms both hypotheses 1 and 3. For what concerns hypothesis 2, external R&D is found to be more adaptive rather than techno-sourcing oriented, as it still shows attractiveness towards high-IPR countries. However, as expected, this attractiveness is limited with respect to the case of commercial R&D.

7.7.1 Robustness Checks

My results are robust to different specifications of the fixed effects.[23] I decided to include sector and country-year fixed effects which are able to better capture most of the variation along different dimensions of the dataset.

The life-cycle index, *T*, has been built using information on patent citations in the USA.[24] Even though I believe that it reflects sector-specific characteristics, which should remain the same across different countries, there is still the possibility of it being country-specific; in this case, the analysis conducted so far would be invalid. In order to avoid endogeneity issues with the use of *T*, I remove all innovation undertaken in the USA from my sample. This ensures the removal of the bias associated with the possibility of life-cycle length being US-specific. In this specification, my previous findings still hold confirming the validity of my assumption (see Table 7.4).

Considering that the granting process of a patent could take up to some years, I expect my sample of patents to be downward-biased towards the end of the period; also, this may differ depending on the application authority, as in certain countries might be faster to obtain a granted patent than in others. In order to avoid this type of distortion, and check the robustness of my specification to changes in the time interval under analysis, I run the same estimation on the shorter window (2004–2008). I exclude more recent years, when the granting distortion has a greater probability to arise. In this way, I also get rid of the years of the financial crisis which fully exploded at the very end of 2008, even though the country-year fixed effect should have already controlled for this event. Results do not change, as reported in Table 7.3: coefficients are rather stronger in such a specification (Table 7.4).

As a control for the simultaneity bias between patent law implementation and patent applications, I run the same specification of Eq. 7.7 in Tables 7.5 and 7.6 using, respectively, first the one-period lag, and then the two-period lag of the IPR, and results are robust. Adding temporal lags reduces progressively the coefficient associated with the interaction between IPR and *T*. This change in size is normal if we consider that increasing in IPR influences progressively less innovation which is more far away in time, eventually converging to a long-term effect of 0. Nevertheless, the coefficients for both types of R&D remain positive and significant.

[23]For example, I run the same regressions using sector-country specific fixed effects and a time trend or using the three distinct effects, country sector and time, finding exactly the same results.

[24]See Bilir (2014).

Table 7.3 Robustness checks—(2004–2008) period

Dependent variables	Commercial innovation		External innovation		Commercial innovation		External innovation	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IPR	−0.002 (0.031)	0.155 (0.099)	0.005 (0.021)	0.219*** (0.068)	–	–	–	–
lnGDP	0.121** (0.061)	0.081 (0.050)	0.097** (0.041)	0.112*** (0.035)	–	–	–	–
IPR·T	–	–	–	–	0.575*** (0.077)	0.972*** (0.099)	0.278*** (0.061)	0.435*** (0.065)
IPR·T^2	–	–	–	–	−0.036*** (0.004)	−0.060*** (0.006)	−0.017*** (0.004)	−0.027*** (0.004)
lnGDP·T	–	–	–	–	0.736*** (0.056)	0.691*** (0.046)	0.409*** (0.045)	0.424*** (0.036)
lnGDP·T^2	–	–	–	–	−0.045*** (0.003)	−0.042*** (0.003)	−0.025*** (0.003)	−0.026*** (0.002)
Country FE, year FE	Yes	Yes	Yes	Yes	No	No	No	No
Country-year FE	No	No	No	No	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13,135	14,615	13,135	14,615	13,135	14,615	13,135	14,615

Country-year and sector fixed effects are included in all estimations. Dependent variable is inserted in logarithmic form. Cluster-robust standard errors are in parentheses. *, ** and ***, respectively, denote significance at 10, 5 and 1% levels. Coefficient of constant has not been reproduced

Table 7.4 Robustness checks—without US innovation

Dependent variables	Commercial innovation		External innovation		Commercial innovation		External innovation	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IPR	0.071*** (0.015)	0.158*** (0.059)	0.046*** (0.010)	0.158*** (0.041)	–	–	–	–
lnGDP	0.220*** (0.030)	0.219*** (0.032)	0.135*** (0.020)	0.205*** (0.022)	–	–	–	–
IPR·T	–	–	–	–	0.545*** (0.052)	0.925*** (0.081)	0.234*** (0.040)	0.381*** (0.050)
IPR·T^2	–	–	–	–	−0.034*** (0.003)	−0.057*** (0.005)	−0.015*** (0.002)	−0.024*** (0.003)
lnGDP·T	–	–	–	–	0.643*** (0.039)	0.632*** (0.040)	0.325*** (0.031)	0.354*** (0.031)
lnGDP·T^2	–	–	–	–	−0.039*** (0.002)	−0.038*** (0.002)	−0.020*** (0.002)	−0.022*** (0.002)
Country FE, year FE	Yes	Yes	Yes	Yes	No	No	No	No
Country-year FE	No	No	No	No	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	24,790	20,942	24,790	20,942	24,790	20,942	24,790	20,942

Country-year and sector fixed effects are included in all estimations. Dependent variable is inserted in logarithmic form. Cluster-robust standard errors are in parentheses. *, ** and ***, respectively, denote significance at 10, 5 and 1% levels. Coefficient of constant has not been reproduced

Table 7.5 Robustness checks—one-period lagged IPR

Dependent variables	Commercial innovation		External innovation		Commercial innovation		External innovation	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IPR	0.057*** (0.018)	0.126 (0.101)	0.026** (0.012)	0.067 (0.068)	–	–	–	–
lnGDP	0.219*** (0.038)	0.214*** (0.052)	0.107*** (0.025)	0.171*** (0.035)	–	–	–	–
IPR·T	–	–	–	–	0.542*** (0.056)	0.933*** (0.094)	0.220*** (0.044)	0.342*** (0.058)
IPR·T^2	–	–	–	–	−0.034*** (0.003)	−0.058*** (0.006)	−0.014*** (0.003)	−0.022*** (0.003)
lnGDP·T	–	–	–	–	0.686*** (0.040)	0.653*** (0.045)	0.366*** (0.033)	0.382*** (0.036)
lnGDP·T^2	–	–	–	–	−0.042*** (0.002)	−0.040*** (0.003)	−0.022*** (0.002)	−0.023*** (0.002)
Country FE, year FE	Yes	Yes	Yes	Yes	No	No	No	No
Country-year FE	No	No	No	No	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	20,202	14,578	20,202	14,578	20,202	14,578	20,202	14,578

Country-year and sector fixed effects are included in all estimations. Dependent variable is inserted in logarithmic form. Cluster-robust standard errors are in parentheses. *, ** and ***, respectively, denote significance at 10, 5 and 1% levels. Coefficient of constant has not been reproduced

Table 7.6 Robustness checks—two-period lagged IPR

Dependent variables	Commercial innovation		External innovation		Commercial innovation		External innovation	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IPR	0.037* (0.021)	0.222 (0.145)	−0.026* (0.014)	0.148 (0.098)	–	–	–	–
lnGDP	0.146*** (0.045)	0.114* (0.063)	0.072** (0.029)	0.129*** (0.043)	–	–	–	–
IPR·T	–	–	–	–	0.536*** (0.060)	0.911*** (0.104)	0.187*** (0.048)	0.301*** (0.064)
IPR·T^2	–	–	–	–	−0.034*** (0.003)	−0.056*** (0.006)	−0.012*** (0.003)	−0.019*** (0.004)
lnGDP·T	–	–	–	–	0.702*** (0.044)	0.667*** (0.052)	0.375*** (0.038)	0.386*** (0.043)
lnGDP·T^2	–	–	–	–	−0.043*** (0.003)	−0.040*** (0.003)	−0.023*** (0.002)	−0.024*** (0.003)
Country FE, year FE	Yes	Yes	Yes	Yes	No	No	No	No
Country-year FE	No	No	No	No	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	16,502	11,211	16,502	11,211	16,502	11,211	16,502	11,211

Country-year and sector fixed effects are included in all estimations. Dependent variable is inserted in logarithmic form. Cluster-robust standard errors are in parentheses. *, ** and ***, respectively, denote significance at 10, 5 and 1% levels. Coefficient of constant has not been reproduced

7.8 Conclusions

This paper analyses innovation responsiveness to intellectual property rights protection. The analysis of a newly created dataset allows me to distinguish among two types of innovation offshoring: commercial innovation, which is carried out in areas where the firm is present directly or indirectly through a subsidiary, and external innovation which is undertaken in countries where the MNC only collaborates with local firms or inventors. My aim is to study the influence of IPR stringency on the attraction of offshored innovation. I find that stronger IPRs attract commercial R&D; this positive effect is particularly relevant for innovation in long life-cycle industries which, ceteris paribus, rely for a longer period on patented inventions, rather than their short cycle counterparts. External R&D is also attracted into countries with stronger IPR, exhibiting a more adaptive rather than techno-sourcing inclination. However, if compared to its commercial counterpart, the estimated effect is smaller.

The contribution of this study is twofold: first of all, it analyses the impact of IPR on innovation using a life-cycle length measure to isolate this effect from the overall business and legal framework's impact; secondly, it distinguishes between commercial and external R&D, rejecting the hypothesis that the same effect of IPR on innovation is observed among the two. Understanding firm's operational mechanisms seems a crucial step in order to be able to seize and redirect firms' activities across the globe. This paper provides insights that could help policy makers undertaking more oriented and effective policies in that respect. Future work needs to be done to understand which factors are determinant in redirecting external R&D. As it is showed in this paper, external innovation is not strongly attracted into countries with stringent IPR protection. This type of innovation could, therefore, be the key to drag firms' technologies towards less developed countries which exhibit laxer legal systems if compared to their developed counterparts.

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Appendix 1: Theoretical Model

In this section, I examine in more detail the resolution of the model in Sect. 7.3, deriving the main formula of the paper. Firm i wants to maximize, with respect to the obsolescence time t, its expected profits:

$$\max_{t_s} E(\Pi_{i,s,c}) \tag{7.8}$$

just taking the expectation of Eq. 7.1:

$$E(\Pi_{i,s,c}) = (\pi_{i,s,c} + k_{i,s,c})E(\text{MIN}[t_s, m_c]) + \sum_{z \neq i} k_{z,s,c}(T_{\max} - E(\text{MIN}[t_s, m_c])) + E(\varepsilon_{i,s,c}) \tag{7.9}$$

where ε is a white noise process and m has a uniform distribution accordingly to Assumption 1. It follows that the probability density function and the cumulative distribution function for m are, respectively, as follows:

$$f(m_c) = \frac{1}{m_c} \tag{7.10}$$

$$F(m_c) = P(m_c \leq x) = \frac{x}{\overline{m_c}} \tag{7.11}$$

To ease the calculation, I assume just one competitor firm in the market: company j.

Notice that the expectation in (7.9) can be rewritten as follows:

$$E(\text{MIN}[t_s, m_c]) = t_s \cdot P(t_s < m_c) + E(m_c \cdot P(t_s \geq m_c)) \tag{7.12}$$

with

$$P(t_s < m_c) = 1 - P(t_s \geq m_c) = 1 - \frac{t_s}{\overline{m_c}} \tag{7.13}$$

and

$$E(m_c \cdot P(t_s \geq m_c)) = \int_0^{t_s} m_c \cdot f(m_c) dm_c = \frac{t_s^2}{2\overline{m_c}} \tag{7.14}$$

I can therefore simplify (7.9) into:

$$E(\mathit{\Pi}_{i,s,c}) = (\pi_{i,s,c} + k_{i,s,c})t_s - \frac{t_s^2}{2\overline{m_c}}(\pi_{i,s,c} + k_{i,s,c}) + k_{j,s,c}T_{\max} - k_{j,s,c}t_s + \frac{k_{j,s,c}t_s^2}{2\overline{m_c}} \tag{7.15}$$

A comparison between expected profits in North and in South leads to (7.2). Finally, extracting the FOC for Eq. (7.9), I arrive at the expression in Eq. (7.3).

For the external innovation case, I just followed all precedent steps considering $\pi_{i,s,c} = 0$.

Appendix 2: Database Creation

MNC Group Identification

Orbis database, compiled by Bureau Van Dijk, is a commercial dataset containing financial and administrative data on over 150 million firms across the planet. While coverage of firms is not exhaustive, it has been proved that it offers a fair representation of economic activity in each state, arriving to cover almost 75–80% of firms in developed countries such as European ones (Kalemli-Ozcan et al. 2015). National censuses are, by far, more complete including a large number of small companies, but they typically lack of annual representation of the firms as surveys are not conducted every year. For the purposes of my study, given the focus on multinational activity and innovation, I am not concerned about the exclusion of smaller firms, which are rarely conducting R&D activities, and I prefer more systematic data on bigger companies offered by Orbis. The Bureau Van Dijk's platform presents two sections: "Companies" which contain financial data on each firm present in the database, and "Patents" which include all information on patents hold by represented firms and accessed through PATSTAT database. Orbis advantage is to connect these two parts through a unique BvD ID number which exclusively identify each enterprise.

I start my analysis downloading all granted patents owned by a firm with a publication date between 1 January 2005 and 1 July 2015 (initial date of my research). Orbis does not allow you to select patents based on their priority date; therefore, even if my analysis is limited to the interval of time 2005–2013 (years in which I have data for IPR at country level), I extended the time of selection in order not to lose any observation, knowing that typically patents are published after 18 months from the priority date except for certain patents at the USPTO which are published only if/when granted. For each patent, I download IPC codes, BvD ID of the firm which currently owns it, priority date, application number, inventors' names and countries of residence.

Once obtained all the innovating firms, I need to build, for each of them, the corporate group in order to understand if they are the head of a corporation or just subsidiaries held by other companies. Additionally, since my paper focuses on multinationals, I want to rule out national enterprises which only have subsidiaries within their national territory. Building precisely the ownership structure of the MNCs is crucial to attribute the correct patents to each multinational. In the Companies section, I download the Global Ultimate Owners (GUO) associated with the previously extracted BvD ID; for all firms which lack this information, I assume that they are themselves GUOs. Subsequently, I download all their subsidiaries owned at more than 25% by all the GUOs in my sample: the participation level threshold, fixed at 25%, is intended to include only effectively controlled subsidiaries. Also, I make sure to unfold up to the 10th, and last, subsidiary level. Subsidiaries can be controlled at different levels. As Fig. 7.5 shows if firm A holds 100% of firm B, and firm B holds 100% of firm C, then indirectly firm A holds

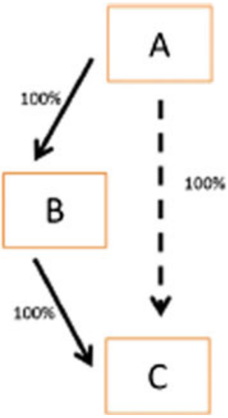

Fig. 7.5 Different levels of ownership

100% of firm C: firm C is a second-level subsidiary, while firm B is a first-level subsidiary for A.

Here, a limitation of the platform arises: Orbis, according to his settings, only gives a maximum of 1.000 subsidiaries at a time. Since some MNCs have many more, I isolate them in a group of “big” GUOs, and I download manually all their subsidiaries from their reports one by one. This task is very time consuming, but it is necessary since the bigger multinationals in my sample are more likely the more active ones in terms of R&D, and excluding them would inevitably bias my findings. Also, there is a limit of 40.000 subsidiaries that can be downloaded in Excel from Orbis, but none of my GUO exceeds this threshold.

Commercial and External Innovation Identification

In order to distinguish the two categories of commercial and external R&D, I have to identify the countries where the MNCs undertake some manufacturing activity. I use the distinction that Orbis provides about different types of entities. I select as “commercial” subsidiaries only these registered as industrial companies. “This category includes all companies that are not banks or financial companies nor insurance companies. They can be involved in manufacturing activities but also in trading activities (wholesalers, retailers, brokers, etc.)”.[25] They also figure as a separate category from research institute; therefore, making use of this classification, I am sure not to include in my dataset any isolated research laboratory which does not operate in combination with a manufacturing or resale activity.

[25]Orbis’s Ownership Manual.

Table 7.7 Robustness checks—all MNCs

Dependent variables	Commercial innovation		External innovation		Commercial innovation		External innovation	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IPR	0.083*** (0.015)	0.147*** (0.061)	0.057*** (0.010)	0.224*** (0.046)	–	–	–	–
lnGDP	0.247*** (0.031)	0.240*** (0.033)	0.176*** (0.021)	0.264*** (0.025)	–	–	–	–
$IPR \cdot T$	–	–	–	–	0.605*** (0.053)	1.015*** (0.083)	0.273*** (0.043)	0.508*** (0.060)
$IPR \cdot T^2$	–	–	–	–	−0.037*** (0.003)	−0.062*** (0.005)	−0.017*** (0.002)	−0.032*** (0.004)
$lnGDP \cdot T$	–	–	–	–	0.698*** (0.035)	0.663*** (0.035)	0.389*** (0.032)	0.475*** (0.036)
$lnGDP \cdot T^2$	–	–	–	–	−0.042*** (0.002)	−0.040*** (0.002)	−0.024*** (0.002)	−0.029*** (0.002)
Country FE, year FE	Yes	Yes	Yes	Yes	No	No	No	No
Country-year FE	No	No	No	No	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	25,308	21,978	25,308	21,978	25,308	21,978	25,308	21,978

Country-year and sector fixed effects are included in all estimations. Dependent variable is inserted in logarithmic form. Cluster-robust standard errors are in parentheses. *, ** and ***, respectively, denote significance at 10, 5 and 1% levels. Coefficient of constant has not been reproduced

Table 7.8 Robustness checks—multiple subsidiaries

Dependent variables	Commercial innovation		External innovation		Commercial innovation		External innovation	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IPR	0.079*** (0.015)	0.156*** (0.059)	0.062*** (0.012)	0.168*** (0.049)	–	–	–	–
lnGDP	0.218*** (0.029)	0.214*** (0.032)	0.168*** (0.024)	0.227*** (0.027)	–	–	–	–
IPR·T	–	–	–	–	0.544*** (0.050)	0.853*** (0.076)	0.322*** (0.046)	0.596*** (0.061)
IPR·T^2	–	–	–	–	−0.034*** (0.003)	−0.052*** (0.005)	−0.021*** (0.003)	−0.038*** (0.004)
lnGDP·T	–	–	–	–	0.596*** (0.039)	0.592*** (0.041)	0.459*** (0.033)	0.455*** (0.033)
lnGDP·T^2	–	–	–	–	−0.036*** (0.002)	−0.036*** (0.002)	−0.028*** (0.002)	−0.028*** (0.002)
Country FE, year FE	Yes	Yes	Yes	Yes	No	No	No	No
Country-year FE	No	No	No	No	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	25,049	21,201	25,049	21,201	25,049	21,201	25,049	21,201

Country-year and sector fixed effects are included in all estimations. Dependent variable is inserted in logarithmic form. Cluster-robust standard errors are in parentheses. *, ** and ***, respectively, denote significance at 10, 5 and 1% levels. Coefficient of constant has not been reproduced

Appendix 3: Additional Robustness Checks

I perform additional robustness checks to validate my findings. In Table 7.7, all MNCs are included in the sample, not only those undertaking both commercial and external innovation. The results remain valid.

As the distinction between commercial and external R&D can be tackled, I run an estimation restricting commercial innovation only to these cases where at least two industrial subsidiaries belonging to the MNC are present in the country. In this way, I can be sure that there is a real presence of the MNC in the country in terms of production and sales. Results are presented in Table 7.8.

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Chapter 8
Innovation–Consolidation Nexus: Evidence from India's Manufacturing Sector

Beena Saraswathy

Abstract Often mergers and acquisitions (M&As) are approved by competition regulator(s) based on the likely impact of it on innovation, which is further expected to enhance consumer welfare. During the initial years of M&As activity, the relationship between M&As and technological performance was not a major concern. During those days, the studies were focusing on the trade-off between efficiency generation and market power creation. However, there has been an unprecedented increase in the value and volume of technology-related mergers, acquisitions and alliances during globalization with a view to minimize cost of production and to effectively withstand market competition. Overall, the study observed that cross-border M&As are spending more for royalties and technical know-how, which indirectly indicates the continuing dependence of foreign firms on import of technology compared to in-house R&D creation in the Indian manufacturing sector.

Keywords Market structure and innovation · Mergers and acquisitions · Anti-trust issues · Government policy and regulations · Monopolization strategies · Innovation

JEL classification G34 · G38 · L44 · L12 · O32

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B. Saraswathy (✉)
Institute for Studies in Industrial Development (ISID),
4, Institutional Area II, Vasant Kunj, New Delhi 110070, India
e-mail: vsbeena@gmail.com; sbeena@isid.org.in

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During the initial merger waves, the relationship between M&As and technological performance was not a major concern. That time much of the research on this topic was concentrating on the trade-off between efficiency generation and market power creation. However, there has been an unprecedented increase in the value and volume of technology-related mergers, acquisitions and alliances during globalization with a view to minimize cost of production and to effectively withstand market competition. This study is an attempt to bring out whether the firms could effectively operationalize their desired objective of improving innovation efforts through consolidation. The study is divided into six sections. The first section deals with the nexus between consolidation and innovation, followed by the relevant literature in the second section, data and methodology in the third section, variables selection and model specification in the fourth section, major observations based on analysis in the fifth section and the sixth section concludes with policy implications.

8.1 Innovation Via/Led Consolidation: Some Insights

Rationally speaking, when two or more firms decide to consolidate their operation through M&As, it is expected to increase the productivity and efficiency of the combined firm. This increased productivity may be the outcome of the elimination of the multiple expenses such as on Research and Development,[1] which both the firms were incurring during the pre-consolidation period. Moreover, *ceteris paribus*, the time needed for innovation, may come down compared to the pre-consolidation period since the combined entity can work together for a new product or process and the resultant complementarities in knowledge speed up the innovation process. In other words, the combined entity will benefit through deriving synergies in knowledge compared to their own independent past. This becomes crucial for firms involving in more riskier or uncertain inventions such as pharmaceutical and biotech, where the probability of success may be very much unpredictable. Generally, this type of inventions involves huge capital requirement, which most of the firms from developing countries are either incapable or hesitant to undertake due to the high opportunity cost of capital. Further, if another firm succeeds to bring out the new product/process more quickly to the market, that will result in huge loss to the former firm with respect to the capital, time and effort. Even if the firm succeeds to bring out a new product quickly into the market, there exists a threat from competitor's introduction of new product/process. All these may result in losses to the innovative firm(s), which prevents the innovation incentives of the firms. Here comes the importance of consolidation strategies such as M&As to share the uncertainties related to competition for innovation. Entry into

[1]Other such expenses are advertising, marketing and distribution.

M&As is thus expected to enhance the innovative effort of the firms, which is the core of economic growth and development.

With the effective implementation of globalization in developing countries such as India, domestic firms are competing with the international products even within the domestic boundaries, which are facilitated through the relaxations on foreign investment regulations. In order to face the new challenges arising out of increased competition, firms are trying to relocate their resources and also to re-equip their R&D facilities (Guellec and Potterie 2001). Research networking plays a critical role in successful operation of firms under this scenario. In this context, cross-border consolidation activities provide golden opportunities for the firms to internationalize their R&D activities. It enables firms to locate their R&D centres at different international locations to tap the comparative advantage in different R&D locations. It will especially help the firms, which are at different stages of patenting their innovation. Horizontal M&As will make the step-by-step innovations easier through the systematic matching of competencies of both the firms. However, the success of it depends on the proper post-merger integration of both the firms situated from different cultures. Even though the integration risk exists for domestic deals too, it is not as vulnerable as cross-border deals.[2] Local firms will be able to benefit from this through knowledge spillovers from the foreign ones. Another view in this regard is that though technology is globalized, most of the foreign firms establish their research facilities abroad mainly to cater their products to the needs of local market conditions rather than to tap foreign technology (Guellec and Potterie 2001), which essentially means foreign firms also gain from their partnership with local ones. In this context, it is worth noting that the degree to which both firms benefit from spillovers depends to a great extent on the absorption capacity[3] of firms (Narula 2003), which is considered to be higher for foreign firms compared to the domestic firms.

So far we were discussing how the fast-changing innovation scenario is leading to M&As. Some researchers have rightly pointed out that any study on this topic should also consider the countereffect that is how M&As change the innovation efforts of the surviving parties as well as the rest of the firms in the industry (Schulz 2007). When firms go for M&As, the resultant enlarged firm size enable the combined entity to undertake more R&D investment, which was impossible previously due to the need for huge amount of capital. Moreover, the combined entity is expected to generate more profit due to the operation of economies of scale and scope, which can be reinvested for making strong R&D base for the future operations of the combined entity. It becomes particularly important for mega deals and

[2]The integration risk varies across the deals.

[3]Absorption capacity indicates a minimum level of knowledge is inevitable to acquire or adapt technology of foreign firms. Firms from developing countries are considered to have less absorption capacity since they are using relatively outdated techniques and are at initial stages of innovation.

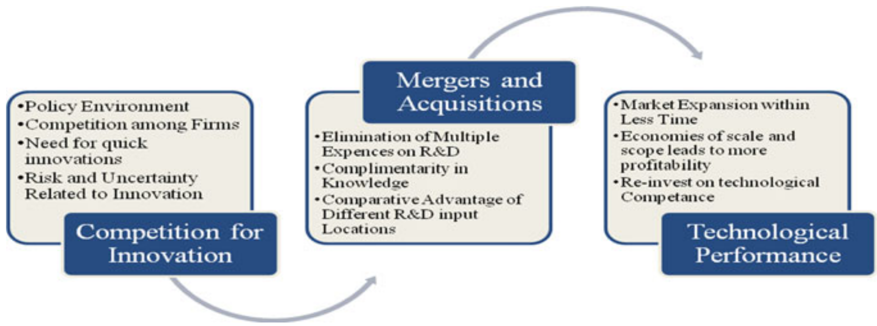

Fig. 8.1 Innovation–consolidation nexus, *Source* Author's compilation

horizontal M&As. We have summarized the above-discussed innovation–consolidation nexus—that is, the competition for innovation scenario leads to M&As, which in turn leads to better technological performance—with the help of a figure (see the Fig. 8.1).

8.1.1 Intellectual Property Rights (IPR) Versus Competition Law (CL)

The link between innovation and market structure has been one of the highly debated topics in economic literature. It is widely accepted that competition and open market provides better incentives for fostering innovation. When competition exists among firms to gain market, it will induce firms to invest on innovation creation. The emergence of new products and processes is the outcome of innovation creation efforts. If effective competition exists between the firms producing similar line of products, it is expected to enhance the quality of products or it may results in reducing the cost of production. Thus, it can be argued that innovation helps to escape competition. One of the major features of the current innovation scenario is *Schumpeterian Rivalry*. That is, competition for innovation in some markets may result in the creation of *Temporary Monopolists* who displaces one another through innovation, and as a result, there is little or no head-to-head price competition. However, there will be high competition for innovation over time (Katz and Shelanski 2004). It is also possible that due to the fear of acute competition through imitation of innovation, firms may prefer not to invest on innovation or remain less innovative. This will adversely affect the economic development itself. Here comes the role of intellectual property rights (IPR).

IPR allows the right holder to eliminate competition by imitation and hence to derive complete benefit from the protected innovation. Hence, it encourages firms to develop new or improved version of products/process. This will ultimately enhance competition by product substitution and contribute to the dynamic competition that is to promote innovation. However, a right balance between the innovation promotion and maintaining effective competitive environment that forces firms to innovate is very important. In this context, the IPR may be abused like any other rights. Such concerns are the subject matter of the Competition Act across the countries. Competition Act restricts the right holders from hindering competition in any manner. Thus, act puts limit on what IPR holders may do with their rights (Gallego 2010). In this context, a major challenge with the regulators is to choose the right balance between 'firm size and monopolization of innovation' on the one side and 'innovation creation' on the other side. The competition authorities consider these facts and try to ensure maximum consumer surplus without harming that of producers (Dhall 2007).

8.2 A Look at the Relevant Literature

There were only few attempts to study the theoretical relationship between M&As and innovation efforts. A review of literature on the relationship between M&As and innovation made by Schulz has also mentioned this fact (Schulz 2007). Earlier, much of the attention was given to the impact of consolidation on market structure and various performance indicators since the economic environment before the 1980s was very much different from the present market-oriented or neo-liberal regime, where the product life cycles are too short due to the competition for innovation among the firms. The changed global scenario led to the occurrence of more and more technology-related M&As during the present scenario. In this context, we shall discuss a few studies, which are directly linked to this topic.

Hagedoorn and Duysters (2000) studied the effects of M&As on the technological performance in a high-tech sector, namely computer industry for the period 1986–1992. The study reached the conclusion that M&As do have its impact on technological performance, which varies according to the degree of relationship between the combined entities. In other words, it varies according to the type of integration such as horizontal, vertical or conglomerate deals that occurred. Guellec and Potterie (2001) studied the internationalization of technology using the patent data applied to European patent office over the period 1985–86 and 1993–1995. The study found that small nations and the nations with low R&D intensity go for internationalization of R&D than the big ones. Dessyllas and Hughes (2005) analysed the propensity to acquire firms in the high-technology industry during the period January 1984–June 2001 using R&D and patent data. The major finding of the study is that firms are using acquisitions as a means of sourcing information externally as a substitute to in-house R&D. Ravenscraft and Scherer (1987) studied the impact of M&As on R&D performance for US firms that went for mergers during 1950–1977 and compared the R&D of the acquirers to that of the industry average using R&D intensity as the measure. The study found a negative relationship. Kleer (2006) examined the impact of mergers on the incentive of firms to invest on cost-reducing innovations and found that merger enhances the innovation effort of the surviving firms. But the rivals of the combined entity change the innovation efforts according to the strength of the combination. When the organizational problems are included into the analysis, even a clear picture of increased incentives of the surviving parties is disappeared (as in Schulz 2007).

Overall, the studies were dealing with different aspects of technological performance through M&As. From their conclusion, it becomes clear that the consolidation strategies are having its impact on technological performance, even though the direction is not clear. In the Indian context, there has not been any specific attempt to study the technological performance of the firms entering into consolidation. However, there are certain studies, which passively dealt with the R&D intensity during the post-merger period (Beena 2004, 2008). Studies on M&As have noticed that similar to the global scenario, there is a gradual shift from greenfield to brownfield mode of foreign investment in India. This must have led to the improvement in technology. Industrialized countries such as UK, USA and Germany are the most common dealmakers in India. Further, most of the top-valued M&As are occurring in technology-intensive sectors such as drugs and pharmaceutical, telecom, IT, power generation, and there is high instance of horizontal and vertical deals. Horizontal and vertical deals are expected to generate more synergies and involves higher cost cutting. It follows that the growing value and volume of cross-border M&As are expected to improve technological performance of firms since they are in similar line of business activity. Here, the point made by studies on the effect of FDI on innovation creation in India also becomes important. One major argument made by these studies has been that FDI has not resulted much in in-house R&D creation, rather the payments for import of technology increased. Scholars observed that foreign subsidiaries in India are spending a substantial amount for import of technology rather than in-house R&D creation. Coming to the consolidation scenario in India, many foreign firms are entering to the Indian market through M&As and there has been an apprehension that the disappearance of highly competitive national firms will adversely affect domestic consumers in future through various ways. In this context, this study examined the impact of M&As on technological performance of firms involved in cross-border M&As vis-à-vis the domestic deals.

8.3 Data and Methodology

One of the major problems faced by M&As studies in India was the absence of an appropriate long-term firm-level data on mergers, acquisitions and the like consolidation strategies.[4] Without having such a data, one cannot get into the ground realities of this phenomenon. In the absence of a proper data, normally what researchers have been doing is to build their own database based on various secondary sources of information such as CMIE and newspaper reports [see Beena (2000, 2008), Saraswathy (2015), Kumar (2000), Basant (2000) Pradhan (2007)]. The present study also used data compiled from different secondary sources such as Monthly Review of the Indian Economy (MRIE), M&A Database brought out by Centre for Monitoring Indian Economy (CMIE), Newspaper reports and various company reports.[5] These data we have applied to the PROWESS database of CMIE, to get data on financial performance of firms. The data covers 1631 M&As[6] in the *manufacturing sector*, of which PROWESS database provides data on 1060 deals (i.e. in the case of 65% of the M&As, the corresponding surviving firms can be identified from PROWESS database). Regarding CM&As, the data are available on 61% of the deals (383 deals out of 631). The period of analysis is from 1988–1989 to 2009–10.[7] The year of first merger or acquisition is taken as the cut-off point to treat a firm as 'surviving' firm. In this context, it is very important to note that many of the firms went for multiple M&As, which reduced the number of surviving firms further. The number of firms in the sample got reduced considerably when all these criteria are considered. The total number of surviving firms available is 484; out of this, 278 firms involved only in domestic deals and 206 are involved in cross-border deals. Intensity of multiple deals (i.e. the average frequency of a surviving firm to undertake M&As) is two for overall deals, and in some sectors such as pharmaceutical industry, it is high at 4 deals per firm.

Technological performance in the study is defined in terms of two major input measures of technology, such as R&D intensity and payments made for royalties and technical know-how.[8] Here, the major question emerges would be, what is the appropriate indicator of an improvement in technological performance after getting

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[4]Recently, some databases like Venture Intelligence, EMIS started to collect data on M&As. However, these data cover recent periods only.

[5]MRIE covers data up to the period May 2001 and M&A Database starts from the month of November 2001. These two data sources are explanatory nature; however, both of these suffer from the fact that they are based on announcement basis rather than effective date of deals. SEBI covers data for acquisitions from 1997 onwards.

[6]Excluding primary and service sector.

[7]Restricted this analysis till this period since from 2011 onwards CCI regime started, which makes difference in policy regime.

[8]Patents would have been another good indicator; however in the Indian context, only few firms are able to make such innovation. Moreover, the number of patents is not an appropriate indicator of the qualitative value of a particular innovation. Linking the patent to a particular merger or acquisition is also a difficult task.

into M&As? Or to put it in another way, whether an increased R&D intensity shows better performance as under normal conditions? As Cassiman and Colombo (2008) mentioned, a decreased R&D intensity during the post-merger period is also an indicator of successful M&As. The logic behind this is that when firms go for consolidation, it will reduce the multiple expenses on R&D along with such other expenses, which will help the firms to utilize the R&D investment more efficiently. However, an increased R&D intensity can be seen as a measure of improved performance after M&As since it is also possible when the firm expands its scale of operation. Nevertheless, a better utilization of R&D inputs is envisaged under both conditions.

The study hypothesis is that the intensity of technological performance changes according to the type and characteristics of M&As.[9] Technological performance is expected to be higher for CM&As compared to the domestic deals, for the new entities (through M&As) have better opportunity to learn from the firms from highly industrialized countries. However, the intensity of it depends on the absorption capacity of the domestic firms too, which is considered to be less than that of the foreign firms. Further, the effect of M&As can vary from industry to industry, firm to firm and time to time. Within cross-border and domestic deals, the intensity of it may vary according to the type of integration such as horizontal, vertical or conglomerate deals. It is expected to be higher under the first two types. Next, we shall discuss the variables used and the model.

8.4 Variables Selection and the Model

8.4.1 Variables Selection

Based on the literature, along with M&As and its nature and structure, size and market power of the firm, trade components may affect the technological performance of the firms. The relationship between size and technology activity has been one of the long debated issues in the literature, especially by the neo-Schumpeterian literature. According to the neo-Schumpeterian literature, firm size favours innovation activity[10] (Kumar and Siddharthan 1997). It is argued that if the size of the firm is large enough, it can spend more amounts on technology. It becomes possible due to the ability to mobilize more resource from the capital market. Moreover, the size allows the firms to undertake costly innovations, which is unable to be done by

[9]One of the major limitations of this study is that the analysis is not based on the M&As triggered based on technological performance. Such kind of information is not available from the existing databases on M&As.

[10]See Kumar and Siddharthan (1997), Chap. 4 for a detailed review.

the small sized firms, which will also help to derive greater economies of scale. In that case, we expect a positive impact of this variable on technological performance. It is conventional to use *sales* data to measure the size of the firm (Katrak 1997; Basant 1997). The study used the natural log of sales (denoted as logsales) to capture this effect.

Another major factor affecting the innovation efforts of firms is the market power of the firm. Like the size of the firm, this has also been one of the major debates in the economics of innovation literature. Schumpeter was among the first to relate market structure and innovative activity, who argued that perfectly competitive markets are not conducive to innovation, because it does not generate resources for investment in such ventures due to the absence of extra normal profit and favoured the concentrated markets to promote innovation. However, Schumpeter favoured the short- term nature of monopoly profit to enhance the innovation and not for the legal institutionalized monopoly power. In the medium and long run, there is threat of new entry and hence the need for continuous innovative activity emerges (Kumar and Siddharthan 1997). Even though we have used a size variable (i.e. logsales) to capture the size effect, it will not represent the market power of the firm, which in turn depends on other factors such as number of firms in the respective industry and its size distribution. Empirical studies on the developing country context show that as the market power increases, there is a possibility to reduce the spending on innovation through using monopoly elements, unless there is a threat of new entry. If so, we expect this variable to exert a negative pressure on technology. Measurement of market concentration has been an ever-discussed topic in the industrial organization. Considering the data availability, the study used price cost margin (PCM) or Lerner's Index (L), which is a theoretical measure to capture the effect of market concentration. For a single firm, Lerner's Index (L) is defined as[11]:

$$L = (P - \mathrm{MC})/P$$

For more than one firm in a particular industry, it is defined as: $L = \sum_{i=1}^{n} S_i(P_i - \mathrm{MC})/P_i$, that is the weighted average of PCM. If MC is constant, then

$$L = \sum_{i=1}^{n} S_i(P_i - C_i)/P_i$$

[11]However, the theoretical validity of PCM has been criticized by many studies on the ground that there are instances in which high competition leads to higher margins (see Boone 2008). It is also criticized that measurement of marginal cost (MC) is an approximation.

$$L = \sum_{i=1}^{n} S_i (P_i q_i - C_i q_i)/P_i q_i$$

$$L = \sum_{i=1}^{n} S_i (\prod_i)/R_i$$

where P is the price, MC is marginal cost, $\prod_i$ denotes the profit of ith firm S is the market share, and R_i is the revenue of firm i. We have applied this formula for all sectors and got the respective Lerner's Index, which shows the weighted average profit of a firm in the industry.[12] We have used the log of PCM, denoted as logpcm for the analysis.

Trade is the next major factor inducing technological improvements (Parameswaran 2010). Innovation is essential to compete in the global market especially under the present global scenario. The developing countries had been supporting the firms to improve their innovation effort to compete in the international market. Thus, extent of export is expected to enhance the technological performance of the firms. However, if trade induces the firms to go for import of technology rather than in-house R&D investment, the expected benefits may not be able to achieve. We have used log of export and log of import (denoted as logexport and logimport) to capture this effect. Like exports, when the firms imports, it is expected to strengthen the technological capability of the firm, especially because the import mainly consists of the spending on capital goods and finished goods, raw materials, royalties and technical know-how. This has also link with the in-house R&D investment. There are arguments which suggest that the foreign purchase of technology is a substitute for the in-house investment. Therefore, import of technology would be inimical to the building up of local technological capabilities (Pillai 1979). However, another view emerged is that the import of technology is complementary to the local capabilities due to the need to adapt it to the local needs, which requires a certain level of in-house investment[13] (Kumar and Siddharthan 1997). In this context, Subrahmanian (1991) observed that under liberal economic environment, firms will depend on continuous import of technology to build technological capacity rather than in-house R&D creation. However, under protection, it will be of complementary nature.

Next is the variables related to M&As. As discussed earlier, M&As are expected to increase the spending on technology due to the combination of different firms and the resultant expansion in the availability of capital. However, it can also lead to a reduction in the multiple expenditures. Thus, this variable's direction of influence depends on each event. We have used both the number of M&As (denoted as manos_{t-n}) as well as the value of deals[14] (denoted as mavalue_{t-n}) for estimating this in separate models. However, this effect will operate with a lag,

[12] We used profit after tax (PAT) and revenue of the firm for calculating this. Market share is calculated as the share of sales of a firm in the respective industry's aggregate sales.

[13] See Kumar and Siddharthan (1997), Chap. 9 for a detailed review and discussion.

[14] Available for acquisitions only.

since the proper post-merger integration will take some time. Exact amount of time requirement depends on each event. In the analysis, lag is selected based on the Akaike information criterion (AIC). From the above discussion, we hypothesis that the effect of M&As on technological performance will vary according to the type and structure of deals. Horizontal and vertical deals may be having positive and significant impact on technological performance compared to conglomerate, if it could adequately capture the synergies. A (0, 1) dummy variable is used to capture this. This variable will take the value '1' if it is horizontal or vertical deal and '0' if it is conglomerate deal (denoted horver). Another such dummy variable is used to separate cross-border and domestic deals (denoted domcb). Here, domestic deals take the value '0' and cross-border deals take the value '1'. As discussed earlier, cross-border deals may be having more impact on technological performance compared to the domestic deals.

Technological performance is measured by using two major input measures of technology, namely R&D intensity (denoted rdintensity*)* and the payments made for royalties and technical know-how (denoted as royalties). Among this, the former will capture the in-house investment on R&D, whereas the latter will capture the effect of import of technology. We have constructed two models based on R&D intensity, one taking the number of M&As and the second based on the value of M&As [Eqs. (8.1) and (8.2)]. Similarly, we have two models based on the import of technology, by taking number and value of M&As in separate models [Eqs. (8.3) and (8.4)]. We are limiting the analysis to the input measures alone. Patent would have been a good indicator of output measure, but in the Indian context in majority of the sectors, patenting is still at a nascent stage. Even if it is available, we cannot clearly demarcate the impact is 'due to M&As' since patenting involves long years of innovation effort. The patent measure also suffers from the limitation that the number of patents cannot fully capture the innovation content, as the value differs widely. One major problem with the spending on R&D and payments for royalties and technical know-how figures provided by PROWESS database is the presence of large number of 'zero' values, which will lead to the loss of information for a substantial part of the sample. Thus, this is a case of limited dependent variable. Hence, we have used Tobit Regression to capture the effect.[15]

8.4.2 The Model

The general solutions for the model are:

[15]The technical details on the model are discussed in Appendix 1.

$$\text{rdintensity}^* = \beta_0 + \beta_1 \text{logsales}_{it} + \beta_2 \text{logpcm}_{it} + \beta_3 \text{logexport}_{it} + \beta_4 \text{logimport}_{it} + \beta_5 \text{manos}_{i(t-n)} + \beta_6 \text{horiver}_{it} + \beta_7 \text{domcb}_{it} + U_{it} \tag{8.1}$$

$$\text{rdintensity}^* = \beta_0 + \beta_1 \text{logsales}_{it} + \beta_2 \text{logpcm}_{it} + \beta_3 \text{logexport}_{it} + \beta_4 \text{logimport}_{it} + \beta_5 \text{mavalue}_{i(t-n)} + \beta_6 \text{horiver}_{it} + \beta_7 \text{domcb}_{it} + U_{it} \tag{8.2}$$

$$\text{royalties}^* = \beta_0 + \beta_1 \text{rdintensity}_{it} + \beta_2 \text{logsales}_{it} + \beta_3 \text{logpcm}_{it} + \beta_4 \text{logexport}_{it} + \beta_5 \text{manos}_{i(t-n)} + \beta_6 \text{horiver} + \beta_7 \text{domcb}_{it} + U_{it} \tag{8.3}$$

$$\text{royalties}^* = \beta_0 + \beta_1 \text{rdintensity}_{it} + \beta_2 \text{logsales}_{it} + \beta_3 \text{logpcm}_{it} + \beta_4 \text{logexport}_{it} + \beta_5 \text{mavalue}_{i(t-n)} + \beta_6 \text{horiver}_{it} + \beta_7 \text{domcb}_{it} + U_{it} \tag{8.4}$$

where i is the ith firm and t denotes time, $t = 1, 2, 3, \ldots, 20$ and $U_i|X_i \sim$ Normal $(0, \sigma^2)$.

8.5 Major Observations

Major findings of the analysis are as follows. First, the case of R&D intensity is discussed (see Table 8.1). For both the R&D-based models, we got two lag as the best-fitted model.[16] Both the models are significant as shown by the significant Wald statistic as well as the likelihood ratio (LR) test.[17] When the number of M&As is used, three major factors are significantly affecting R&D intensity, and they are export, sales and M&As. The resultant coefficients show that size of the firm measured by sales is having the largest and positive impact on in-house R&D creation. Interestingly, among the trade variables, only export has significant impact and that too negative, which is against our expectation. In fact, these two results are common for both the models. Coming to the merger variables, the number of M&As is having a positive and significant impact on R&D intensity. However, here none of the variables explaining the type of merger (domcb and horver) is having any significant

[16]AIC with the lowest value is selected, which shows the best-fitted model.

[17]Likelihood ratio test (LR) is based on the same concept of F-Test in the linear regression model. The major difference between Wald statistic and LR is that the former will not estimate the constraint model, but evaluate its fit based on the difference between the estimates and its constrained value. When the restricted model and unrestricted models are calculated, LR is attractive. Also, unlike the linear models, Tobit maximizes log likelihood rather than R-square (Wooldridge 2000).

Table 8.1 Estimated coefficients of Tobit regression: R&D intensity

Model: 1 number based			Model: 2 value based		
rdintensity	Coefficient	*p*-value	rdintensity	Coefficient	*p*-value
logsales	1.31**	0.00	logsales	1.53**	0.00
logexport	−0.29*	0.04	logexport	−0.27	0.06
logimport	−0.13	0.50	logimport	−0.11	0.58
logpcm	0.17	0.22	logpcm	0.12	0.39
manos2	0.19*	0.01	mavalue2	0.00	0.15
horver	0.28	0.80	horver	0.34	0.77
domcb	−0.17	0.78	domcb	−0.22	0.72
constant	−9.57	0.00	constant	−10.98	0.00
sigma_u	9.6	0.00	sigma_u	9.54	0.00
sigma_e	3.867063	0.00	sigma_e	3.88	0.00
rho	0.860304		rho	0.86	
LLF	−4156.8129		LLF	−4158.8973	
LR test	1612.22**		LR test	1562.06**	
No. of observations	2065		No. of observations	2065	
Wald chi2(7) = 48.79 Prob > chi2 = 0.0000			Wald chi2(7) = 44.82 Prob > chi2 = 0.0000		

Source Calculated from PROWESS, CMIE
Note **Significant at 1% leve; *Significant at 5% level; For LR test, chi-square values are reported

Table 8.2 Estimated coefficients of Tobit regression: royalties and technical know-how

Model: 3 number based			Model: 4 value based		
Variable	Coefficient	*p*-value	Variable	Coefficient	*p*-value
rdintensity	0.0314487	0.679	rdintensity	0.0314487	0.679
logsales	7.734827**	0.00	logsales	7.734827**	0.000
logexport	−1.524871**	0.00	logexport	−1.524871**	0.000
logpcm	0.5976767	0.185	logpcm	0.5976767	0.185
manos4	0.6544711*	0.024	Mavalue3	0.6544711*	0.024
horver	23.27919**	0.00	horver	23.27919**	0.000
domcb	12.26791**	0.00	domcb	12.26791**	0.000
constant	−82.30375	0.00	constant	−82.30375	0.000
sigma_u	22.86916	0.00	sigma_u	22.86916	0.000
sigma_e	9.933843	0.00	sigma_e	9.933843	0.000
rho	0.8412668		rho	0.8412668	
LLF	−3220.3769		LLF	−3220.3769	
LR test	1484.92**		LR test	1484.92**	
No. of observations	2070		No. of observations	2070	
Wald chi2(7) = 232.15 Prob > chi2 = 0.0000			Wald chi2(7) = 230.16 Prob > chi2 = 0.0000		

Source Calculated from PROWESS, CMIE
Note **Significant at 1% level; *Significant at 5% level; For LR test, chi-square values are reported

impact on this. When the value of M&As is taken as the merger variable, the effect is insignificant, which may be due to the less coverage of value of deals in the data.

Table 8.2 shows the impact of M&As on the payments made for royalties and technical know-how based on number and value of M&As, respectively. Here, based on the AIC criteria, three lags selected for value based model and four lags selected for number-based model. In addition to the significant sales and export variables, all the merger variables—number/value of M&As, dummy variables for cross-border and domestic deals as well as the merger structure—are significantly affecting payments made for royalties and technical know-how. Number/value of M&As is positively affecting the import of technology. Moreover, the cross-border firms are having significant impact on the payments made for royalties and technical know-how, which is an indication that these firms are becoming more technology import intensive rather than focusing only on the in-house R&D creation. Another point is the role of horizontal and vertical deals. In the overall result, it is having a positive and significant effect in the payments made for royalties and technical know-how, compared to the conglomerate deals. Thus, altogether, a trend in favour of cross-border deals with horizontal or vertical M&As can be seen to have greater say in the import of technology.

Thus, from the analysis, it is becoming clear that compared to the in-house R&D creation, M&As, especially the cross-border deals, affect the import of technology. However, we believe that each deal is a separate event and its success or failure depends on so many factors, which may be more event-specific. Therefore, the study has also tried to understand the effect of M&As on technological performance in a more disaggregated level and found that even though the result at the sectoral level is almost similar to that of the macro-incidence, it varies for different sub-sectors[18] when we applied the same models for each industry.[19] It is interesting to note that in majority of the sectors, M&As do have its impact on technological performance, with a variation in the direction of impact. In the case of R&D intensity, drugs and pharmaceutical industry (measured by number of M&As) and metals and minerals (in terms of value of deals) have positive impact, while the chemical sector is negatively affected in terms of both number and value. In textiles, the horizontal and vertical deals are resulting in reduced spending on R&D, which may be due to the efficient utilization of the existing resources and the synergy creation. However, more investigation is necessary to establish this. The consolidation strategies not much affected the R&D spending of machinery, non-metallic minerals and transport sectors.

In the case of the payments made for royalties and technical know-how, chemicals, metals and minerals and transports have positive impact of M&As—which means spending increases with the M&As—on it in terms of the value of the deals, and non-metallic minerals, textiles and transport sectors are positively related

[18]The study used only broad industry classification since for some sectors, the incidence of M&As is higher and for others it is too less. So the study is limited to nine broad sectors.

[19]We realize the fact that sector-specific, there may be differences.

in terms of the number of deals. Only for the machinery sector, a negative and significant association—which means the spending declined after getting into M&As—is noted. In terms of R&D intensity also machinery sector was not showing any change after merger. This may be due to the efficient utilization of the unutilized capacity after getting into M&As in this sector, which reduces the need for import of technology. Interestingly, as noted earlier, the cross-border deals are having a strong positive relation with the import of technology as compared to the domestic deals in majority of the sectors such as drugs and pharmaceutical, machinery, metals and minerals, non-metallic minerals, transport equipments, which is true for both number and value of deals. Even though the machinery sector as a whole was showing reduced spending on import of technology, in the case of cross-border deals, it is showing increasing trend, which may be due to the more than proportionate increase in the spending on in-house R&D by the domestic deals in this sector. In general, the regression results support the involvement of M&As in increased spending on innovation activity, especially for the import of technology.

8.6 Concluding Observations and Policy Implications

The study examined whether the changing mode of investment—from greenfield to brownfield nature—is contributing to the technological performance of firms. The Tobit Regression analysis indicates that M&As play a very important role in changing the technological performance measured in terms of R&D intensity and the payments made for royalties and technical know-how. Overall, M&As influence R&D intensity positively, while the mode of investment (i.e. domestic and cross-border classification of M&As) is not contributing to the R&D performance. This may be indicating the absence of in-house R&D creation by cross-border M&As. The cross-border M&As seems to be spending more for royalties and technical know-how, which indicates that the foreign firms in India are still spending more on import of technology rather than creation of in-house R&D. This is similar to the findings of FDI studies on innovation. The disaggregated level of analysis shows that the incidence and impact of M&As varies for different sectors according to the sector-specific characteristics.

The changing mode of investment was criticized for not generating fresh investment. The dependence of the cross-border firms on the import of technology may not be bad per se if it is used as complementary to the in-house technological capabilities. However, when we take the 'nationality' content similar to the case of direct foreign investment, we can say that the *in-house R&D creation has been still away from the foreign firms' research agenda. Most of them are still depending on the foreign headquarters for this.* Now, the question here is that, whether this will really increase the spillovers to the domestic counterparts, without direct investment in R&D activities. In India, technology is not the main motive behind M&As. Hence, it seems the Competition Commission of India, the competition regulator is not assessing the innovation effect of M&As seriously. In the coming years, M&As'

importance in acquisition of technology will increase. In short, the study points to the need to rethink the 'technology spillover defence', especially arising from the cross-border deals. The periodic review of approved transactions becomes the need of the day in this context.

Appendix 1: Tobit Regression and Multicollinearity

According to Verbeek, '*In certain situations, the dependent variable is continuous, but its range may be constrained. Most commonly this occurs when the dependent variable is zero for a substantial part of the population, but positive (with many different outcomes) for the rest of the population. Tobit models are particularly suited to model this type of variables*' (Verbeek 2000). Conventional regression models fail to account for the qualitative differences between zero observations and continuous observations (Greene 2003). Tobit model is suggested by Tobin (1958) to handle this type of situations. Since we are also facing this type of limited dependent variables, we have applied Tobit regression framework. Tobit model assumes that there is a latent or unobserved variable Y^*. The observable variable Y is equal to Y^* if $Y^* > 0$ and $Y = 0$ when $Y^* \leq 0$. That is,

$$Y = \begin{cases} Y^* & \text{if} \quad Y^* > 0 \\ 0 & \text{if} \quad Y^* \leq 0 \end{cases}$$

Y has continuous distribution over strictly positive values. That is, the latent variable Y^* (here, rdintensity* and royalty*) satisfies the assumptions of the classical linear model; in particular, it has a normal, homoscedastic distribution with linear conditional mean. The log likelihood function for each variable i is:

$$l_i(\beta, \sigma) = 1(Y_i = 0)\log[1 - X_i\beta|\sigma] + 1(Y_i > 0)\log\{(1/\sigma)\phi[(Y_i - X_i\beta/\sigma]\}$$

where σ is the SD of U. Maximum Likelihood estimates of β and σ are obtained by maximizing log likelihood (Wooldridge 2000).

The study used random effects Tobit model. If the individual specific effects are independent of the regressors, the parameters can be consistently estimated with random effects model. Fixed-effects panel Tobit is affected by the *incidental parameters problem* (Lancaster 2000; as in Henningsen); that is, the estimated coefficients are inconsistent unless the number of time periods approaches infinity (Henningsen 2010).[20] However, Greene (2004) showed the slope parameters can be estimated consistently, but not the variance, even if the number of time periods is small.

[20]Henningsen (2010), "Estimating Censored Regression Models in R using the censReg Package", University of Copenhagen, available at http://cran.rproject.org/web/packages/censReg/vignettes/censReg.pdf. Accessed on 8/5/2012).

Before entering into the results, we have checked multicollinearity of the variables—which is important to check since we are dealing with the independent variables, which are having close relationship—and found none of the independent variables are significantly correlated with other variables (see table).

Check for multicollinearity: variance component estimation (VCE) correlation matrix

Model 1	logsales	logexport	logimport	logpcm	manos2	horver	Domcb
logsales	1						
logexport	−0.3366	1					
logimport	−0.4975	−0.2307	1				
logpcm	−0.3162	0.0407	−0.0847	1			
manos2	−0.3092	−0.0553	−0.0457	0.1491	1		
horver	−0.0014	−0.0178	−0.0194	0.0121	−0.0343	1	
domcb	0.013	0.0155	−0.0342	0.0132	0.0315	−0.0248	1
Model 2	logsales	logexport	logimport	logpcm	mavalue2	horver	Domcb
logsales	1						
logexport	−0.3706	1					
logimport	−0.5364	−0.2337	1				
logpcm	−0.2849	0.0492	−0.0789	1			
mavalue2	−0.1178	0.0034	0.0128	−0.0027	1		
horver	−0.0112	−0.0185	−0.0208	0.0176	−0.027	1	
domcb	0.0233	0.0178	−0.0332	0.0089	−0.0042	−0.0228	1
Model 3	rdintensity	logsales	logexport	logpcm	manos4	horver	Domcb
rdintensity	1						
logsales	−0.0486	1					
logexport	0.066	−0.5161	1				
logpcm	−0.0245	−0.4612	0.0448	1			
manos4	0.0077	−0.415	0.0172	0.1243	1		
Horver	−0.0008	0.0019	−0.0238	0.0045	−0.0336	1	
Domcb	0.0222	0.04	−0.0254	−0.0036	−0.1006	−0.027	1
Model 4	rdintensity	logsales	logexport	logpcm	mavalue4	horver	Domcb
rdintensity	1						
logsales	−0.0405	1					
logexport	0.0629	0.561	1				
logpcm	−0.0269	−0.445	0.0437	1			
mavalue3	−0.0276	−0.1928	0.0578	0.013	1		
horver	0.002	−0.0096	−0.0222	0.0063	−0.0142	1	
domcb	0.026	0.0085	−0.0272	0.0078	−0.0319	−0.0283	1

Source Calculated from PROWESS, CMIE

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Chapter 9
Impact of R&D Spillovers on Firm-Level R&D Intensity: Panel Data Evidence from Electronics Goods Sector in India

Richa Shukla

Abstract In this paper, we quantify the impact of R&D spillovers along with other firm-specific characteristics, such as the technology imports, firm size and age, in determining the in-house R&D intensity for a selected sample of electronic firms in India. This study, therefore, explores the significance of the R&D-induced technological efforts of electronic firms for the *other* R&D units operating within *similar* industry groups during the recent past decade of economic reforms (2002–2014). We construct an *unbalanced* panel of 63 electronic firms for the time period 2002–14 based on annual firm-level data available in CMIE Prowess database. Our results indicate that the Indian electronic firms benefitting from R&D spillovers within their line of business are spending relatively less on in-house R&D activities. However, for select industry groups within this sector, there also exists *complementarity* between (own) R&D efforts that are induced by the technological know-how obtained from innovations by others. Firms, therefore, look for spillover effects which are easier to obtain than their own in-house R&D whose results can be achieved in the medium or long term. We could possibly attribute this to the presence of multinationals in this sector and the resultant pressure on competition as driving these firms to spend more on R&D. While the (modern) Indian electronics goods sector predominantly consists of young-and middle-aged firms, but even then age of the firm (implying 'learning by doing') turns out to be positively significant. When we consider possible R&D spillovers *within* the similar industry group together with experience of the firms, it is observed that the relatively older firms are better equipped to benefit from such R&D spillovers and hence are incurring less R&D expenditure per unit of (net) sales. Small

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R. Shukla (✉)
Humanities & Social Sciences Department, Indian Institute of Technology Bombay, Powai, Mumbai 400076, India
e-mail: richa.shukla@iitb.ac.in

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and medium firms catering to the huge consumer electronics market are more R&D intensive than their larger counterparts.

9.1 Introduction

With the increased demand world over for more and more cross boundary trade facilitated by the new-age technological revolution, firms whether newly born start-ups or the existing giant incumbents are facing ‘cut-throat’ competition for survival, maintaining market share and profit margin, as well as market value in the eyes of the shareholders. In fact, in today’s world (domestic), firms face competition not only from within the domestic industry, but rather more aggressive competition is felt from across the national boundaries with flooding of similar or qualitatively differentiated products that are constantly threatening the domestic firms to manage their existence in the business. Therefore, it appears to be a mere necessity to continuously upgrade the products and processes to remain in the business and look for opportunities to offer improved variety of goods and services. Hence, the need is felt to look somewhat deeper into the firm-level R&D activities that the modern corporate firms are expected to undertake to maintain (if not improve) their basic objectives such as increasing sales turnover or profit margin.

In this paper, we attempt to explore whether being a part of an industry group gives any added advantage to an incumbent firm in terms of technology sharing/adaptation from (distantly) similar ‘other firms’. In doing so, we focus on the impact of R&D spillovers in determining the firm-level R&D intensity of the electronic firms in India apart from examining the effect of other firm characteristics such as firm size, experience of the firm in its core business and intensity of technology imports. The importance of spillovers arises from the fact that the ‘input’ derived from own R&D investment may in fact be positively influenced by the input ‘borrowed’ from other sectors (Griliches 1979). The literature on the influence of R&D spillovers on firm’s in-house R&D efforts is based on conflicting theoretical perspectives. Also, there exists empirical non-conformity as to whether R&D spillovers actually lowers R&D incentives or step-up the in-house R&D efforts of firms undertaking new research activities.

The rest of the paper is organized as follows: Sect. 9.2 presents an overview on the Indian electronics sector. Section 9.3 describes the theoretical underpinning and forms the empirical hypotheses. Section 9.4 describes the data and variables followed by Sect. 4.1 unfolding the industry as well as firm-level characteristics of the selected sample of firms over the data period considered in this study. Sections 9.5 and 9.5.1 explain the estimation methodology and discuss the empirical results, respectively. Lastly, Sect. 9.6 concludes the paper.

9.2 The Indian Electronics Sector

Almost two decades after the independence as India gradually embarked upon an industrialization process along with heavy engineering, growing need was felt to initiate the electronics sector. During the early phase (1960s to late 1970s), the defence segment was the primary focus area for India's electronics sector. During the 1980s, initiative was towards making the electronics sector self-reliant in the area of computers. This period marked the birth of India's consumer electronics market (beginning with the indigenous development of televisions and telephones). In the post-liberalization period, rapid globalization and large scale policy and structural changes led to a drastic reduction in the cost of imported hardware. While the economic policy reforms opened up new opportunities for the domestic firms, at the same time, the electronic firms had to depend on imports of technology for expansion of production.[1] This pressure of capacity expansion went on for some time even though the electronics sector steadily continued to grow with gradual digitalization in all sectors.

We confine ourselves to the data period 2002–14 because (i) till 2012, *GoI* did not have any national policy framework explicitly for the electronics sector; (ii) the Indian electronics industry took a quantum jump after the mid-1990s; and (iii) during the decade of 1990s, the domestic supply for Indian electronic products were very small and had a negligible share in the world market. It is only in the early phase of the decade 2000–2010 that the Indian electronics market started gaining momentum.[2] For instance, the domestic demand for electronics products in 2008–09 stood at USD 45 billion and is expected to reach USD 400 billion by year 2020.[3] Market for white goods (consumer durables), which remains the fastest expanding segment, has been growing at close to 14% per annum and is expected to accelerate to close to 17% in the coming years. However, arguably it still remains underpenetrated as compared to the world consumer durables market.[4] The electronics sector in India constitutes 0.7% of the global electronic sector. The net sales growth rate has been quite erratic during the second phase of India's economic reforms. On an average, the annual sales growth rate has been around 11% in the electronics industry. The growth rate has picked up in 2004 but decelerated at the onset of 2007–08 global financial crisis (Fig. 9.1).

Industry concentration measured by market share of major 4 electronic firms and their average R&D intensity over the study period indicate that there exists an

[1]About 65–75% of Indian electronics market depends on imports of finished goods and components; Ernst and Young Report (2015).

[2]In 2011, the National Policy on Electronics was drafted to boost India's electronics systems and design manufacturing industry and improve its global market share. The other objective was to create a globally competitive sector in the country by investing about USD 100 billion and create employment opportunities to approximately 28 million people.

[3]For a detailed overview, see Annual Report of the Ministry of Information and Technology, *GoI*, 2008–09.

[4]While the average market penetration in India for consumer durables is estimated to be 23.2%, the average penetration in the global market stood at 76% for the period 2009–2013, Ernst and Young Report (2015).

Fig. 9.1 Net sales and sales growth in Indian electronics industry. *Data source* Prowess database, Centre for Monitoring Indian Economy

underlying impetus amongst those top electronic firms to gain momentum in undertaking R&D efforts during periods in which the sector was relatively more competitive.[5]

The major growth drivers in this industry are generally identified as R&D in design and engineering services, talented young workforce and rise in outsourcing of professional and counselling jobs. The sector got a major boost when customs duty has been eliminated with effect from 1 March 2005. In order to attract investors, incentives provided by the *GOI* include subsidy of up to USD 10 million per 100 acres of project in electronics manufacturing clusters, reimbursement of excise duties for capital equipment in non-SEZ units, no central taxes and duties for 10 years in high tech facilities, 2–5% of duty credit on exports of different products, and proposal to promote innovation, R&D, product commercialization and nano-electronics. The current focus is to rejuvenate India's hardware manufacturing along with wireless, consumer electronics, aerospace and defence, medical devices and security solutions.

9.3 Theoretical Underpinning and Empirical Hypotheses

The two principal characteristics of the technological activities of firms belonging to the Indian electronics sector are: *first*, their in-house R&D effort is inclined towards 'non-drastic' as opposed to 'drastic innovations'. *Secondly*, technological learning forms an in-built component of their research drive (Ray and Bhaduri 2001). It is

[5]In 2008, average R&D intensity of the largest 4 firms rose to about 2%, while their market share dipped significantly to 59%; see Appendix 2.

emphasized in the theoretical literature that spillovers may influence the incentives to engage in innovative activities (Geroski et al. 1993).[6] Firms may receive valuable information at a cheaper price that is below the cost of developing it internally or of acquiring it in the market. This may incite the firms to invest relatively less in own R&D activities than they would without such spillover effects.[7] On the contrary if spillovers are *complementary*, it may give an incentive to firms to commit to one's own in-house R&D efforts Cohen and Levinthal (1989, 1990). Empirical studies on the impact and significance of spillovers remain inconclusive. For instance, Jaffe (1986) finds the impact of R&D spillovers to be positive and highly significant on firm-level R&D activities; Bernstein and Nadiri (1989) contrarily conclude that spillovers have a negative effect on the rate of investment for R&D. In the Indian context, Basant and Fikkert (1996) observe the positive and significant effect of spillovers for firms belonging to the manufacturing sector. In what follows, we therefore formalize our first hypothesis as:

Hypothesis 1: R&D spillovers from firms operating in related industry group affect the level of in-house R&D activity of the Indian electronic firms.

The journey from adaptation of R&D spillovers to internalize the same in in-house R&D efforts may be conditioned by the experience accumulated over time. Age of the firm represents the experiences and learning acquired by the firm over a period of time. It is possible that the relatively younger firms are more innovative and the new entrants in the industry are possibly also those that penetrate into new markets. Martinez-Ros (2000) found that the experience encourages the (process) innovation. By contrast, Thornhill (2006) found firm age to have a negative effect on innovation.[8]

In the context of the electronic products that are continuously improved (to be more user friendly) at a speedy rate, one can argue that the technological capability of an incumbent is a function of the capacity to assimilate and adapt, thereby improving upon the existing technologies. This capacity is derived from both the in-house R&D efforts and learning through experience. Thus,

Hypothesis 2: Experience of the firm positively impacts the in-house R&D efforts.

Learning through R&D spillovers and learning through experiences mutually reciprocate each other in the process of acquiring skill by undertaking own R&D efforts. With respect to the role of learning through spillovers, it requires cumulated experience in order to absorb information available in the public domain. Concerning the acquisition of technological efforts through experience,

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[6]Arrow (1962) argued that that *involuntary* transmission of knowledge to competitors may weaken the firm's incentive to invest in R&D activities. Spence (1984) illustrated that the firm's R&D intensity will be a *decreasing* function of the extent of spillovers.

[7]Such negative effects of spillovers on firm's R&D expenditure are discussed in Spence (*op. cit.*), Levin and Reiss (1988), Jovanovic and MacDonald (1994), and Eeckhout and Jovanovic (2002).

[8]Over a longitudinal span of time, firms may face 'rigidity and inertia that can negatively affect innovative activity and overall firm performance', Thornhill (*op. cit.*).

the relatively older firms in the electronics sector is observed to be more inclined to invest in in-house R&D activity than their younger counterparts, see Appendix 2. In what follows, we formulate our next empirical hypothesis as:

Hypothesis 3: Industry-level R&D spillovers and firm-level experience together positively affect firm-level R&D efforts.

Our fourth hypothesis seeks to examine the association between firm size and R&D efforts that has been presented in earlier empirical studies.[9] For the reason that R&D activity involves sunk cost, it is argued in the literature that large firms can disperse the huge cost of R&D over a wider range of output than their smaller counterparts (Cohen and Klepper 1996). In addition, large firms can reduce the aggregate risk by diversifying over a broader array of product lines (Kraft 1989). The various empirical studies however remain inconclusive as to the exact relationship between firm size and the innovative activity of the firm. It is argued that some of these studies have been constrained to a limited range of firm sizes and a limited number of industries (for details see Mansfield (1963), Scherer (1965) amongst others). In the Indian context while Katrak (1989) and Basant (1997) found a positive relationship between technological activity and firm size, Narayanan and Bhat (2009) suggest that the medium-sized firms are more R&D intensive than their smaller and larger counterparts.

On account of the primarily concentrated industrial structure of the electronics sector in India with the dominant firms appropriating close to 80% of the market with an average R&D intensity of roughly 3.2% (for the period 2012–2014), it entails as a possibility that large-sized firms tend to undertake risky R&D investment. Therefore, we hypothesize:

Hypothesis 4: Firm size is positively associated with the R&D intensity of firms.

The diverse industry groups within the electronics sector may influence the relationship conjectured in hypothesis 3. In the context of industry evolution, it is argued that in early stages after the emergence of technically useful knowledge, firms may pursue complementary research activities so that R&D spillover should be a strategic complement to the firm's own R&D at this stage. However, over a longitudinal span of time, the technical knowledge accumulated by one firm may become a substitute for other firms' ideas. In what follows, we hypothesize:

Hypothesis 5: Inter-industry differences based on product lines impact the relationship between R&D spillovers and the level of in-house R&D activity of the firm differently.

In order to undertake innovative activities, firms may take on various strategies that involve own R&D efforts either *complemented* or *substituted* by import of

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[9]The famous Schumpeterian hypothesis and subsequent theoretical research emphasized on the intensity and direction of R&D efforts at the firm level under different forms of market structure (see Schumpeter 1942; Arrow 1962; Dasgupta and Stiglitz 1980).

technology. These technological opportunities generate potential for undertaking adaptive R&D in which case firm's import technology and then invest in R&D. Firms then use R&D efforts to adapt and develop imported technology (see Ray et al. (ibid.) and Narayanan et al. (ibid.)).[10] A number of studies for India and other countries have examined this relationship between R&D and technology imports and have found mixed results. Evidences from Japan and India suggest that the relationship of complementarity dominates that of substitution (see Odagiri 1983; Lall 1983; Katrak 1985; Siddharthan 1988; Kumar and Aggarwal 2005). On the contrary, studies by Kumar (1987), and Basant and Fikkert (1996) found substitutability between technology import and domestic R&D efforts.

For the reason that the Indian Electronics firms are largely characterized by the assembly technology that involves the act of gathering the know-how, their in-house R&D efforts have been chiefly pitched towards application of scientific knowledge, setting machines and putting up capital goods rather than undertaking basic research. Therefore, we attempt to examine empirically the following hypothesis.

Hypothesis 6: Import of technology is positively associated with the level of in-house R&D efforts of the firm.

9.4 Data and Variables

Annual firm-level data are compiled from the secondary data source, namely CMIE Prowess database at the NIC-5 digit classification level. As we confine ourselves only to the Indian electronics goods sector, the Prowess database gives us data on total 304 listed electronic firms. However, data unavailability of concerned empirical variables given our selected study period led to an *unbalanced* panel of 63 electronic firms (Table 9.1).

Our econometric estimation is, therefore, based on a total of 335 observations for the 13-year period. In what follows, we now depict the definition (and construction) of our relevant variables for econometric analysis.

Dependent Variable

Research & Development Intensity (RDI): It is measured as the ratio of annual R&D expenditure to (nominal) net sales at time *t*.

Independent Variable

R&D spillovers: We apprehend that firms which are closely related in the sense of falling within the same industry group classification are presumed to benefit from

[10]However, if the firm's R&D activity is geared towards substituting for the imported technology as well as intermediate inputs, we may expect a *negative* relationship between technology import and R&D. This may hold particularly for disembodied technology imports.

Table 9.1 Brief sample description

Data period	2002–14
Number of firms	63
*Size distribution over time** Small and medium	81%
Large	19%
Age distribution over time 2–20	36%
21–40	46%
41 and above	18%

*Authors' own calculation given the selected sample of firms. The size classification is calculated by standardizing net sales with deviation from average net sales (measured across cross-sectional units over time)

each other's R&D efforts than firms in distinctly different product lines (see Griliches 1979). We take the aggregate of the R&D expenditure undertaken by firms in related industry groups normalized by their net sales at time $t-1$ as a measure of spillovers available to a R&D undertaking firm at time t.[11] We take industry group-level aggregation on the basis that we are analysing here only one industry under the premise that all firms within the industry would always operate exclusively in one and the same product area.[12] It is assumed that the R&D effort of an innovating firm increases the pool of ideas available to other firms by the total amount of the other firm's R&D and that firms absorb all available information that is in the public domain.[13]

Hence, we define:

$$R\&D\ \text{spillovers}_i = \left[\frac{\sum_{j=1}^{n} \text{RD}_j}{\sum_{j=1}^{n} \text{Net Sales}_j}\right]_{t-1} \quad \text{where } j \neq i$$

Learning through R&D spillovers is measured as the assimilation of technical know-how from similar (or related) industry groups gained through the experience till the immediate recent past.

Control Variables

Control variables are used to account for other factors that could influence firm-level R&D intensity. We controlled for *firm size* by taking log transformation of (nominal) net sales measured in millions of INR. For *firm age*, year of

[11]For (other) alternative measures of spillovers, see Dasgupta and Stiglitz (1980), Levin and Reiss (1984, 1988) Jaffe (1988), Bernstein and Nadiri (1988, 1989) and Cohen and Levin (1989).

[12]A similar construction can be seen in Martinez-Ros (2000) where spillovers are measured by the industry knowledge stock *minus* the own firm R&D expenditure normalized by the industry sales *net* of firm's sales.

[13]'The problem arises when we want to extend this scale across the other … industries. Here, there is no natural order of closeness (e.g. is "leather" closer to "food" or to "textiles"?)'; Griliches (1979).

Table 9.2 Descriptive statistics of the variables

Variable	Mean	Median	Std. dev.	Min.	Max.	No. of firms
R&D intensity	1.94	0.80	3.71	0	45.41	63
Nominal net sales (*in Rs. Billions*)	4.14	1.11	9.08	0.006	62.16	63
Age (*in years*)	26.96	24	12.25	6	60	63
R&D spillovers	2.59	0.97	6.16	0.007	78.57	63
Embodied technology	1.78	0.16	4.85	0	57.22	63

incorporation is considered. Since our main emphasis is on firm-level R&D intensity, we believe that for a technologically dynamic sector such as electronics, imports of (superior) technologies play an important role, and hence, e*mbodied technology* (measured as imports of capital goods expenditure deflated by net sales) is used to control for the firm's technology base which impacts firm-level R&D activities.

9.4.1 Descriptive Statistics

The data set contains annual data from March 2002 to March 2014 for an unbalanced panel of 63 electronic firms that have been selected based on the reporting of R&D expenditure. The data include both the multinational corporations (MNCs) and the domestic firms operating in India. Table 9.2 presents the descriptive statistic of the variables for the panel of 335 observations examined in the present study.

Figure 9.2 shows the pattern of R&D intensity for a panel of 63 firms belonging to the Indian electronics sector for the study period 2002–2014. As observed from the figure, R&D intensity has a positive trend and has increased from less than 0.73% in 2002 to approximately 5.8% in 2014. The mean R&D as a proportion of firm net sales was found to be 2% during the time period. The figure also displays the average R&D spillovers during the 13-year time span. On an average, the graph of R&D spillovers lies above the average R&D intensity for the period 2002–2006 and lies beneath it for the remaining time period up to 2014.

Figure 9.3 demonstrates the bar diagram of average R&D intensity and average R&D spillovers for the 12 industry groups forming our sample. As noticed from the bar plot, the maximum R&D spillovers of approximately 8.5% are experienced by the Communication and Equipment industry (NIC code: 26302), while the highest recorded R&D intensity is computed for the 'Other Electronics' industry group (NIC code: 26405) manufacturing electronic buzzers, soft ferrites, amplifiers, etc.[14]

[14]We take this industry group (NIC code: 26405) as our reference category when introducing the *slope dummies* in our econometric model.

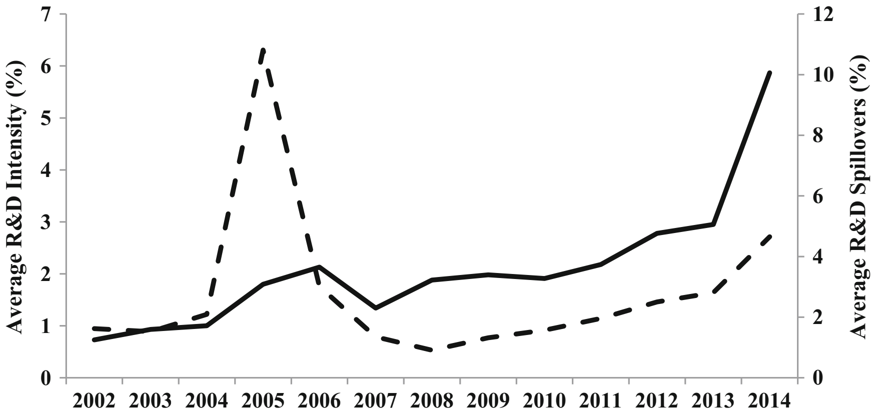

Fig. 9.2 Average R&D intensity and average R&D spillovers of electronic firms

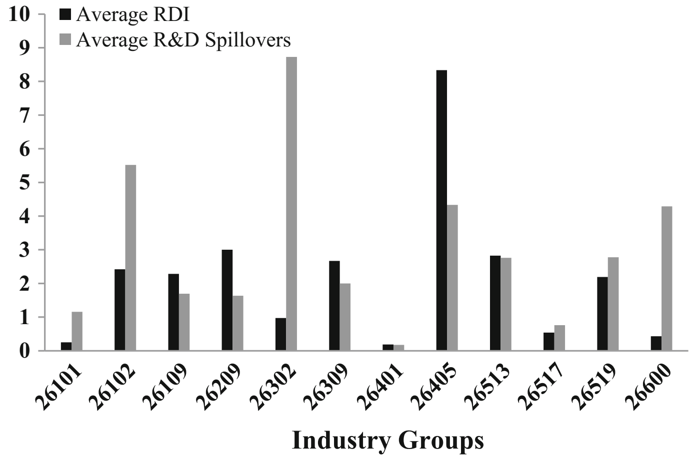

Fig. 9.3 Average R&D intensity and average R&D spillovers of industry groups

9.5 The Econometric Method

Our baseline specification consists of a *one-way* fixed-effects model to estimate the impact of R&D spillovers on in-house R&D efforts of the Indian electronic firms.

Our baseline model (Model I) is specified as follows:

$$\text{RDI}_{it} = \alpha + \beta_1 \text{R\&D spillovers}_{it-1} + \beta_2 \text{Age}_{it} + \beta_3 \text{Size}_{it} + \beta_4 \text{Embodied Tech}_{it-1} + \beta_5 [D_{IG} \times \text{R\&D spillovers}_{it-1}] + \ldots + \beta_{15} [D_{IG} \times \text{R\&D spillovers}_{it-1}] + \mu_i + \varepsilon_{it}$$

Table 9.3 Model specification tests

Model specification	Computed test statistic	p-value
Model I	Breusch-Pagan LM : $\chi^2(1) = 143.43$ Hausman : $\chi^2(14) = 35.15$ F-Test : $F(62, 257) = 3.74$	0.00
Model II	Breusch-Pagan LM : $\chi^2(1) = 153.22$ Hausman : $\chi^2(16) = 34.79$ F-Test : $F(62, 256) = 3.85$	0.00

where D_{IG} are the dummy variables for the 11 industry groups in our sample μ_i are the unobserved time-invariant firm-specific effects, such as managerial skills, and other firm-specific innate attainments and abilities ε_{it} is assumed to be identically and independently distributed.

Subsequently, we estimate Model I with the *interaction effect* (specified as Model II) by introducing an interaction term of R&D spillovers considered interacting with the age of the firm. In this case, the econometric model specification is:

$$\begin{aligned}\text{RDI}_{it} = {} & \alpha + \beta_1 \text{R\&D spillovers}_{it-1} + \beta_2 \text{Age}_{it} + \beta_3 \text{Size}_{it} + \beta_4 \text{Embodied Tech}_{it-1} \\ & + \beta_5 \{\text{Age} \times \text{R\&D spillovers}\}_{it-1} + \beta_6 [D_{IG} \times \{\text{Age} \times \text{R\&D spillovers}\}_{it-1}] + \ldots \\ & + \beta_{16} [D_{IG} \times \{\text{Age} \times \text{R\&D spillovers}\}_{it-1}] + \mu_i + \varepsilon_{it}\end{aligned}$$

The Breusch–Pagan Lagrange Multiplier (1980) justified the use of panel estimation. The Hausman (1978) specification test (Table 9.3) rejects the null hypothesis that firm-specific effects are not correlated with the regressors.[15] The estimated F statistic indicates the presence of fixed effects in the database and suggests that unobservable firm-specific characteristics influence the in-house R&D intensity of the electronic firms in India.[16]

The Breusch–Pagan (1979) test showed heteroscedasticity problem. The structure of our database (highly *unbalanced*) does not allow us to generate evidence for cross-sectional dependence in our data set. Data suffering by heteroscedasticity or any potential cross-sectional dependence can lead bias to the standard errors, causing less efficient estimates. The correction we use is the fixed-effects regression with Driscoll and Kraay's (1998) *corrected standard errors*. The error structure is assumed to be heteroscedastic, autocorrelated up to some lag and possibly correlated between the groups. The nonparametric covariance matrix estimator provides consistent standard errors robust to these problems.

[15]We perform the Hausman test that is heteroskedasticity consistent and robust to spatial and temporal dependence. The null hypothesis of the Hausman test states that the random effects model is valid. The null hypothesis of *no FE* is *rejected* at the *5%* level of significance. As a result, the regression model should be estimated by fixed effects (within) regression. Stata's Hausman command performs a panel-robust Hausman test that is consistent in the presence of cross-sectional dependence.

[16]The fixed effects model allows μ_i to be correlated with the independent variables.

Table 9.4 Endogeneity test result

Variables	*LM* statistic
Size	3.62
Age	0
R&D spillovers	0.58
Embodied technology	0

Note Critical value of $\chi^2(1\ df) = 6.63$ (at 1%)

Table 9.5 Results of *Driscoll–Kraay* corrected standard errors for fixed-effects estimation

Variables	Model I with R&D spillovers	Model II with interaction effect: R&D spillovers *X* age
R&D spillover$_{t-1}$	−0.105 (*−6.85*)***	0.009 (*0.19*)
Age$_t$	0.003 (*4.26*)***	0.003 (*4.45*)***
{Age × R&D spillover}$_{t-1}$	–	−0.005 (*−1.99*)*
Size$_t$	−0.018 (*−3.82*)***	−0.019 (*−3.62*)***
Embodied technology$_{t-1}$	0.022 (*1.67*)	0.021 (*1.65*)
Constant	−0.017 (*−1.22*)	−0.020 (*−1.45*)
No. of firms	63	63
No. of observations	335	335
R^2 within	0.11	0.11
F(26, 12)	(510.32)***	
F(27, 12)		(306.19)***

*, *** imply statistical significance at the 10 and 1% level, respectively

Before presenting our estimation results, we verify the absence of multi-collinearity as well as any potential endogeneity problem.

The variance inflation factor (VIF) indicates the absence of multicollinearity problem. In order to rule out the possibility of inconsistent regression coefficients if the independent variables are endogenous, we conducted the Hausman (1978) endogeneity test. The results are given in Table 9.4 below. Clearly, none of the independent variables entering our model is endogenous.

9.5.1 Empirical Results

The regression results of (one-way) *fixed-effects* model that takes account of *Driscoll–Kraay* correction for cross-sectional dependence as well as possible autocorrelation and heteroscedasticity in our *unbalanced* panel are reported in Tables 9.5 and 9.6. While reporting the statistically robust parameter estimates, we make sure that all our regressors are *exogenous* and there is no multicollinearity problem in our reported model specifications.

Table 9.6 Slope coefficients of R&D spillovers and the interaction term and the corresponding marginal effects for the slope dummies

NIC code	Industry group	Slope coefficients of R&D spillovers	Marginal effects	Slope coefficients of age*R&D spillovers	Marginal effects
26101	Other Electronics$_1$	0.239 (3.71)***	0.134 [C]	0.011 (4.37)***	0.005 [C]
26102	Other Electronics$_2$	0.2981 (5.39)***	0.1927 [C]	0.0102 (5.15)***	0.004 [C]
26109	Other Electronics$_3$	0.071 (1.25)	–	0.005 (2.09)**	0.000 [C]
26209	Computers and Peripherals	−0.285 (−2.73)***	−0.390 [S]	−0.022 (−3.46)***	−0.027 [S]
26302	Communication Equipment$_1$	0.135 (6.83)***	0.029 [C]	0.006 (3.30)***	0.001 [C]
26309	Communication Equipment$_2$	−0.021 (−0.23)		0.001 (0.38)	
26401	Consumer Electronics	−2.037 (−2.62)**	−2.142 [S]	−0.106 (−4.29)***	−0.111 [S]
26513	Miscellaneous Manufactured Articles$_1$	0.092 (3.44)***	−0.013 [S]	0.004 (3.29)***	−0.001 [S]
26517	Other Electronics$_4$	0.240 (1.76)*	0.135 [C]	0.007 (0.97)	
26519	Miscellaneous Manufactured Articles$_2$	−0.538 (−1.99)*	−0.644 [S]	−0.014 (−1.98)*	−0.019 [S]
26600	Other Electronics$_5$	0.133 (6.35)***	0.028 [C]	0.006 (4.36)***	0.000 [C]
Overall		−0.105 (−6.85)***		−0.005 (−1.99)*	

*, **, *** imply statistical significance at the 10, 5, and 1% level, respectively
[C] indicates complementarity, while [S] denotes substitutability between R&D spillovers and R&D intensity

As mentioned in Sect. 9.5, in our Model I specification, we primarily emphasize on the role of R&D spillovers, amongst other traditional firm-specific determinants of the R&D intensity of firms in the Indian electronics goods sector during the period 2002–14. The results exhibit that R&D spillovers assimilated from (other) related firms within a specific product category *negatively* affects R&D intensity of firms. Such *substitutability* between R&D spillovers and a firm's own in-house R&D efforts indicate that firms having sufficient in-built expertise perhaps prefer to exploit the available technological know-how from similar or related industry group (s) than to engage in (relatively risky) own in-house R&D activities. A probable reason for such substitutability could also be that the cost undertaken for acquiring similar information (which is viewed as a substitute to the firm's own stock of technological knowledge) from related industry group(s) is less than the amount of resources required to be spent on in-house R&D activities. This may prompt the firms to have a lower incentive to spend on own R&D efforts.

Amongst the traditional individual firm-specific characteristics, experience of the firms in business (reflecting *learning by doing*) *positively* influences the R&D intensity of electronics firms in India. However, since the consumer electronics industry which predominantly rules the Indian electronics sector, took off majorly in the late 1990s, it seems reasonable to find that the coefficient value of age of the firms is much less than that of the R&D spillovers. Following Lall (2000), age of the firm could be considered as a 'catch-all' variable; it represents learning by doing. Firms who have been in the same line of business for a long period of time are expected to continually engage in search for improved and better know-how. Since the electronics goods sector in India is highly competitive, firms may also feel the pressure of competition to be engaged in this search activity. This could be the reason why coefficient of the age variable has turned out with a positive and significant coefficient.

In what follows, we extend our conceptualization of Model I by inserting an 'interaction term' ($\text{Age}_{t-1} \times$ R&D spillovers_{t-1}) and examine the relative significance of both of these two variables in Model II.[17] It is noteworthy that while the coefficient value attached to the age of the firms remains same (with stable t-values), in the presence of the interaction term, R&D spillovers turn out to be statistically *insignificant*. However, now the interaction between accumulated business experiences of *individual* electronics firms with the available technological know-how from *other related firms* turns out to be *negatively* affecting the R&D intensity of firms. It can therefore be argued that the relatively more experienced firms have a lesser incentive to undertake in-house R&D activities *when* they have the advantage of a favourable *learning curve* to substitute their own R&D efforts in which case they may easily absorb the industry spillovers and adapt to the technological activities carried out by other firms within the same industry group.

The other firm-specific determinant that is mostly considered in the (empirical) literature is *size* of the firms. Firm size is found to be *negatively* affecting the R&D activities of firms. This result is somewhat uncommon compared to the extant literature. It seems that domination in the market by the large firms makes it less attractive to these firms to spend relatively more on new (risky) in-house R&D activities.[18] Looking at the steep growth of the demand for electronic products and the sector predominantly flooded by the firms dealing with consumer electronics, it appears that the urge to grow is more with the relatively smaller firms and they are the dynamic ones who undertake R&D investment in order to differentiate their

[17]We had also examined the relative significance of firm size and R&D spillovers put together in Model II. However, the coefficient value of the interaction term does not turn up to be statistically significant.

[18]This is due to the presence of economies of scale advantages in R&D enjoyed by larger firms. While the R&D expenditures of large-sized firm increases, it is less than proportion to the increase in firm size.

product(s) and services to penetrate into the domestic as well as the export market (s).[19] At the same time, the R&D efforts in the electronics goods sector in India have mostly been directed to bring about incremental changes in product design and improving cost efficiency. While both the small- and large-sized firms engage in this process, there are no specific scale advantages for firms to engage in these specific, minor search processes. In fact, the outcome of learning from in-house R&D gets implemented in products very fast. Such a fast translation of R&D learning to commercialization could be relatively easier for small-sized firms than their larger counterpart. In large enterprises, there could even be disconnect between in-house R&D unit on the one hand and manufacturing and marketing on the other. This could also be the reason why size is taking a negative coefficient.

Unlike the former empirical evidences in the Indian context, our empirical estimates of the import of capital goods do not surface as statistically significant. Perhaps more reliance is laid on R&D spillovers in deciding whether to engage in in-house R&D efforts, and therefore, it did not show any significant impact on firm's in-house R&D efforts.[20]

Allowing the slope coefficient of R&D spillovers to vary between industries (in Model I), we find that substitutability between R&D efforts and R&D spillovers holds true for select industries. Varying the coefficient of the interaction term (Model II) across the industry groups reveals similar pattern. The slope coefficients as well as the marginal effects of the significant slope coefficients are calculated and presented in Table 9.6. While four industry groups exhibit *substitutability*, five industries demonstrate *complementarity* between in-house R&D efforts and R&D spillovers. Amongst the industry groups exhibiting complementarity between R&D spillovers and in-house R&D efforts are the following industry groups such as 26101, 26102, 26109, 26302, 26517 and 26600 falling in the following product categories: Other Electronics such as capacitors, semiconductor devices, LCR bridges, LED lamps, diodes, transistors, other display devices, microwave passive components, laminates, moulding compounds in electronics, coils, magnetic media, insulators in electronics,

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[19]In order to take account of any possible nonlinearity of the age and size characteristic of the firm, their squared terms were introduced into the model. They did not turn out to be statistically significant.

[20]Other empirical variables such as vertical integration, disembodied technology as well as the industry concentration were also considered. Disembodied technology measured by payments made towards the acquisition of royalty and technical know-how does not surface as an important source of knowledge and information for the Electronics Goods Sector in India. Similarly, even though it can be argued that a concentrated industry structure has a higher incentive to undertake R&D efforts in order to protect market position and create entry barriers, the present analysis does not find any significant impact of the HHI variable in influencing R&D intensity. Therefore, none of these variables came out with any possible implication for the outcome of the in-house R&D efforts of the electronic firms. We found the coefficient of the current value of vertical integration to be statistically significant with a negative sign implying that higher levels of knowledge transfer are likely to discourage the firms to undertake own R&D efforts and therefore have a negative influence on producing new products (Ling Li and Je Tang 2010). Since this variable had endogeneity problem (Chi^2 = 11.69), we introduced a one-period lag of the vertical integration variable. However, it did not surface as a statistically significant determinant of in-house R&D efforts.

floppy disks, control instrumentation and industrial electronics, therapy equipment, surgical equipment, medical equipment, surgical equipment, pacemakers, diagnostic equipment and communication and broadcasting equipment such as electronic telephones, cordless phone, transmission equipment, VHF radio systems, electronic exchanges, point-to-point/two-way radio systems. We recognize that the presence of MNCs in related industry groups and increased pressure of competition propel these firms to spend more on R&D. The industry groups displaying substitutability are the computers, peripherals and storage devices group (26209), consumer electronics (26401), chiefly the white goods such as refrigerators, air conditioners, washing machines and television and finally the Miscellaneous Manufactured Articles (26513 and 26519) such as energy metres and strategic electronics equipment, scientific and laboratory instruments, thermal analysis equipment, Industrial electronics and automation equipment, electronic test and measuring instruments.

The groups demonstrating complementarity are the primary producers or creator of advanced technology, while the substitutability relationship between R&D spillovers and in-house R&D efforts conforms primarily to the user industries applying such technology. We observe that the computers, peripherals and storage devices industry group as well as the consumer electronics industry with an average experience of 16 years are engaged in substituting their in-house R&D efforts with R&D spillovers from related industry groups.[21] The pre-reform period has been dominated by small and medium enterprises primarily engaged in the manual assembly of lower-end consumer electronics products which was no longer considered feasible for remaining in operation in the post-reform era. The survival of the electronic firms necessitated acquiring as well as adapting the latest technologies.[22] Given the short-product cycles in user industries applying similar technology, it became necessary for the Indian electronic firms to assimilate and adapt the latest advents in technology in order to remain functional.[23]

For firms belonging to the Other Electronics industry group as well as those producing communications and broadcasting equipments, R&D spillovers is a strategic complement to the firm's own R&D.[24] It is possible that economies of

[21]This is contrary to the life cycle theory of knowledge where, in the early formative years of learning and performing within the industry, firms typically pursue many complementary research trajectories.

[22]Technological innovations have offered immense potential for lower costs at higher volumes within this industry, therefore making scale important. As a result, large firms dominate the consumer electronics markets although small-scale firms have a scope in niche markets.

[23]While a negative effect of spillovers on in-house R&D efforts suggest substitutability, it does not indicate that spillovers must be low if the industry has a relatively high R&D intensity [for details see Harhoff (2000)].

[24]Technological changes have made various parts of the electronics goods sector interdependent wherein research and development, development of new processes, manufacturing and sourcing, distribution and end-user application are integrated. For instance, the growth of the consumer electronics segment, especially TV and audio systems, led to the growth of the electronics sector directly and also indirectly via the growth in the components segment. For instance, 70% of the production of the components segment goes to consumer electronics industry group.

scope in R&D may be stronger for these industry groups exhibiting complementarity between R&D spillovers and in-house R&D efforts [see Harhoff (2000)]. As an example, the industry group 26102, manufacturing semiconductor devices amongst other electronic products have a high R&D intensity of 2.42% alongside high R&D spillovers of 5.52%.[25]

Some features of the industry groups and the impact of R&D spillovers on their R&D Intensity (Appendix 1 provides details for the descriptive statistics analysed below).

In the context of the Indian Electronics industry, the industry groups with a relatively larger numbers of average years of experience have a greater proportion of older firms. These include, for instance, the Other Electronics_1 (26101) and the Other Electronics_2 (26102) group with an average experience of 29 and 32 years, respectively, and the Miscellaneous Manufactured Articles_2 (26519) group having an average age of 37 years. While the former two groups belonging to the Other Electronics product category show complementarity, the latter displays substitutability between R&D spillovers and in-house R&D activities. As the pattern suggests there is no clear indication that complementarity of technological efforts should prevail in relatively young industries within the electronics goods sector in India.

In order to look at the impact of R&D spillovers for industry groups with varied size (brought up in Appendix 1), we find that substitutability is high for the large-sized industry groups. For instance, the industry groups, Consumer Electronics (26401) and Miscellaneous Manufactured Articles_2 (26519) with average net sales of Rs. 3915.46 and 13346.68 million, respectively, have relatively high marginal effect of R&D spillovers on in-house R&D efforts: −2.14 and −0.64, respectively. On the other hand, strong complementarity is found for some small-sized industry groups; these correspond to the NIC codes 26101, 26102 and 26517. The regression result indicates that small-sized firms are relatively more engaged in in-house R&D activities. It appears that these R&D efforts tend to be directed mostly towards complementing existing information obtained from related industry groups.

To sum up, the significant sign of the (overall) coefficient of the R&D spillover variable suggests substitutability. Thus, if the cost of acquiring information from the market is less than the amount of resources required to be spent on R&D activities, then the firms may substitute their own in-house R&D efforts for the information attained through R&D spillovers from similar industry groups. Contemporaneously, we notice the positive marginal effects of the slope coefficients of the R&D spillover variable in the estimated regression equation. This implies a complementarity relationship for select industrial sub-sectors within the electronics goods sector in India. Consequently, these industry groups have an inducement to invest in own R&D efforts in order to develop the ability so as to absorb more of the spillover benefits.

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[25]Spence (1984) and many subsequent contributions ruminate the fact that the semiconductor industry is characterized by a high R&D intensity in combination with a high spillovers.

9.6 Summary

Some of the earlier literature that have analysed the Indian electronics sector include the works of Joseph (1989), Chaudhuri (1995), amongst others. These works have looked at this sector during the decade of the 80 s and the 90 s in an environment of liberalization vis-a-vis the earlier period of controls. Our database is constructed for analysis for the second phase of the economic reforms, from post-2001 onwards. The motive is to see the technological capability of firms in this sector after undergoing almost two decades of continuing technological change that came through the process of import of technology from developed countries and internal development through in-house R&D activities. A set of works have also looked at electronics as a separate sector. These include studies by Siddharthan (1988), Subrahmanian (1991), and Mani (1993), amongst others. They analysed the nature of the relationship between the expenditure on imported technology and R&D expenditure on the basis of the (aggregate) industry-level data. In this paper, we depart from the earlier empirical works: first, by examining the determinants of R&D intensity at the (disaggregated) industry group's level representing different product lines within the electronics goods sector in India, and second, we attempt to capture the impact of R&D spillovers on in-house R&D intensity along with the technological efforts such as import of technology and other traditional firm-specific characteristics such as firm size and experience of the firms.

In what follows, we look into the role of R&D spillovers from 'other' firms in similar industry groups. The theoretical literature has mostly followed the view that spillovers are substitutes, with public goods properties and that new information is homogeneous across firms, irrespective of the industry's age and technological intensity. Using the CMIE Prowess database, we construct a measure for the potential pool of R&D spillover and analyse the impact of this measure on firm's in-house R&D efforts. We apprehend that firms which are closely related in the sense of falling in the same industry group classification are presumed to benefit more from each other's R&D efforts than firms at a greater distance from each other.

Using panel data estimation for the period 2002–2014, this paper finds that firms benefitting from R&D spillovers in their line of business are spending less on in-house R&D activity. The results, however, suggest complementarity between in-house R&D efforts and R&D spillovers for select industries within this sector. Age of the firm, representing the learning by doing proposition, turned out with a positive and significant coefficient. When R&D spillover is considered interacting with the age of the firm, we find that older firms that benefit from R&D spillover appear to be less engaged in in-house R&D efforts. This result strongly supports the 'absorptive capacity' hypothesis developed by Cohen and Levinthal (1989). Contrary to the extant empirical literature, small-sized firms appear to be more R&D intensive than their larger counterparts. The paper highlights the possibilities of benefits appropriated by large and older firms from the available pool of R&D spillovers. Small as well as young firms continue to rely on in-house R&D for their survival and growth. Also, the results clearly point out inter-industry differences, based on product lines, in technological efforts in the electronics sector in India.

While spillovers are important in determining expenditures on R&D, there are certain other factors that also influence in-house R&D activity. One of them is related to the impact of intellectual property rights (IPR) (Siddharthan 2015). This aspect has been analysed by Hernan et al. (2003), Bonte and Max (2005), amongst others. They found that IPR is a hindrance to joint venture formation in carrying out R&D.[26] Therefore, while development of new products and design depends on in-house R&D efforts and research joint ventures with other enterprises, strong IPR could result in less diffusion of new ideas from the R&D efforts of firms operating in related product lines. On the positive side, given the econometric evidence of substitutability between R&D spillovers and R&D intensity for firms belonging to the computers, peripherals and storage devices industry group as well as the consumer electronics industry, presence of IPR may instead induce these firms to rely on their (own) in-house R&D efforts and, therefore, spend more on R&D activities. However, for firms producing communications and broadcasting equipments and other electronics components wherein research and development, design and end-user application are integrated with the growth of other segments, R&D spillovers from firms operating in similar industry groups and their in-house R&D effort complement each other. For these firms, strong IPR may be found to be counterproductive.

Appendix 1 Descriptive Statistics: Industry Group-Wise

NIC Code	Industry group	[C/S]*	Average age (years)	Average size (Rs. Billion)	R&D intensity (%)	R&D spillover (%)	Young firms (%)
26101	Other Electronics	C	29	0.42	0.25	1.15	42
26102	Other Electronics	C	32	1.62	2.42	5.52	50
26109	Other Electronics	C	25	2.70	2.28	1.69	57
26209	Computers and Peripherals	S	16	1.55	3.00	1.63	66
26302	Communication Equipment	C	22	4.04	0.97	8.72	60
26309	Communication Equipment	S	28	2.78	0.02	0.02	50
26401	Consumer Electronics	S	16	3.91	0.18	0.17	46

(continued)

[26]As a result of this, more than 70% R&D collaborations are informal and outside the IPR law [see Bonte and Max (2005)].

(continued)

NIC Code	Industry group	[C/S]*	Average age (years)	Average size (Rs. Billion)	R&D intensity (%)	R&D spillover (%)	Young firms (%)
26513	Miscellaneous Manufactured Articles	S	22	3.18	2.82	2.76	69
26517	Other Electronics	C	29	1.04	0.53	0.76	55
26519	Miscellaneous Manufactured Articles	S	37	13.34	2.19	2.77	47
26600	Other Electronics	C	25	1.87	0.43	4.28	46

Data Source Prowess database, Centre for Monitoring Indian Economy
*[C] indicates complementarity, while [S] denotes substitutability between R&D spillovers and R&D intensity

Appendix 2 Market Share, Average Age and Average R&D Intensity of the Top Four Firms

Year	Market share (%)	Average age	Average RDI (%)
2002	72	25	1.3
2003	75	26	1.4
2004	79	27	0.5
2005	78	26	1.3
2006	76	28	1.0
2007	73	26	1.0
2008	59	32	1.8
2009	58	26	1.2
2010	59	30	1.5
2011	67	38	2.4
2012	75	39	3.5
2013	84	34	3.4
2014	83	34	2.7

Data Source Prowess database, Centre for Monitoring Indian Economy

Appendix 3 The 12 Industry Groups Constituting the Sample Used in the Present Study

NIC code	Industry group	Product/service category
26101	Other Electronics	Capacitors, electrolytic capacitors, plastic film capacitors, ceramic capacitors
26102	Other Electronics	Crystals, piezoelectric elements semiconductor devices, LCR bridges, LED lamps, diodes, diodes and transistors, other display devices, integrated circuit, quartz crystals
26109	Other Electronics	Heat sinks, switches, connectors, filters, servo components, microwave passive components, laminates, moulding compounds in electronics, coils, magnetic media, insulators in electronics, floppy disks
26209	Computers, Peripherals and Storage Devices	Computer peripherals, data storage, memory systems
26302	Communication Equipment	Communication and broadcasting equipment, electronic telephones, cordless phone, transmission equipment, VHF radio systems, electronic exchanges, point-to-point/two-way radio systems
26309	Communication Equipment	Defence communication equipment
26401	Consumer Electronics	TV picture tubes colour, television receivers
26405	Other Electronics	Electronic buzzers, soft ferrites soft ferrites, amplifiers and PA systems
26513	Miscellaneous Manufactured Articles	Metres electricity, polyphase energy metres
26517	Other Electronics	Control instrumentation and industrial electronics, weighing system, load cell control instrumentation and industrial electronics, control panels, sensors and indicators
26519	Miscellaneous Manufactured Articles	Strategic electronics equipment, scientific and laboratory instruments, thermal analysis equipment, industrial electronics and automation equipment, electronic test and measuring instruments
26600	Other Electronics	X-ray machine, therapy equipment, surgical equipment, medical equipment, surgical equipment, pacemakers, diagnostic equipment

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Part IV
Technology and Competitiveness

Chapter 10
Is Intra-industry Trade Gainful? Evidence from Manufacturing Industries of India

Sagnik Bagchi

Abstract Considering a range of both static and dynamic indices to measure magnitude of *intra*-industry trade (IIT), this paper demonstrates that the liberalization process has led to increase in dominance of India's trade in products of similar or different technologies. According to OECD classification of industries, we find major share of India's IIT has evolved from industries of India that are categorized into *high*, *medium-high* and *medium-low* technology groups. Decomposing IIT of these industries into its varied forms, we find that India's export of *low* technological products to be more dominant in India's IIT than export of *similar* or *high* technological goods—indicating a downward trend in the terms of trade. Econometric estimates reveal that product differentiation representing consumer's preference for range of varieties turn out to *positively* affect trade in both similar and different technologies of the same product. Furthermore, we also find increased competition from imports have resulted in the shift of specialization by industries of India from *low* technological products (yet dominant) to *high* and *similar* technological products. Our result also suggests that the magnitude of total IIT has gained impetus with the shift in productive resources from inefficient to efficient product lines within an industry. However, with disentangling total IIT one observes that much of the explanation behind the result is owed to dominance of India's export of *low* technological product. Alongside, we also identify that protectionism in the form of anti-dumping initiations initiated by foreign firms allows them to leapfrog Indian firm's export of *superior* technological variant.

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S. Bagchi (✉)
Department of Humanities and Social Sciences, Indian Institute of Technology Bombay, Powai, Mumbai 400076, Maharashtra, India
e-mail: sagnikb@iitb.ac.in

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10.1 Introduction

Prior to 1990s, stringent (as well as orthodox) protectionist trade policies had eventually turned India into a moribund state such that India was virtually looked down upon being an isolated economy suffering from prolonged balance of payments crisis. With much desperation and political oppositions, the New Trade Policy in 1991 allowed India to break away from the clutches of such restrictive trade policies and integrate gradually with the world economy. The reforms resulted in India's total trade to increase by 16 times in 2013 to what it traded in 1990, and during 2001–08 India's foreign trade grew on an average by around 28%. Furthermore, India's share in world trade increased from 0.58% in 1990 to 0.71% in 2000 while in 2013 it was around 2%.

Empirical evidences from across the world indicate that the process of trade liberalization not only drive growth of *inter*-industry trade but also allows countries to specialize in different varieties of the same product and thus supplement growth of *intra*-industry trade (IIT).[1] It is argued that, for inter-industry trade, liberalization process allows reallocation of productive resources from import competing industries to those industries in the domestic country that have the comparative cost advantage; see, Caves et al. (2008) for a detailed theoretical discussion. While in the context of IIT, it is more likely that reallocation of resources takes place from inefficient to efficient product lines *within* an industry; see, Caves (1981) and Melitz (2003), among others for similar arguments.

Theoretical models of IIT are classified in two parts: two-way trade in horizontally (different varieties of *similar* technologies or qualities) and vertically (different varieties of *different* technologies or qualities) differentiated goods (H-IIT/V-IIT). The first kind follows from the contribution of Krugman (1979), Lancaster (1980), Helpman (1981) where product differentiation, and/or scale economies and consumer preferences for product diversity have been modelled. On the other hands, models of vertical IIT resort to differences in relative factor intensities which are driven by comparative cost advantage between two trading partners; see, Falvey (1981), Falvey and Kierzkowski (1987), Flam and Helpman (1987), among others. Collectively, models of vertical IIT demonstrate that in accordance with comparative cost advantage a relatively capital and labour abundant country would export a *high* and *low* quality of the same product (*h*-VIIT/*l*-VIIT), respectively.

In the context of India's *intra*-industry trade, Bhattacharyya (1991) finds even before the deliberation of economic reforms in the country there is a rising trend of such trade at the SITC-2 and 3 digit level (1970–87).[2] Having witnessed a decade of

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[1]For instance, empirical studies on Australia, India, Spain, and other cross-country comparisons have shown that trade reforms have a positive impact on the magnitude of total IIT; see, Balassa and Bauwens (1987), Veeramani (2002), Sharma (2004) and Ito and Okubo (2012).

[2]The study argues that the rise in IIT has largely been vertical in nature because of two main reasons: (i) India's growing GNP with a wide income gap gave rise to country's demand for varieties of the same product; and (ii) the co-existence of both traditional and modern methods of production in the country gave way to production of different technological variant of the same product.

economic reforms, Veeramani (2004) argues that the liberalization process in the country had led to reallocation of productive resources from inefficient to efficient product lines within an industry in turn hastened intra-industry trade.[3] Besides providing an explanation to the growth of IIT, the study recommends that Indian trade policies need to be designed in tandem with firms attempt to specialize in narrow product lines. In other words, the country's trade strategies should strive to achieve comparative cost advantage in product lines where firm specializes. Burange and Chaddha (2008) also invokes that the liberalized atmosphere allowed industries to expand their production capacities and thus growth of IIT at the HS-4 digit level in the period between 1987 and 2005. Veeramani (2009) finds again that in a liberalized environment where trade barriers are reduced, Indian firms adapt by specializing in unique varieties of products within an industry which in due course improve the magnitude of IIT.

Given this premise, the main theme of this paper is to undertake a product-level analysis so as to identify whether it is IIT in *horizontally* (similar technologies) and *vertically* (both high and low technologies) differentiated products. This led us to examine whether the liberalization process has been able to reallocate productive resources to efficient product lines within an Indian firm or, to put it succinctly, the empirical verification of the comparative advantage hypothesis. This paper contributes to the existing empirical literature in four distinct ways. *Firstly*, improving from the previous literature on India's IIT in its data construction and computation technique, we calculate the magnitude of IIT by considering a variety of (alternative) indices—*static* as well as *dynamic* and more distinctly at various levels of data disaggregation—namely HS-2, 4 and 6 digit classification level over the period 1990–2013.[4] *Secondly*, we take individually each of 21 broad commodity sections as classified by the India Trade Clarification to identify which among them have relatively high magnitude of IIT across all levels of data disaggregation. *Thirdly*, we use 'unit value dispersion criterion' to disentangle total IIT into technologically similar products [i.e. horizontal (H-IIT)] and products of different technologies [i.e. vertical (V-IIT)] and further V-IIT into technologically inferior products (i.e. *l*-VIIT) and technologically superior products (i.e. *h*-VIIT). This leads us to examine the gains from such trade using the revealed comparative advantage (RCA) at the HS-6 digit level for the commodity groups engaged in IIT in the select manufacturing industries. *Lastly*, we econometrically examine industry-specific determinants of the magnitude of total, (low and high) vertical and horizontal IIT.

The reminder of the paper is organized as follows. Section 10.2 briefly discusses the methods to compute the magnitude of IIT and its different forms. Section 10.3 delves into analysing the trends and patterns of India's IIT, identifies which industries cater more to IIT and finds out the extent of various forms of IIT along

[3]In the facet of import competition, firms compete by specializing and producing a subset of varieties within an industry so as to exploit internal scale economies such as to reduce adjustment cost.

[4]Considering alternative indices allow us to counter the problem of biasedness occurring from 'trade imbalances' on the measurement of IIT. Different levels of data disaggregation conducts the 'categorical aggregation' test.

with RCA. Section 10.4 discusses the data and variables, estimation method and the econometric results. Finally, Sect. 10.5 summarizes the paper.

10.2 Measurement of Intra-industry Trade

In order to inhibit any kind of opinion on the choice of index for the measurement of the magnitude of IIT, we consider indices developed by Balassa (1966) [B_{ij}], Grubel and Lloyd (1971, 1975) [GL_{ij}, GLC_{ij}], Aquino (1978) [AQ_{ij}], Vona (1991) [VN_{ij}] and Brülhart (1994) [$MIIT_{ij}$]. See, Table 10.8 in the appendix for the definition of the indices.

Balassa (1966) index considers the ratio of net trade to total trade to measure the extent of *intra*-industry trade. To arrive at the country level measure, the author assigns equal weight to each commodity group/industry irrespective of their share in total trade. Subsequently, within few years Grubel and Lloyd (1971) developed a composite measure that would calculate the magnitude of IIT as a *percentage* of total trade of a country or for a commodity group/industry. Along with it the index advances over B_{ij} in terms of considering *i*th industry's trade share in total trade of country *j*. Soon after, Grubel and Lloyd (1975) observed that their previous index will always have a *downward* bias as in practice one cannot find balanced trade. In a rectification, the authors divide their previous index with the ratio of country's overall trade imbalance to total trade. Aquino (1978) contest both GL_{ij} and GLC_{ij} by arguing that since all industries do not have *equi*proportional trade imbalances, adjustment made by Grubel and Lloyd (1975) must be at industry level rather and not at the aggregate level.[5] The author corrects it by estimating export and import value of each commodity group/industry such that total exports *equal* total imports for the country.[6] Vona (1991) on the other hand develops its index on the idea that the existence of intra-industry trade is justified at the most disaggregated level of data, irrespective of whether trade is balanced or imbalanced. Brülhart (1994) builds a *dynamic* index that measures the magnitude of IIT in *new* trade flows over two point of time for a country *j*.

10.2.1 Decomposing Horizontal and Vertical IIT

Following the extant empirical literature pioneered by Greenaway et al. (1994), we use the ratio of unit value of exports to the unit value of imports, to disentangle total

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[5]Both GL_{ij} and GLC_{ij} would have *downward* and *upward* bias, respectively for their measurements of IIT. GL_{ij} would have a *downward* bias because trade imbalance is associated with each commodity. GLC_{ij} would be *upward* biased since each commodity (or industry) does not have equiproportional trade imbalance.

[6]Theoretically, Aquino (1978) finds his index to be exactly equal to the index of Michaely (1962).

IIT into trade of similar technological products (i.e. horizontal IIT) and trade of different technological products (i.e. vertical IIT) of the same *i*th product.

$$\text{Horizontal IIT} = \frac{\text{Unit Value of Exports for Good } i}{\text{Unit Value of Imports for Good } i} \in [1-\alpha, 1+\alpha]$$
$$\text{Vertical IIT} = \frac{\text{Unit Value of Exports for Good } i}{\text{Unit Value of Imports for Good } i} \in [1+\alpha, +\infty] \quad \text{and} \quad [0,\ 1-\alpha]$$

where α is the dispersion criterion which is usually taken in literatures anything between 10 and 35%. Furthermore, in considering different technology of the same *i*th product, Azhar and Elliott (2006) points out that an *exported* product is considered to be of a *high* technology (*h*-VIIT) and *low* technology (*l*-VIIT) when the ratio lies between ($1 + \alpha$, $+\infty$) and (0, $1 - \alpha$), respectively. Thus, in disentangling total IIT for the *i*th product, we have the following identities: $\text{IIT}_i = \text{H-IIT}_i + \text{V-IIT}_i$ and $\text{V-IIT}_i = l\text{-VIIT}_i + h\text{-VIIT}_i$.

10.3 How Extensive Is India's IIT?

This section illustrates the India's experience of intra-industry trade over the period 1990–2013. It has two broad sections covering results of India's magnitude of IIT, identifying manufacturing industries of India catering to such trade and finally the share of different forms of IIT along with RCA in the selected manufacturing industries.

Looking at Table 10.1, one finds that across all HS classification levels with fluctuations there has largely been a positive trend in the growth of IIT. Even when we plot the dynamic index MIIT_{ij}, we find that there is an upward trend in the share of IIT in new trade flows across all HS classification levels; see, Fig. 10.1. Both static and dynamic indices reveal that period of 2002–2007 has witnessed a high magnitude of IIT across all the HS classification levels. We also observe that, when compared to the periods of 1990–95 and 1996–01, MIIT_{ij} during the period 2008–13 had depicted high percentage of IIT in new trade flows but it fell from the 2002–07 level. One also finds from Table 10.1 that with a higher level of data disaggregation, there is a fall in the magnitude of IIT for both static and dynamic indices. This happens because with a higher classification level, not all commodity groups have simultaneous exports and imports and thus bring the value of index down. Another important observation that we find is that compared to a low level of data disaggregation variance is small for a high level of data disaggregation. This is because at an aggregated level trade values do not contain the necessary information for an IIT analysis—the classic case of an 'aggregation problem'; see, Finger (1975). Following Aquino (1978), we also verify whether GL_{ij} and GLC_{ij} are *under* and *over* biased, respectively. We find that across all HS classification levels, GLC_{ij} to be over biased. However, GL_{ij} is under biased at HS-2 and 6 digit classification

Table 10.1 Periodic average magnitude of IIT for static indices

Index	1990–1995	1996–2001	2002–2007	2008–2013
HS-2 digit				
B_{ij}	0.62	0.57 (*−8.06*)	0.53 (*−7.02*)	0.49 (*−7.55*)
GL_{ij}	38.17	44.96 (*17.79*)	53.06 (*18.02*)	55.37 (*4.35*)
GLC_{ij}	40.93	50.1 (*22.40*)	60.6 (*20.96*)	70.99 (*17.15*)
AQ_{ij}	36.3	46.78 (*28.87*)	56.5 (*20.78*)	64.48 (*14.12*)
VN_{ij}	99.73	99.94 (*0.21*)	100 (*0.05*)	100 (*0*)
HS-4 digit				
B_{ij}	0.72	0.66 (*−8.33*)	0.6 (*−9.09*)	0.6 (*0.00*)
GL_{ij}	26.12	28.45 (*8.92*)	32.58 (*14.52*)	30.74 (*−5.65*)
GLC_{ij}	27.31	31.51 (*15.38*)	37.7 (*19.64*)	39.47 (*4.69*)
AQ_{ij}	25.99	27.83 (*7.08*)	31.59 (*13.51*)	30.47 (*−3.55*)
VN_{ij}	81.37	89.08 (*0.09*)	98.56 (*0.10*)	99.58 (*0.01*)
n	1198.67	1221.83 (*1.93*)	1236 (*1.15*)	1216.67 (*−1.56*)
HS-6 digit				
B_{ij}	0.78	0.72 (*−7.69*)	0.67 (*−6.94*)	0.67 (*0.00*)
GL_{ij}	14.04	16.63 (*18.45*)	21.33 (*28.26*)	22.48 (*5.39*)
GLC_{ij}	15.36	18.86 (*22.79*)	25.64 (*35.95*)	29.5 (*15.05*)
AQ_{ij}	14.41	16.88 (*17.14*)	21.37 (*26.60*)	22.75 (*6.46*)
VN_{ij}	66.32	78.88 (*18.93*)	95.16 (*20.63*)	98.7 (3.72)
n	4523.33	4843.67 (*7.08*)	5035 (*3.95*)	4919 (*−2.30*)

Note Figures in the parenthesis represent growth in percentage term.
n represents number of commodity groups. For HS-2 digit classification $n = 97$ for all years

levels only. For GL_{ij}, the size of the bias falls as one move to a higher classification level, whereas for GLC_{ij} size of bias is similar for HS-4 and 6 digit classification levels. More importantly, unlike Aquino (1978) the size of bias obtained by us is relatively small and thus possesses no serious problem in using GL_{ij} or GLC_{ij}.[7] On the other hand, we find an equivalence of MH_{ij} and AQ_{ij} at all classification levels. In case of VN_{ij}, we find that the index is inappropriate when it is calculated at a lower classification level. Expectedly, we find all its values to be 100 at the HS-2 digit classification level. Thus, as the author argues that this index needs to be computed at a disaggregated level is validated for our sample.

The pair-wise correlation between different static indices calculated at all the HS classification levels turn out to be statistical significant at 1% level. More importantly, the signs between the indices turn out to be as expected. Thus, given the small size of the bias and the strong correlation between the indices makes it conducive to choose any one index for further empirical analysis.

[7]The average size of the bias at HS-2, 4 and 6 digit classification levels for GL_{ij} and GLC_{ij} are 6.86, −1.64, 1.47 and −7.81, −13.69, −13.84, respectively.

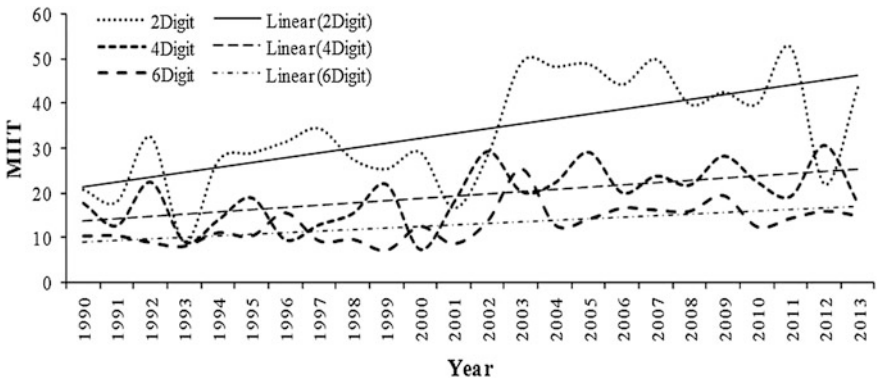

Fig. 10.1 India's marginal IIT

We argue that much of the growth in IIT which occur in the period after 2002 can be linked with India's improved trade performance in the second decade of the liberalization period. Furthermore, as articulated above one finds that empirical literature on India's IIT argues that liberalization process in India has allowed Indian firms to specialize and produce only a subset of product lines within an industry while import the different technological variations of the same product. These arguments led us to examine the dominant form of IIT in industries catering to such trade and then study whether the liberalization process has led India to gain relative efficiency in production of goods engaged in different forms of IIT.

Based on the values of GL_{ij} across HS-2, 4 and 6 digit classification levels we segregate 21 broad industries of India into groups catering to *intra-* and *inter-*industry trade (Table 10.2).

Table 10.2 Manufacturing industries of India cater to intra-industry trade (1990–2013)

HS classification level	Intra-industry trade		Avg. GL_{ij} of other industries
	Industries	Avg. GL_{ij}	
2 digit	Chemicals; plastic and rubber; stone, cement and glass; gems and jewellery; base metals; machinery and mechanical app.; transport equip.; arms and ammunitions; misc. manufacturers	65.79	25.73
4 digit	Chemicals; plastic and rubber; stone, cement and glass; gems and jewellery; base metals; machinery and mechanical app.; transport equip.; optical, photographic, surgical and clock; arms and ammunitions; misc. manufacturers	41.15	13.51
6 digit	Chemicals; plastic and rubber; wood, charcoal and coke; stone, cement and glass; base metals; machinery and mechanical app.; transport equip.; optical, photographic, surgical and clock; transport equip.; misc. manufacturers	30.60	10.44

Table 10.3 OECD classification of industries

Industries	OECD classification
Chemical	Medium-low and high technology industries
Plastics and rubber	Medium-low technology industries
Stone, cement and glass	Medium-low technology industries
Base metals	Medium-low technology industries
Machinery and mechanical appliances	High and medium-high technology, information and communication technology industries
Transport equipment	High, medium-high and medium-low technology industries

The common Indian industries catering to high magnitude of IIT across the HS classification levels are chemical (HS-28 to 38), plastics and rubber (HS-39 to 40), stone, cement and glass (HS-68 to 70), base metals (HS-72 to 83), machinery and mechanical appliances (HS-84 to 85) and transport equipment (HS-86 to 89). In Table 10.3, we categorize these selected industry groups into the various technological classifications as provided by the OECD.

10.3.1 Varied Forms of Intra-industry Trade and Revealed Comparative Advantage

This section uses the *unit value dispersion criterion* to disentangle magnitude of total IIT into its various forms at the HS-6 digit classification level.[8] Following it, using Balassa (1965) we compute the share of RCA for commodity groups engaged in IIT.

One can find from Fig. 10.2 that the industry of Chemical Products exhibits V-IIT to be dominant. By considering 1990 as the base year, we find share of H-IIT to have a rising trend in lieu of a decline in share of V-IIT. For instance, the share of H-IIT and V-IIT in total IIT changed from around 10% and 89% in 1990 to 16% and 83% in 2013, respectively. Average annual growth for the share of H-IIT and V-IIT in IIT has been around 4% and −0.2%, respectively. In the case of V-IIT, we find the share of *l*-VIIT to be dominant; however, by considering 1990 as the base year we find the share of *h*-VIIT to rise in lieu of a declining share of *l*-VIIT. The average annual growth computed for the share of *l*-VIIT and *h*-VIIT in V-IIT has been around −0.17% and 1.18%, respectively. Furthermore, on an average out of 730 commodities traded around 86% of them had been exported and imported simultaneously.

[8]In the paper we report only the values obtained using Greenaway et al. (1994) measure at $\alpha = 0.15$. We also check the sensitivity of our results by considering α at 10, 25 and 35%. In all such cases our results did not change qualitatively from that reported.

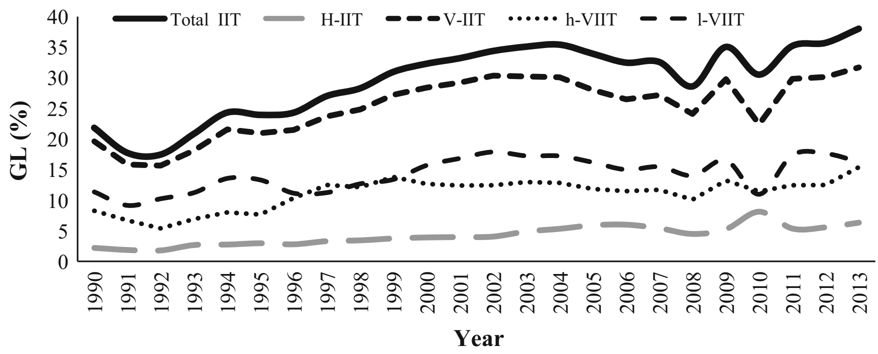

Fig. 10.2 IIT in industry of chemical products

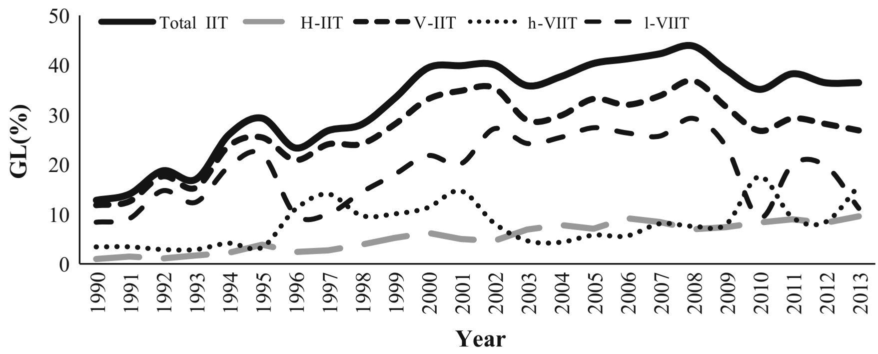

Fig. 10.3 IIT in industry of rubber and plastics

The industry of Rubber and Plastics too witnessed the share of V-IIT to be high; however the average annual growth rate for share of V-IIT in total IIT was around −0.89%. For instance, the share of V-IIT fell from 92% in 1990 to 73% in 2013. In V-IIT, the contribution of *l*-VIIT to total IIT has fallen from 70% in 1990 to 41% in 2013. Comparing *h*-VIIT and *l*-VIIT from the base period of 1990, we find that growth of the former has been rapid than the latter. See, Fig. 10.3. In 1990, out of 182 commodity groups traded only 130 had a two-way trade whereas in 2013 it was 266 out of 295 commodity groups. The share of commodity groups engaged in IIT has an average annual growth rate of around 5%.

Yet again we find that the share of V-IIT to be more as compared to H-IIT in the industry of stone, cement and glass; see, Fig. 10.4. Over the entire sample period the average share of V-IIT has been around 90%. It is only after 2002 that average share of H-IIT somewhat rose [i.e. from around 1.4% (1990–02) to around 5% (2003–13)]. In the case of V-IIT, contribution of *l*-VIIT has been higher but it shows a declining trend. For instance, around 93% of V-IIT has been contributed by *l*-VIIT in 1990 while it fell to around 50% in 2013. Compared to base year of 1990, we observe that H-IIT and *h*-VIIT to have risen more than *l*-VIIT. On an average,

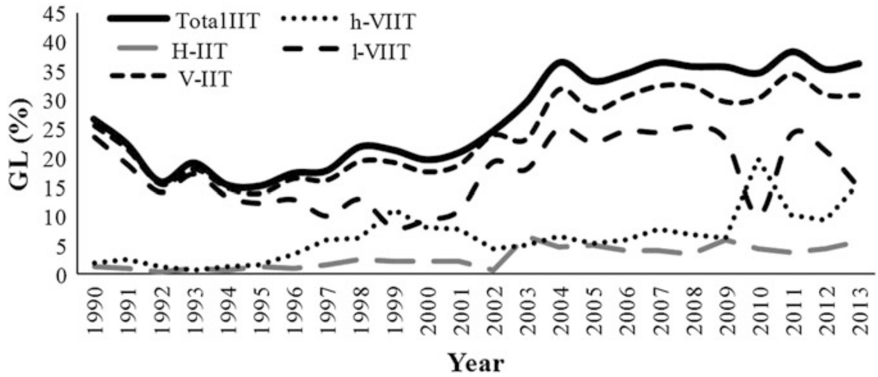

Fig. 10.4 IIT in industry of stone, cement and glass

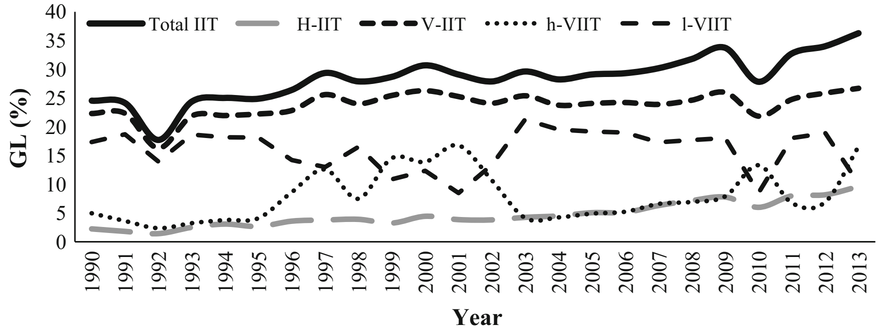

Fig. 10.5 IIT in industry of base metals

around 89% of the commodity groups have the property of IIT. In 1990, around 71% of the commodity groups were engaged in IIT while in 2013 it rose to 97%. The average annual growth rate for commodities engaging in IIT is around 2.5%. For *h*-VIIT and *l*-VIIT average annual growth has been around 22% and 1%, respectively signifying a shift in dominance. Commodity groups under H-IIT also grew rapidly with around 33% as the annual average growth rate.

A similar case is repeated in terms of share of V-IIT in the industry of Base Metals. Over the entire period the average share of H-IIT is around 15%. The average annual growth for magnitude of H-IIT has been around 5% whereas that of V-IIT has been around 1%. While comparing the share of *l*-VIIT and *h*-VIIT in V-IIT, though we find the average share of the former is dominant but there is a shift of dominance from the former to the latter. For instance, one can find from Fig. 10.5 that the share of *l*-VIIT and *h*-VIIT were around 77% and 22% in 1990 and around 38% and 62% in 2013, respectively. On an average around 89% (annual average growth being 2%) of the commodity groups have both simultaneous exports and imports with the major chunk in V-IIT. Furthermore, commodity groups under *h*-VIIT and *l*-VIIT grew around 14% and 1.5%, respectively. Growth in share of commodity groups under H-IIT in total IIT has been around 5%.

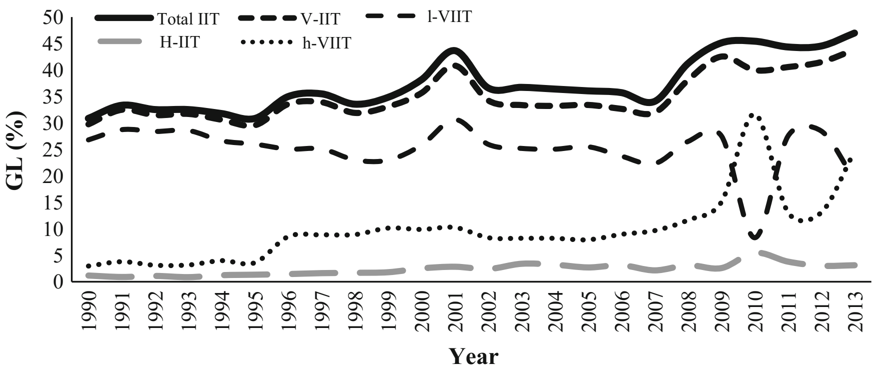

Fig. 10.6 IIT in industry of machinery and mechanical appliances

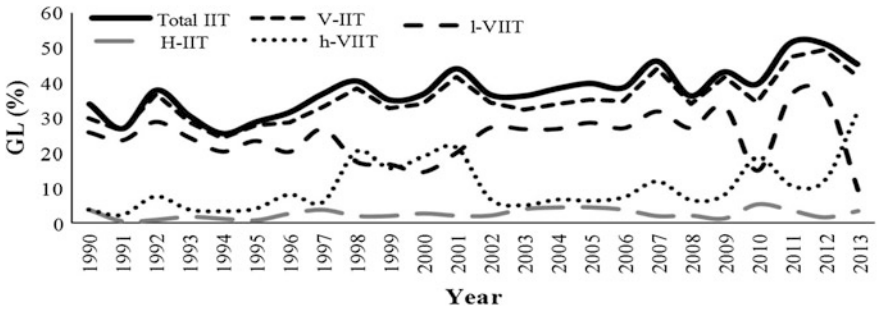

Fig. 10.7 IIT in industry of transport equipment

In case of the industry of Machinery and Mechanical Appliances, we find there has been marginal rise in the share of H-IIT from around 3% in 1990 to around 7% in 2013. See, Fig. 10.6. Nonetheless, the average annual growth for share of H-IIT and V-IIT in total IIT has been around 6% and −0.10%, respectively. In the case of V-IIT we find again that it is *l*-VIIT that dominates. The growth rate for share of *l*-VIIT and *h*-VIIT in V-IIT has been around 13% and 4%, respectively. On an average around 90% of the commodity groups have simultaneous exports and imports. The annual average growth rate for commodity groups under IIT has been around 4%. Interestingly, we find that share of commodity groups engaged in *h*-VIIT to grow rapidly than *l*-VIIT (i.e. average annual growth being 14% and 4%, respectively).

We find that in the industry of Transport Equipment the average share of H-IIT is marginal compared to that of V-IIT (i.e. 7%). However, the annual average growth rate for share of H-IIT and V-IIT in total IIT has been around 19% and 0.2%, respectively. In case of V-IIT, *l*-VIIT had majority of share with an average of 71%. But for the period between 1997–2001 and 2013, *h*-VIIT surpassed *l*-VIIT; see, Fig. 10.7. On the other hand, average annual growth rate reveals contribution of *h*-VIIT and *l*-VIIT in V-IIT grew by around 26% and −0.7%, respectively. Compared to the other industries we find that the percentage of commodity groups having the property of IIT is relatively less. Only, averagely around 77% of the commodity groups have simultaneous exports and imports with the annual growth rate around 3%. However, like other industries too average annual growth rate for *h*-VIIT has been better then *l*-VIIT (i.e. 25.60% and −0.7%, respectively).

Some of the common observations that we make from the preceding discussion is that in these industries number of commodity groups which are traded simultaneously have increased from about 60% in 1990 to above 90% in 2013. More importantly, we observe that all selected manufacturing industries have *l*-VIIT as the major contributor to IIT with *h*-VIIT and H-IIT gaining momentum towards the end of the last decade.

With vertical IIT the dominant type, one finds in the literature that such form of IIT is a manifestation of the traditional trade models where comparative advantage plays a pivotal role as a determinant; see, Martini (1997), Baleix and Egido (2010)

Table 10.4 Commodity groups with RCA (1990–2013)

Industries		Commodity groups		Revealed comparative advantage (RCA)				
		mean	S.D.	mean	S.D.	Share. Mean	Share. S.D.	Mean test |t|
Chemical	H-IIT	89.70	26.01	32.45	11.71	36.42	12.25	16.26[a]
	V-IIT	542.20	85.17	184.67	41.48	33.86	4.30	33.09[a]
	l-VIIT	305.87	48.93	99.16	21.48	32.36	3.95	31.15[a]
	h-VIIT	236.33	47.91	85.83	22.26	36.07	5.39	23.05[a]
Plastics and rubber	H-IIT	30.41	13.34	5.37	3.49	16.78	7.49	11.57[a]
	V-IIT	154.83	22.32	28.20	9.01	17.98	4.51	35.35[a]
	l-VIIT	107.67	27.59	20.62	8.70	18.78	5.27	19.66[a]
	h-VIIT	47.62	24.83	7.58	4.66	15.99	5.92	9.29[a]
Stone, cement and glass	H-IIT	12.83	6.81	2.37	2.22	18.48	16.06	12.86[a]
	V-IIT	111.16	14.49	23.20	4.38	20.94	3.36	35.1[a]
	l-VIIT	81.70	17.83	17.41	5.04	21.38	4.24	22.35[a]
	h-VIIT	29.45	17.77	5.79	4.28	20.66	9.48	7.99[a]
Base metals	H-IIT	81.29	33.63	24.79	11.23	30.12	7.12	11.48[a]
	V-IIT	420	37.82	113.25	22.77	26.78	3.74	61.5[a]
	l-VIIT	281.62	70.55	77.16	26.29	26.98	4.06	21.06[a]
	h-VIIT	138.41	75.53	37.75	20.62	27.74	6.69	8.59[a]
Machinery and mechanical appliances	H-IIT	41.41	15.44	7.08	3.77	16.27	5.14	13.67[a]
	V-IIT	645.79	89.42	97.95	27.06	15.21	3.61	34.64[a]
	l-VIIT	475.5	100.59	69.41	18.21	14.94	3.25	21.8[a]
	h-VIIT	170.29	77.32	28.91	17.77	15.61	5.19	11.3[a]
Transport equipment	H-IIT	6.75	2.95	1.33	1	21.67	21.63	9.43[a]
	V-IIT	83.75	15.33	19.67	4.86	23.43	4.08	25.82[a]
	l-VIIT	59.17	17.51	14.70	4.43	26.49	12.67	14.09[a]
	h-VIIT	24.58	16.60	4.95	2.34	25.48	13.19	5.97[a]

Note [a]significant at 1% level

Table 10.5 Linear trend model: share of RCA (1990–2013)

Industries	H-IIT	*l*-VIIT	*h*-VIIT
Chemical	−0.087	0.393	0.638
Plastics and rubber	0.439	0.317	0.454
Stone, cement and glass	−0.264	0.28	−0.033
Base metals	0.244	0.048	−0.799
Machinery and mechanical app.	0.523	0.397	0.579
Transport equipment	0.222	0.469	0.885

and also Ito and Okubo (2012). These arguments leave us to compute the extent of revealed comparative advantage attained by the commodity groups at the HS-6 digit level engaged under the varied forms of IIT; see, Table 10.5.

Apart from the industry of Chemical and Allied Product, the share of RCA attained by commodity groups across different forms of IIT has been relatively low over the period. The share of RCA for other industries was around 15–20% while for the chemical industry it was around 35%. For the industries of plastics and rubber; stone, cement and glass and transport equipment the share of RCA have been highest for India's *l*-VIIT. It is also important to note here that the share of RCA for the different forms of IIT do not change much within an industry. The low value of standard deviation for the share of commodity groups having RCA reveals not much change in the share over the time period. The trend values reported in Table 10.4 indicates in most cases the share of RCA has marginally improved over time. The results from paired mean test suggest that means of commodity groups engaged in IIT and commodity groups with RCA across the different forms of IIT over time are statistically different at 1% level of significance.

Given this distinctive attribute of India's IIT, we attempt to econometrically examine in the following section as to what determines the magnitude of IIT and its different forms in these Indian industries over the two half decades of the liberalization process.

10.4 Empirical Analysis

Addressing to the possible problems of cross-sectional dependence, heteroskedasticity and serial autocorrelation, this section econometrically identifies the determinants of the magnitude of IIT, *l*-VIIT, *h*-VIIT and H-IIT of the Indian industries at the HS-6 digit level over the period 1990–2013. Section 4.1 discusses data and variables followed by the econometric method in Sect. 4.2. Finally, Sect. 4.3 explains the empirical findings from the estimated model.

10.4.1 Data and Variables

The dependent variable (i.e. magnitude of total IIT/*l*-VIIT/*h*-VIIT/H-IIT) in our paper is computed using GL_{ij}. In doing so, we constructed a balanced panel for six industries combining data on trade share, net exports, RCA, share of products engaged in IIT and its different forms from UN Comtrade database and Anti-dumping initiations from Global Antidumping Database; The World Bank. In what follows, we discuss the rationale behind our explanatory variables.

Product Share: The magnitude of *i*th industry's intra-industry trade along with its different forms is expected to improve if the ratio of number of commodities engaged in such trade to total number of commodities involved in trade (i.e. both *inter* and *intra*-industry trade) increases. In other words, as the number of commodities engaged in IIT increases, it reflects that domestic firms in a particular industry are able to exploit scale economies and cater to consumer preference for diversity; Krugman (1979), Lancaster (1980), Corden (1979), Greenaway et al. (1994), among others.

Net Exports: In order to examine whether it is the rise in the *i*th industry's rise in imports or exports that determine the magnitude of IIT with its different variations, we consider the difference in exports and imports of the industry. Thus, instead of trying to posit a sign of its coefficient, we leave it to be determined empirically. This variable also controls for any possible bias occurring from trade balance in estimating the determinants; see, Clark and Stanley (1999), Thorpe and Zhang (2005).

Trade Share: An indicator about the relative openness of the *i*th industry is its trade share in the country's total trade. It is expected that as the share of the *i*th industry improves more is the possibility that it would engage in IIT. This is because a greater competition from imports leads the domestic firms to exploit scale economies and specialize in unique varieties of commodities.

Revealed Comparative Advantage: Even if *i*th industry experiences a growth in share of IIT in its total trade by production of unique varieties, does it have a comparative advantage in their production? In other words, has the liberalization process in India been able to reallocate productive resources to efficient product lines within the industry. In this regard, we consider both the number of products engaged in IIT, *l*-VIIT, *h*-VIIT and H-IIT having a RCA and also the share of it with the total number of products engaged in such trade. It is expected that as both the number and the share improves it would positively influence the magnitude of the said forms of trade and would help the Indian industries to gain which eventually lead to welfare gains for the country.

Anti-dumping Initiations: For members of WTO, market protection via orthodox protectionist measure are limited as the countries commit themselves towards reducing tariff rates and custom duties during their multilateral trade negotiations. As a result developing economies start using the contingent protection measures of which anti-dumping has been a relatively favourable policy choice. India is the largest initiator of anti-dumping cases across the world and the selected industries of India initiates around 83% of total India's anti-dumping initiations and face around 77% of initiations targeted. Moraga-Gonzàlez and Viaene (2015) theoretically argues that in the context of vertical IIT by using an anti-dumping initiation, a technological inferior domestic firm producing low technological good can leapfrog foreign firm superior technology good and thereby become a quality leader in the international market. This satisfies the incentives of both the domestic firm and the home government which in turn lead to welfare improvement. Based on the preceding arguments, we consider the sum of anti-dumping initiations initiated and faced by these industries as a determinant to the magnitude of total and horizontal IIT; see, Bown and Tovar (2011) for similar arguments. For low and high vertical IIT we consider anti-dumping initiations initiated and faced by the Indian industries, respectively to examine whether such a protectionist policy leads to production and export of alternate quality.

Table 10.9 in the Appendix summarizes choice of variables used, definitions and the statistical sources.

10.4.2 Estimation Method

The panel data structure in this study follows the asymptotic properties of macro panels (i.e. $T \rightarrow \infty$ and N being finite). Hence, prior to obtaining parameter estimates, one needs to control for the problems of cross-sectional dependency, heteroskedasticity and autocorrelation of MA (q) process. Thus, relying on large T asymptotic and nonparametric covariance matrix estimator we estimate our regression model using Driscoll and Kraay (1998) corrected standard errors that controls said problems. The robust standard errors for the parameter estimates are then obtained as the square roots of the diagonal elements of the asymptotic covariance matrix $V\left(\hat{\beta}\right) = (X'X)^{-1}\hat{S}_T(X'X)^{-1}$; where $\hat{S}_T = \hat{\Omega}_0 + \sum_{j=1}^{m(T)} w(j,m) \left[\hat{\Omega}_j + \hat{\Omega}_j'\right]$ following Newey and West (1987). In other words, the estimation technique retains the parameter estimates of fixed effects or the pooled regression model and corrects the standard errors. The method do not hold any limiting behaviour on the cross-sectional dimension and produces a much better consistent estimate than the OLS or the SUR technique in presence of the above mentioned diagnostic problems.

Another issue pertaining to the estimation method is the selection of the functional form as a linear regression will give predicted values of the dependent variable outside the (0, 100) range. Hence, following extant empirical literature on intra-industry trade, our dependent variable is a logit transformed one. Therefore, the regression equation to be estimated is:

$$\ln\left(\frac{y_{it}}{100 - y_{it}}\right) = \alpha + \beta' x_{it} + \varepsilon_{it}$$

where y_{it} represent alternatively the magnitude of total, low and high vertical and horizontal IIT. x_{it} denote the set of above mentioned explanatory variables.[9] ε_{it} symbolises the error term in the regression model.

10.4.3 Empirical Results

The regression results testing the industry-specific hypothesis about total, (*low* and *high*) Vertical and Horizontal IIT are set out in Tables 10.6 and 10.7, respectively.[10] In what follows, we discuss the regression results obtained in this paper.

1. Across the model specifications, we find that the magnitude of total IIT along with its different forms to get *positively* influenced as the share of products engaged in such form of trade increases. The result indicates that over the last two decades of liberalization process, Indian manufacturers have shifted its focus from specialize in narrow product lines by exploiting scale economies; see, Helpman (1990) for similar arguments. For instance, across all the industries we find the growth in share of products engaged in total IIT from 1990 to 2013 has been around 40%. The relatively lower coefficient values of the variable in case of low vertical IIT points out that over the years Indian industries have moved away from specializing from *low* to *high* technological products.[11]
2. For (low and high) vertical and horizontal IIT, net exports have yielded a *negative* coefficient value with almost similar coefficient values across the model specifications. In other words, it has been the relative rise in industry's imports over exports that have improved the magnitude of the said forms of IIT.
3. Trade share of the *i*th industry have a mixed result in determining magnitude of India's IIT. For instance, magnitude of *l*-VIIT *falls* as the share of industry's trade *increases*; while for *h*-VIIT and H-IIT one finds a *rise* in its magnitude with an *improvement* of the trade share. Thus, taking a cue from Sect. 10.3, one can argue that in the facet of import competition domestic firms within these industry groups tend to specialize more in producing superior or similar technological products relative to the quality of the imports.
4. Protectionism in the form of total anti-dumping activities does not affect the industry's magnitude of IIT and H-IIT. Such a result coheres with that obtained in Bagchi et al. (2015) where the authors argue that anti-dumping initiations of India lack conventional economic arguments. On the other hand, we find anti-dumping initiations taken up by foreign countries have a *negative* effect on

[9]In order to avoid problem of multicollinearity, Net Exports and Trade Share are taken alternatively in different model specifications.

[10]Considering Pesaran (2007) panel unit root test, we find the reported variables are all stationary.

[11]The average growth rate for share of products engaged in *low* vertical IIT has been around 1.28% while for high vertical and horizontal IIT it is around 16 and 13%, respectively.

Table 10.6 Regression results: magnitude of total, vertical and horizontal IIT (with share of RCA)

Variables	Total IIT		*Low* vertical IIT		*High* vertical IIT		Horizontal IIT	
	Model I	Model II	Model I	Model II	Model I	Model II	Model I	Model II
Product share	0.01313 (2.90)[a]	0.01327 (2.85)[a]	0.01970 (8.57)[a]	0. 01851 (7.61)[a]	0.03784 (9.63)[a]	0.03921 (9.98)[a]	0.10315 (10.49)[a]	0.10296 (10.30)[a]
Net exports	−2.84e−06 (−0.95)	*NI*	−0.00001 (−4.71)[a]	*NI*	−0.00001 (−4.66)[a]	*NI*	−0.00001 (−3.58)[a]	*NI*
Trade share	*NI*	−0. 02496 (−1.23)	*NI*	−0.02169 (−2.30)[b]	*NI*	0. 02476 (6.36)[a]	*NI*	0. 01663 (3.18)[a]
Total ADA	−0.00031 (0.44)	0. 00016 (0.21)	*NI*	*NI*	*NI*	*NI*	0.00028 (0.45)	8.52e−06 (0.02)
ADI	*NI*	*NI*	0. 00029 (0.33)	0.00152 (1.76)	*NI*	*NI*	*NI*	*NI*
ADF	*NI*	*NI*	*NI*	*NI*	−0.00241 (3.36)[a]	−0.00316 (−4.18)[a]	*NI*	*NI*
RCA share	0.02891 (8.68)[a]	0. 03175 (8.85)[a]	0.03233 (0.52)	0.34653 (2.86)[a]	−0.00287 (−1.61)	−0.00505 (−2.96)[a]	0.00017 (0.11)	−0.00110 (−0.73)
Constant	−2.60251 (−6.03)[a]	−2.52651 (−6.08)[a]	−2.98288 (10.61)[a]	−3.72195 (−9.78)[a]	−3.64491 (−20.14)[a]	−3.69586 (−18.47)[a]	−4.67301 (−26.47)[a]	−4.69573 (−23.50)[a]
R^2	0.32	0.33	0.48	0.52	0.76	0.75	0.78	0.77
Average VIF	1.11	1.12	1.16	1.15	1.08	1.09	1.08	1.12
$F_{4,5}$	23.19[a]	31.10[a]	53.18[a]	56.12[a]	27.34[a]	29.74[a]	105.80[a]	69.79[a]
Hausman specification test $\chi^2_{(4)}$	11.97[b]	20.18[a]	3.44	14.14[a]	0.41	0.84	2.77	5.25
Breusch-Pagan LM test of independence: $\chi^2_{(15)}$	35.53[a]	41.03[a]	–	60.10[a]	–	–	–	–
Modified Wald test: group heteroskedasticity: $\chi^2_{(6)}$	106.60[a]	150.14[a]	–	74.45[a]	–	–	–	–
Wooldridge test for AR (1): $F_{1,5}$	12.85[b]	15.81[b]	13.00[a]	12.36[b]	5.44[c]	6.25[c]	13.17[b]	12.28[a]

Note *t*-statistics are reported in the parenthesis. [a], [b] and [c]denote statistical significance at 1, 5 and 10%, respectively. *NI* Not included

Table 10.7 Regression results: magnitude of total, vertical and horizontal IIT (with No. of RCA commodities)

Variables	Total IIT		*Low* Vertical IIT		*High* Vertical IIT		Horizontal IIT	
	Model I	Model II	Model I	Model II	Model I	Model II	Model I	Model II
Product share	0.00982 (1.85)	0.00931 (1.64)	0.01952 (8.80)[a]	0.01417 (4.97)[a]	0.03781 (9.58)[a]	0.03581 (8.84)[a]	0.10579 (11.27)[a]	0.11256 (11.15)[a]
Net exports	−4.27e − 06 (−1.41)	*NI*	–0.00001 (−4.96)[a]	*NI*	−0.00001 (−4.59)[a]	*NI*	−0.00011 (−3.72)[a]	*NI*
Trade share	*NI*	−0.01596 (−0.91)	*NI*	−0.02660 (−2.60)[b]	*NI*	0.01379 (0.97)	*NI*	0.02895 (6.09)[a]
Total ADA	0.00029 (0.45)	0.00013 (0.19)	*NI*	*NI*	*NI*	*NI*	0.00057 (1.30)	0.00057 (1.11)
ADI	*NI*	*NI*	0.00069 (0.92)	0.00078 (1.05)	*NI*	*NI*	*NI*	*NI*
ADF	*NI*	*NI*	*NI*	*NI*	−0.00253 (−3.81)[a]	−0.00378 (−3.34)[a]	*NI*	*NI*
RCA number	0.00331 (4.75)[a]	0.00388 (4.82)[a]	−0.00054 (−0.93)	0.006844 (3.91)[a]	−0.00008 (−0.16)	0.00825 (8.77)[a]	−0.00212 (−1.30)	−0.00754 (−4.82)[a]
Constant	−1.94998 (4.20)[a]	−1.84957 (−4.09)[a]	−2.84851 (−24.52)[a]	−2.65619 (19.75)[a]	−3.70954 (−20.07)[a]	−3.91548 (17.72)[a]	−4.67893 (−26.49)[a]	−4.81893 (24.70)[a]
R^2	0.28	0.27	0.48	0.54	0.76	0.80	0.78	0.78
Average VIF	1.18	1.81	1.16	1.97	1.29	1.71	1.38	1.95
$F_{4,5}$	11.50[a]	21.80[a]	51.26[a]	116.15[a]	32.08[a]	206.40[a]	165.28[a]	79.37[a]
Hausman specification test $\chi^2_{(4)}$	10.40[b]	19.88[a]	6.65	24.48[a]	4.02	13.56[a]	2.30	4.42
Breusch-Pagan LM test of independence: $\chi^2_{(15)}$	37.46[a]	44.51[a]	–	33.57[a]	–	68.83[a]	–	–
Modified Wald test: group heteroskedasticity: $\chi^2_{(6)}$	149.72[a]	155.14[a]	–	246.65[a]	–	196.92[a]	–	–
Wooldridge test for AR(1): $F_{1,5}$	11.47[b]	14.04[b]	8.20[b]	8.08[b]	5.06[c]	6.33[c]	9.57[b]	8.54[b]

Indian industries export of superior technological product (*h*-VIIT). In other words, technologically inferior foreign firm would use anti-dumping initiations to leapfrog the Indian firm's superior quality and thereby become the quality leader in the international market.[12]

5. The magnitude of total and low vertical IIT improves as both the number as well as share of the products having a RCA engaged in these forms improves. For high vertical IIT we find that its number have positively benefitted its magnitude while its low share have had a crowding out effect. On the other hand, the magnitude of horizontal IIT is *negatively* influenced by the number of products within the form which has a RCA. Couple of reasons can be attributed for such a result: (i) H-IIT relates more with the *new* trade theories; see, (Greenaway et al. 1995); and (ii) commodity groups engaged in H-IIT with a RCA has been relatively much lower to have an effect on its magnitude; see Table 10.3 in Sect. 10.3.

10.5 Summing Up

Using a variety of index at different disaggregated level of trade data, the study computes the magnitude of India's intra-industry trade and finds its increasing dominance in total merchandise trade. In other words, we find the liberalization process drives India to trade more in products which are of similar or different technologies compared to imports. Among the broad industry groups as classified by ITC, it is the industries of chemical; plastics and rubber; stone, cement and glass; base metals; machinery and mechanical appliances and transport equipment that show relatively high magnitude of IIT. Moreover, according to the OECD technological categorization of industries these said industry groups fall under *high*, *medium-high* and *medium-low* technology categories.

Across these six manufacturing industries grouped under different OECD technological classifications, we find the dominance of exports in low technological goods (*l*-VIIT) while exports in similar (H-IIT) and superior technological (*h*-VIIT) products have gained some momentum after the global recessionary period in 2008. Furthermore, in order to examine the argument that magnitude of IIT improves when shift of resources takes place within an industry from inefficient to efficient product lines, we examine as to what percentage of commodities engaged under different forms of IIT have a revealed comparative advantage. Our result show that commodity groups in the industries of Chemical, Base Metals and Transport Equipment have both high number as well as share of RCA. However, the trend for

[12]Our result also indicates that anti-dumping initiations made by Indian firms are not being sufficient for them to leapfrog the foreign firm's technologically superior good.

the share of commodity groups that are produced using inferior technology (*l*-VIIT) with a revealed comparative advantage have been positive across all industry groups.

Regression results suggest that the magnitude of IIT and its different forms have benefitted as more commodity groups of different technological variants are produced. The results also indicates that exports of superior technological (*h*-VIIT) and similar technological (H-IIT) have increased as the industry(s) engages in more trade; while exports of low technological (*l*-VIIT) have fallen. The number of products with RCA have positively aided the magnitude of IIT and its different forms, however the share of it only benefits exports of low technological products (*l*-VIIT). Moreover, the low share of RCA in India's export of high technological (*h*-VIIT) products crowds out its magnitude. Anti-dumping initiations of India have not affect the magnitude, while those face by these industries have negatively influenced India's export of high technological products. This points out that the foreign firm producing *low* technological products have used such a protectionist measure to leapfrog India's technological advancement in select products.

To sum up, this paper shows that the liberalization process in India have influenced the role of intra-industry trade by allowing firms within an industry to exploit scale economies and produce unique varieties of a product. However, the dominance of export in low technological goods can lead to asymmetry in gains from trade. In order to attain a favourable terms of trade situation and reap gains from trade, India must shift its productive resources from production of low to high technological goods.

Appendix

See Tables 10.8 and 10.9.

Table 10.8 Indices to measure magnitude of IIT

Author(s)	Index
Michaely (1962)	$\mathrm{MH}_{ij} = \left[1 - \frac{1}{2}\sum_{i=1}^{n}\left\vert\frac{X_i}{\sum X_i} - \frac{M_i}{\sum M_i}\right\vert\right] \times 100$
Balassa (1966)	$\mathrm{B}_{ij} = \frac{1}{n}\sum_{i=1}^{n}\frac{\vert X_i - M_i\vert}{(X_i + M_i)}$
Grubel and Lloyd (1971)	$\mathrm{GL}_{ij} = \left[1 - \frac{\sum_{i=1}^{n} X_i - M_i}{\sum_{i=1}^{n}(X_i + M_i)}\right] \times 100$
Grubel and Lloyd (1975)	$\mathrm{GLC}_{ij} = \frac{\mathrm{GL}_{ij}}{1-k}\ ; \quad k = \frac{\vert\sum_{i=1}^{n} X_i - \sum_{i=1}^{n} M_i\vert}{\sum_{i=1}^{n}(X_i + M_i)}$
Aquino (1978)	$\mathrm{AQ}_{ij} = \left[\frac{\sum_{i=1}^{n}(X_{ij} + M_{ij}) - \sum_{i=1}^{n}\vert\hat{X}_{ij} - \hat{M}_{ij}\vert}{\sum_{i=1}^{n}(X_{ij} + M_{ij})}\right] \times 100\,;$ $\hat{X}_{ij} = X_{ij}\cdot\frac{1}{2}\frac{\sum_{i=1}^{n}(X_{ij} + M_{ij})}{\sum_{i=1}^{n} X_{ij}}$ and $\hat{M}_{ij} = M_{ij}\cdot\frac{1}{2}\frac{\sum_{i=1}^{n}(X_{ij} + M_{ij})}{\sum_{i=1}^{n} M_{ij}}$
Vona (1991)	$\mathrm{IIT}^i_{A,B} = X^i_{A,B} + M^i_{A,B}\rangle 0$ if each of $X^i_{A,B}$ and $M^i_{A,B}\rangle\, 0$ $\mathrm{IIT}^i_{A,B} = 0$ if either of $X^i_{A,B}$ or $M^i_{A,B}$ is zero $\mathrm{VN}_{ij} = \frac{\sum_{i=1}^{n}\mathrm{IIT}^i_{A,B}}{X^j_{A,B} + M^j_{A,B}} \times 100\,, \quad \forall i$ when $\mathrm{IIT}^i_{A,B}\rangle 0$
Brülhart (1994)	$\mathrm{MIIT}_{ij} = \left[1 - \frac{\vert(X_t - X_{t-k}) - (M_t - M_{t-k})\vert}{\vert X_t - X_{t-k}\vert + \vert M_t - M_{t-k}\vert}\right] \times 100$

Note Notations have their standard meanings. Only, B_{ij} ranges from 0 to 1 and has an opposite sign effect. All other indices range from 0 to 100

Table 10.9 Variables, definitions and sources

Variables	Definitions	Sources
Dependent variable magnitude of IIT, *l*-VIIT, *h*-VIIT and H-IIT	Average magnitude of $\mathrm{GL}_{\mathrm{ij}}$ of the *i*th industry at the HS-6 digit level	UN comtrade
Independent variables product share at the HS-6 digit level		UN comtrade
IIT	$\left(\frac{\text{No. of Products Engaged in IIT}}{\text{Total No. of Products in Total Trade}}\right)_i \times 100$	
l-VIIT	$\left(\frac{\text{No. of Products Engaged in l-VIIT}}{\text{Total No. of Products in V-IIT}}\right)_i \times 100$	
h-VIIT	$\left(\frac{\text{No. of Products Engaged in h - VIIT}}{\text{Total No. of Products in V-IIT}}\right)_i \times 100$	
H-IIT	$\left(\frac{\text{No. of Products Engaged in H-IIT}}{\text{Total No. of Products in Total IIT}}\right)_i \times 100$	
Trade share of the *i*th industry	$\frac{(X+M)_i}{\sum_{i=1}^{22}(X_i + M_i)} \times 100$	UN comtrade

(continued)

Table 10.9 (continued)

Variables	Definitions	Sources
RCA at the HS-6 digit level	(a) No. of products engaged in IIT, *l*-VIIT, *h*-VIIT and H-IIT having a RCA (b) Share of products engaged IIT, *l*-VIIT, *h*-VIIT and H-IIT having a RCA	UN comtrade
(b.1) IIT	$\left(\frac{\text{No. of Products Engaged in IIT having RCA}}{\text{No. of Products Engaged in IIT}}\right)_i \times 100$	
(b.2) *l*-VIIT	$\left(\frac{\text{No. of Products Engaged in l-VIIT With RCA}}{\text{No. of Products Engaged in l-VIIT}}\right)_i \times 100$	
(b.3) *h*-VIIT	$\left(\frac{\text{No. of Products Engaged in h - VIIT With RCA}}{\text{No. of Products Engaged in h - VIIT}}\right)_i \times 100$	
(b.4) H-IIT	$\left(\frac{\text{No. of Products Engaged in H - IIT With RCA}}{\text{No. of Products Engaged in H - IIT}}\right)_i \times 100$	
Net exports	$(X - M)_i$	UN comtrade
Total anti-dumping initiations	Anti-dumping initiations *initiated* by *i*th industry + Anti-dumping initiations *faced* by the *i*th industry	Global antidumping database

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Chapter 11
What Makes Enterprises in Auto Component Industry Perform? *Emerging Role of Labour, Information Technology, and Knowledge Management*

G.D. Bino Paul, G. Jaganth, Minz Johnson Abhishek and S. Rahul

Abstract Auto component industry is an interesting variant of business that is located in the context of dynamic value chain. While one end of the value chain is the sophisticated-oligopolistic original equipment manufacturers (OEMs), the other end has suppliers who are small and medium enterprises. In the whole length and breadth of this value chain, suppliers include small, medium, and large enterprises. Broadly, these enterprises are of two types: organised and unorganised. Unlike in the case of large multinational enterprises, auto component suppliers, in particular small and medium enterprises (SMEs), are not so well endowed to invest in research development and exhaustive capability building endeavours. However, as elucidated in the extant literature on SMEs, a prudent option for these enterprises is to build and foster absorptive capacities that synergise labour, information technology, and knowledge management. To gauge these themes, we analyse four types of data. First, we examine recent time series of select variables that delineate the basic dynamics of performance and resources of organised auto component industry in India. Second, we lay focus on cross-sectional enterprise data drawn from 2012 to 2013 Annual Survey of Industries. Third, we analyse 67th round, for the year 2009–2010, of National Sample Survey, to examine unorganised auto component industry in India. Fourth, we use field data, collected in 2016, to discuss multidimensional aspects of knowledge management, technology, learning, labour, and outcomes, based on a survey conducted in Pune, Maharashtra, India. We conclude that auto component manufacturers seem to rely more on labour, information technology, and attainments like ISO to perform well in the business. While automation appears to be a catching up trend in the value chain, use of information technology seems to be the game-changer as far as value added is concerned.

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G.D. Bino Paul (✉) · G. Jaganth · M. Johnson Abhishek · S. Rahul
School of Management and Labour Studies, Tata Institute of Social Sciences, Mumbai, Maharashtra, India
e-mail: bino@tiss.edu

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Drawing cues from patterns and inferences presented in our paper, for enterprises in the auto component value chain, be they are in the organised and unorganised sector, whether they are small or medium, it is important to create synergies between human resources and information and communication technologies to scale up a sustained higher order performance.

11.1 Introduction

We examine the basic patterns of what makes enterprises perform in auto component industry in India. This industry is positioned in the value chain that features polar opposites like highly sophisticated original equipment manufacturers (OEMs) who are buyers and many a suppliers who include small, medium, and large enterprises. Like many intermediate producers, enterprises in auto component industry appear to be not so resourceful in endeavouring towards technological capability building. Perhaps, in view of the market structure they are in, many a suppliers selling to one or very few buyers, it is quite unlikely that technological capability building by these enterprises is immune to asset specificity. Drawing cues from the extant literature, for an SME, some basic resources such as labour, learning processes, management of knowledge may turn to be dynamic capacities that absorb the transformative power to perform sustainably. As Nonaka (1994, 2008) views, managing knowledge by companies tends to be the primary catalyst to forming dynamic capabilities.

Although there is a vast literature on technology management and development in large enterprises, there appears to be obvious lacunae in understanding how small and medium enterprises (SMEs) organise technology, in particular its acquisition, maintenance, and development. Quite important, continuum of technology is incomplete without looking at the knowledge. There appears to be discernible gaps in the extant literature in unravelling symbiotic and organic interlink ages between technology and knowledge, in particular contexts such as SMEs that are part of a value chain and located in the developing world. While there seems to be abundant literature that examine technology and knowledge separately, presumably there is a need for new perspectives and empirically grounded insights to understand technology and knowledge in an integrated manner. Positing a technology-knowledge continuum, we delineate firm as a behaviour-governance-social-technological system.

We use four types of data for the analysis. First, we examine the time series of select variables, drawn from Annual Survey of Industries that plots the basic pattern of performance and resources of organised auto component industry in India. Second, we examine cross-sectional enterprise data drawn from 2012 to 2013 Annual Survey of Industries. Next, we analyse 67th round of National Sample Survey (NSS), to study organised auto component industry in India. Finally, we use the field data, collected in 2016, to discuss multidimensional aspects of knowledge management, technology, learning, labour, and outcomes, based on a survey conducted in Pune, Maharashtra, India.

The paper is organised into six sections. Section 11.2 discusses SME, knowledge, and absorptive capacity. Section 11.3 examines organised auto component industry in India. An analysis of unorganised sector is presented in Sect. 11.4. Section 11.5 presents survey data. Section 11.6 concludes the paper.

11.2 SME, Knowledge, and Absorptive Capacity

Small and medium enterprises (SMEs) are defined basically either in terms of number of employees working in the company or the turnover the company is making or the investment in the machinery and plant. Each criterion has its own logic and reason and serves different purposes. Small and medium enterprises (SMEs) sector in India plays pivotal role in generating employment and creating backward and forward links that foster regional development. Moreover, SMEs often compliment the large industries as ancillary units. Indian SME employs over 80 million persons across of 36 million units, while it contributes to 8% of GDP, 45% to the total manufacturing output, and 40% to the exports from the country. Thus, the SME sector may be viewed as potential player in spreading industrial growth across the country on the one hand, and on the other as a major partner in the process of inclusive growth. Despite these advantages, factors such as small scale of operation, technological stagnation, inefficiencies in supply chain, introduction of foreign direct investment (FDI) in the sectors, limited credit options, low levels of human capital of the labour force, change in manufacturing strategies and turbulent and uncertain market scenario seem to be salient features of this sector. However, SMEs that are innovative, inventive, and international in their business outlook tend to develop a strong technological base, and competitiveness.

The Micro, Small and Medium Enterprises Development Act, 2006, classifies SME, on the basis of investments in plant and machinery, into Micro, Small and Medium level enterprises (Table 11.1).

Table 11.1 Type of small and medium enterprises (SMEs)

	Investment in equipment (rupees)	
	Manufacturing	Services
Micro-enterprises	≤ Rupees 2.5 million	≤ Rupees 1 million
Small enterprises	>Rupees 2.5 million and	>Rupees 1 million and
	≤ Rupees 50 million	≤ Rupees 20 million
Medium enterprises	>Rupees 50 million and	>Rupees 20 million and
	≤ Rupees 100 million	≤ Rupees 50 million

Source Government of India, Development Commissioner, Ministry of Micro, Small and Medium Enterprises (http://www.dcmsme.gov.in/ssiindia/defination_msme.htm)

In India, the automobile industry occupies a prominent place for its forward and backward linkages due to it multiplier effect, ranging from exports to improvement in basic transportation facility. In the Indian context, significant part of the automobile industry appears to have developed in industrial clusters. There are three major clusters in the automobile industry in India. The major automobile clusters are as follows: Delhi-Gurgaon-Faridabad-Ghaziabad-Gautama Buddha Nagar in North India, Mumbai-Pune-Nasik-Aurangabad-Thane in West India, and Chennai-Bangalore-Dharmapuri-Vellore-Kanchipuram-Thiruvallore in South India. Auto component industry is one of the fastest growing industries during the past two decades among the clusters of SME in India. While these SMEs play key roles in scaling up of auto component manufacturing, the sector also accounts for a significant share in the exports made by the auto component industry in India. However, many a SMEs in this sector are quite small, and account for sizeable informal employment.

SMEs in today's global value chain are situated in the middle of turmoil and have to continuously upgrade and alter its strategy to maintain or upgrade its position in the market. As technology and knowledge have become more volatile, with global buyers situated in the developed world dictating terms of governance, the survival of MSMEs depends on the continuous fine-tuning with the global decision-makers. Further among all this, firms have the pressure to be cost competitive. Any laxity on the cost competitiveness would have risks of running out of business. An important pattern is while SMEs participate in global value chains, these enterprises need to comply with standards of the big players such as transnational enterprises (Humphrey and Schmitz 2001).

Gereffi et al. (2001) classify global value chains as being producer-driven, buyer-driven, and Internet-driven. While, in the producer-driven value chains, transnational manufacturers are the main actors, the buyer-driven value chain has more focus on the retailers. In Internet value chains, significant part of supply chain is built around the Internet. In the context of value chains becoming global, a greater relevance is given to efficient supply chain management (SCM). Thakkar et al. (2008a) trace the problems that SMEs might face in implementation of supply chain management (SCM) practices due to the improper role interactions. Factors such as insufficient support from the owner, role of vendor, OEMs, market, culture, competitiveness matter in this regard. Finance tends to be an important concern that impacts firm's decision to have new technologies, new processes and ensuing skill development. However, a lot depend on the financial situation of the enterprise and the only way left for enterprises to go about the situation is to build careful alliances that would ease technology transfer. This forms a part of SME strategising which is necessary for its survival (Thakkar et al. 2008b).

However, as pointed out by Pietrobelli and Rabellotti (2011), governance structures of global value chains also influence learning mechanisms in enterprises. A greater recognition of complementary learning systems would foster the intrafirm learning. Also, the need to meet international standards and business compliances motivates a closer connect between firms in the value chains. A more relational kind of governance structures tend to emerge in these interactions.

Majumdar (2010) in his study of foundries in Western India has narrowed down on the two kinds of growth strategies that small enterprises use for growth—relationship-based growth strategy and technology-based growth strategy. While the relationship-based strategy focuses more on the philosophy of sharing, the technology-based strategy is more inclined towards gaining technological prowess for growth. Likewise for technology-based growth strategy, an able support from finance is crucial.

Meso and Smith (2000), while conceptualising knowledge as a strategic resource in a firm, posit that organisational knowledge management requires to be an exhaustive system that captures not just technological infrastructure but also organisational infrastructure, in particular organisational management and philosophy, human resources, and culture. Drawing cues from survey data of small and medium enterprises (SMEs), Gray (2006) shows the pivotal role of 'absorptive capacity' in shaping knowledge management and innovation in SMEs; absorptive capacity is firm's learning and practice of new knowledge, disseminating it internally and utilising new resources. Plotting patterns from a sample survey of firms, Gopalakrishnan and Santoro (2004) show knowledge transfer and technology transfer are not the same. While the technology transfer is a narrower and more targeted construct, the knowledge transfer is a more broader and behaviourally complex phenomenon. Put differently, while technology facilitates the change, knowledge explains the change.

Quite important, as pointed out by Runnar Edvardsson (2008), Human Resource Management practices such as recruitment, reward, performance management, training, and desired behavioural outcomes can be a catalyst to codification of explicit knowledge and personalisation of tacit knowledge. However, SMEs with specialised HRM unit seem to be uncommon phenomena. As posited by Hutchinson and Quintas (2008), formal knowledge management appears to be more pertinent to the large firm, while most of SMEs tend to develop informal knowledge management systems that facilitate creation, communication and sharing, searching and sourcing, synthesising, and applying and reusing of knowledge. As viewed by Wiig (1997), managing knowledge is not a quirky management tool but more a strategic vision that may be internalised by firms of diverse scales.

Drawing inferences from the multivariate analysis of a cross section collected from SMEs specialising in bio-technology, Alegre et al. (2013) show that knowledge management, as dynamic capabilities, positively impacts innovation practices. However, Durst and Wilhelm (2012) point to the critical issues of knowledge attrition or loss due to employees exit in SME, entailing strategic interventions to obviate such possibilities. Interestingly, as shown by Desouza and Awazu (2006), SMEs, depending upon the level of maturity, tend to cope with the issues of knowledge loss by resorting to practices like creating processes that ease internalisation of common knowledge. Emphasising that knowledge management in SME is different from that of large organisations, Sparrow (2001), aided by in-depth qualitative research, identifies four components of KM in SMEs:

appreciation of individual and shared understanding, effective knowledge base and system, integrated and contextualised action, and effective learning processes.

Discussing the meta-content drawn from the extant literature, Durst and Edvardsson (2012) view that there is discernible lacunae in the literature on KM in SMEs, calling for more empirical research, in particular to capture heterogeneity of SMEs. Apart from internal processes such as learning, as shown by Uchikawa (2011) based on field study of SMEs in Indian automobile clusters, there appears to be knowledge spillover from large assembly or original equipment manufacturing companies to SMEs through practices like collaborative mechanisms.

It is noteworthy that, positing the perspective of strategic knowledge management, Sanchez and Mohoney (1996) point to how important is to have flexible and self-ordered modular product and organisational design to reap dynamic efficiencies from the knowledge management. Drawing patterns from the field research conducted in automobile clusters in Thailand, Chaminade and Vang (2008) present scenarios of upgradation of technology and learning among SMEs that supply automobile components to transnational enterprises. Quite important, the study delineates that SME in the value chain tends to operate according to the expectations of MNEs. However, among lower tier SMEs that produce low value added goods, there are no discernible positive externalities like interactive learning.

Technology is considered to be one of the vital parameters for a firm to remain competitive in the market. As stated by Porter (1983), technological attainment of firm is one of the important determinants which determines the competition among firms. Extant literature links technology and strategy, in developed and developing nations (Jones and Smith 1997; Momaya and Ajitabh 2005). Innovation is one of the vital components for a firm to advance its growth and wealth in the market. Moreover, in a competitive environment, innovation becomes a crucial factor for a firm to sustain in the market. As defined by Oslo Manual (OECD 2005, p. 46) 'Innovation is the implementation of any new or significantly improved product (goods or services), operational processes (methods of production and service delivery), any new marketing methods (packaging, sales and distribution methods), or new organizational or managerial methods or processes in business practices, workplace organization or external relations'.

Innovation is also about the development and exploitation of new ideas or invention. The innovation activity in an organisation can be product innovation or process innovation. The result of innovation process, the type of innovation created by the firm or the actual implementation of the new product or service business process or method can be considered as product innovation. The process of innovation refers to 'the temporal sequence of events that occur as people interact with others to develop and implement their innovation ideas within an institutional context' (Poole and Van de Ven 1989, p. 32). Both of these activities can affect firms' performance (Gronum et al. 2012). Though Schumpeter highlights that large firms innovate more than small and medium sized firms do, the recent research provides substantial evidences of innovation activities being carried out by small and medium sized enterprises (SMEs), too.

11.3 Organised Auto Component Industry

To capture the dynamics of organised auto component industry in India during 2004–05 to 2013–14, we plot the trend of net value added (NVA) at constant prices, persons engaged, fixed capital at constant prices, NVA at constant prices per person, and fixed capital at constant prices per person (Table 11.2). Interestingly, while fixed capital at constant prices grew at a discernibly higher rate (26%) during this period, persons engaged grew at 12%. Presumably, fixed capital and persons employed culminate in NVA. During this period, NVA at constant prices grew at 17%. However, NVA per person employed grew at a measly rate of 4%. It appears, drawing cues from the patterns presented in Table 11.2, there had been perceptible deepening of capital in auto component industry during this period. Corroborating this pattern, fixed capital at constant prices per person grew at 13%. As shown in Fig. 11.1, during this period, share of profit in NVA fluctuated in the range of 30–55%, while share of emoluments varied between 30 and 50%, clearly depicting a cyclic pattern.

Table 11.2 Net value added (NVA), persons engaged, and fixed capital in auto component industry (NIC-2008 4 digit 2930 and NIC-2004 4 digit 3430)

Year	Real net value added (NVA) (at 2004–05 prices) (Rupees Lakh)[ad]	Person engaged[d]	Real NVA per person engaged (Rupees Lakh)	Real fixed capital (at 2004-05 prices) (Rupees Lakh)[bc]	Real fixed capital per person engaged (Rupees Lakh)
2004–2005	723,516	234,463	3.09	1,030,452	4.39
2005–2006	742,826	253,003	2.94	1,144,923	4.53
2006–2007	869,227	290339	2.99	1,404,031	4.84
2007–2008	962,460	329,362	2.92	1,909,125	5.80
2008–2009	914,655	357,401	2.56	2,655,154	7.43
2009–2010	1,574,780	463,033	3.40	3,980,698	8.60
2010–2011	1,903,301	540,007	3.52	5,148,340	9.53
2011–2012	2,803,137	565,078	4.96	5,003,085	8.85
2012–2013	2,376,287	561,405	4.23	6,048,965	10.77
2013–2014	1,957,898	566,153	3.46	6,788,885	11.99
Trend growth	16.74	11.92	4.31	26.17	12.73
Rate (%)	($p < 0.01$)	($p < 0.01$)	($p < 0.05$)	($p < 0.01$)	($p < 0.01$)

[a]Real NVA is computed by dividing NVA at current prices by wholesale price index (WPI) deflator of auto parts

[b]Real fixed capital is computed by dividing fixed capital at current prices by wholesale price index (WPI) deflators in respect of industrial machinery and machine tools

[c]*Source* Office of the Economic Advisor, Government of India, Ministry of Commerce and Industry, Department of Industrial Policy and Promotion, http://www.eaindustry.nic.in/home.asp

[d]*Source* Compiled from Annual Survey Industries (ASI), http://mospi.nic.in/mospi_new/upload/asi/ASI_main.htm

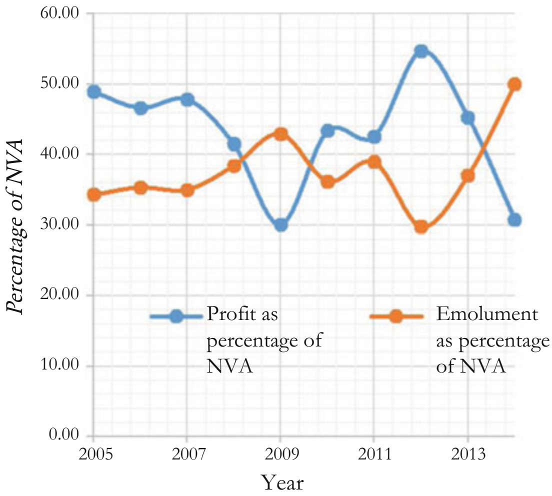


Fig. 11.1 Profit and emolument as percentage of NVA in auto component industry (NIC-2008 4 digit 2930 and NIC-2004 4 digit 3430). *Source* Compiled from Annual Survey Industries (ASI), http://mospi.nic.in/mospi_new/upload/asi/ASI_main.htm

To delineate salient features of organised auto component industry in India, we use Annual Survey of industries (ASI) micro-data for the year 2012–2013. In the database, we filtered 845 units that fall in National Industrial Classification (NIC) 2008 4 digit code ‘2930’. As shown in Table 11.3, the industry is heterogeneous in location, type of organisation, type of ownership, scale of operation, number of persons employed, and attainment of International Organization for Standardisation (ISO) standards. A whopping 55% of factories are located in three states such as Tamil Nadu (20%), Maharashtra (18%), and Haryana (17%). 57% of units are located in the urban. Corporate organisations form 86% of the whole distribution, consisting of private limited (63%) and public limited (86%). Close to four-fifths of units are privately owned. Small and medium enterprises (SMEs) account for 55%, while three fourths of units employ at least 100 persons. Only 30% of enterprises have attained ISO standards.

Table 11.4 outlines median values of select variables—age of the firm, NVA, profit, employment, fixed capital, value of plant and machinery, and value of computer hardware and software—that are disaggregated with respect to type of organisation for the year 2012–13. For the whole, median age of the firm is 16 years. Across type of organisations, there appears to be no discernible variation, ranging from 15 years (private limited) to 22 years (partnership). Median value of NVA is Rs. 119 million, while across type of organisation, value varies from Rs. 4 million (proprietorship) to Rs. 27 million (public limited). Median profit for the whole set is Rs. 33 million. However, there appears to be a large spread between the lowest value (0.85 million for proprietorship-based units) and the highest value (129 million for public limited units). Median value of average person employed in the industry is 255, while the highest and the lowest values are 496 (public limited) and 18 (proprietorship-run units), respectively. In the industry, average number of

Table 11.3 Characteristics of factories—auto component industry (2012–2013) (NIC-2008 4 digit 2930)

State	Percent (%)	Type of ownership	Percent (%)
Tamil Nadu	20.1	Wholly state and/or local govt.	0.1
Maharashtra	18.0	Joint sector public	3.3
Haryana	17.4	Joint sector private	19.0
Uttaranchal	6.9	Wholly private ownership	77.6
Uttar Pradesh	6.9	Total (N = 845)	100.0
Karnataka	5.7	*Scale of enterprises*[a]	*Percent* (%)
Punjab	4.7	Micro-enterprises	10.3
Gujarat	4.4	Small enterprises	29.9
Rajasthan	3.3	Medium enterprises	14.6
Madhya Pradesh	2.6	Large enterprises	45.3
Other states	10.1	Total (N = 845)	100.0
Total (N = 845)	100.0	*Number of persons employed*	*Percent* (%)
Location	*Percent* (%)	Less than 10	3.1
Rural	43.2	More than 10 but less than 20	6.9
Urban	56.8	20 and above but less than 100	15.4
Total (N = 845)	100.0	At least 100	74.6
Type of organisation	*Percent* (%)	Total (N = 845)	100.0
Individual proprietorship	5.4	*Having ISO*	*Percent* (%)
Partnership	8.9	Yes	29.9
Public limited company	23.0	No	70.1
Private limited company	62.7	Total (N = 845)	100.0
Total (N = 845)	100.0		

[a]Table 11.1 defines scale of enterprises
Source Annual Survey of Industries 2012–2013, Unit Records

manufacturing days is 77,315 days, located in the interval of 5040 days (proprietorship) and 158,418 days (public limited units). Daily wage varies in the range of Rs. 327 (proprietorship) to Rs. 761 (public limited units), while the median is Rs. 638. Quite important, the median value of fixed capital is Rs. 167 million, while, across the type of organisation, values range from 4.5 million rupees (proprietorship) to 385 million rupees (public limited units). Moreover, we look into two constituents of fixed capital: value of plant and machinery and value of computer hardware and software. The median of the value of plant and machinery is Rs. 81 million, while the lowest and the highest values are Rs. 1.5 million (proprietorship) and Rs. 237 million (public limited units), respectively. In the industry, on an average, firms own Rs. 1 million worth computer hardware and software, showing a range of Rs. 0.02 million (proprietorship) to Rs. 2.5 million (public limited units). Except the case of enterprise's age, with respect to each variable we have discussed, so far, there is a Pecking order that has public limited at the top and proprietorship at the bottom, while private limited and partnership are placed second and third, respectively. Further, the same Pecking order is valid for NVA per person employed (Rs. 0.2

Table 11.4 Select variables—auto component industry (2012–2013) (NIC-2008 4 digit 2930)

Select variables	Individual proprietorship	Partnership	Private public limited company	Public limited company	Total
(*Median value*)	*Type of organisation*				
Age of firm (years) (*N* = 845)	16	22	15	19	16
Net value added (NVA) (rupees) (*N* = 826)	4061066	8,660,558	116,902,238	270,380,535	119,102,433
Profit (rupees) (*N* = 826)	855480	1,160,293	37,041,006	128,838,631	32,841,702
Total manufacturing days (*N* = 844)	5040	12,652	75,124	148,418	77,315
Average number of persons worked (*N* = 844)	18	44	251	496	255
Supervisors and managers as percentage of persons employed (*N* = 830)	10	11	10	9	10
Daily wage rate (rupees) (*N* = 843)	327	414	662	761	638
Fixed capital (rupees) (*N* = 845)	4,524,906	10,318,897	176,152,573	38,476,0511	167,002,394
Value of plant and machinery (rupees) (*N* = 844)	1,488,968	5,064,321	80,928,829	237,532,784	80,719,108
Value of Computer (hardware and software) (rupees) (*N* = 805)	19,582	29,766	1,083,309	2,522,490	1,048,204
NVA per person employed (rupees) (*N* = 826)	194182.82	225487.07	455521.12	571641.25	416532.14
Fixed capital per person employed (rupees) (*N* = 827)	267,459	211,512	659,137	837,737	613,265
Emolument as percentage of NVA (*N* = 827)	53	59	39	37	42
Profit as percentage of NVA (*N* = 826)	29	26	46	54	43
Profit as percentage of gross sales (*N* = 826)	4	4	7	10	7

Source Computed from unit records of Annual Survey of Industries 2012–2013

million–Rs. 0.8 million). However, supervisors and managers as percentage of persons employed varies in a narrow range (9–11%), showing no perceptible variation across the distribution. Among categories of organisation, the category 'public limited' reports the highest NVA per person employed (Rs. 0.57 million), while proprietorship reports the lowest (Rs. 0.19 millions), and the Pecking order discussed previously is valid here, as well. However, this Pecking order breaks in the case of fixed capital per person employed, although the top slot remains the same (0.84 million in respect of public limited enterprises). In this case, partnership occupies the bottom (Rs. 0.21 million). It is important to note that, unequivocally, profit as percentage of NVA and emolument as percentage of NVA move in opposite direction, conveying obvious trade-off between profit and wage. Moreover, presumably, it appears that capital intensity and scale that are the salient features of public limited and private limited organisations tend to push NVA to profit's share, while the counter pattern is tenable for proprietorship and partnership. Interestingly, the margin defined as profit as a percentage of gross sales is highest for public limited (10%), followed by private limited (7%), and 4% apiece for the rest.

Now, we move from a descriptive exercise to a simple inferential frame by deploying the analysis of variance (ANOVA) and the Pearson correlation coefficient. For ANOVA, while we treat variables and derived percentages presented in Table 11.4 as dependent variables, type of organisation, a nominal scale variable, is taken as the independent variable. Table 11.5 presents the results. Except three derived percentages—emolument and profit as percentages of NVA and profit as a percentage of gross sales—all variables significantly change within as we move from one category of the independent variable to the other, rejecting the null hypothesis of no variation. As shown in Table 11.6, we run Pearson correlation between age of the firm, NVA, profit, manufacturing days, average number of persons employed, daily wage rate, fixed capital, value of plant and machinery, and value of computer hardware and software. It is important to note that there is hardly any strong correlation between age of the firm and other variables. Perhaps, this points to the pattern of no significant direct covariation between longevity of firm, competitiveness, and resources. On the other hand, among other variables that are either outcomes or resources—employment-related, capital-based, NVA, and profit—there exist statistically significant positive correlation coefficients, varying from 0.18 (between wage rate and average number of persons employed) to 0.98 (between NVA and profit). Quite important, there appears to be a plausible pattern of complementarity between capital and labour. There is a strong and significant positive correlation between fixed capital and alternate indicators of labour-manufacturing days (0.65) and average number of persons employed (0.62). Drawing cues from the neoclassical micro-economics, this pattern points to the phenomenon of capital-labour complementarity due to the scale effects that have been crowding out the substitution effects.[1] This positive linkage between capital

[1]While scale effects emanate from strategic choices like expansions of scale, substitution effect tends to emerge from variations in factor/resource prices.

Table 11.5 Analysis of variance select variables—auto component industry with type of organisation (NIC-2008 4 digit 2930)

Dependent variable	Independent variable	*F*	Sig.
Age of firm	Type of organisation	11.99	0.00
Net value added (NVA)	Type of organisation	15.51	0.00
Profit	Type of organisation	10.35	0.00
Total manufacturing days	Type of organisation	35.83	0.00
Average number of persons worked	Type of organisation	35.90	0.00
Share of supervisory/managerial staff	Type of organisation	2.13	0.09
Daily wage rate	Type of organisation	32.18	0.00
Fixed capital	Type of organisation	15.96	0.00
Plant and machinery	Type of organisation	14.86	0.00
Computer hardware and software	Type of organisation	15.05	0.00
NVA per person employed	Type of organisation	8.359	0.000
Fixed capital per person employed	Type of organisation	15.96	0.00
Emolument as percentage of NVA	Type of organisation	0.258	0.855
Profit as percentage of NVA	Type of organisation	0.087	0.967
Profit as percentage of gross SALES	Type of organisation	0.011	0.998

Number of Responses as given in Table 11.4
Source Computed from Unit records of Annual Survey of Industries 2012–2013

and labour appears to be tenable for constituents of capital such as plant and machinery (0.6) and computer hardware and software (0.4). It is noteworthy that there is a significant direct correlation between value of computer hardware and software and outcomes such as NVA (0.46) and profit (0.43).

Further, we examine Pearson correlation coefficient between six ratios: emolument as a percentage of NVA, profit as a percentage of NVA, NVA as a percentage of average persons employed, fixed capital per person employed, profit as a percentage of gross sales, value of computer hardware and software as a percentage of persons employed. As shown in Table 11.7, out of 15 correlation coefficients, only six are statistically significant. Among these, correlation between emolument as a percentage of NVA and profit as a percentage of NVA is the highest (−0.96), confirming an obvious inverse relation between factor shares that represent diametrically opposite class interests (while the former is for the working class, the latter for the capitalist). However, other five statistically significant correlation coefficients are positive and weak. Notable among these is the positive correlation between value of computer hardware and software as a percentage of persons employed and profit as a percentage of gross sales, pointing to a presumably direct linkage between digital resources and firm's performance.

We visualise five core patterns that have been discussed previously. While Fig. 11.2 portrays the relation between natural logarithm of NVA per person employed and natural logarithm of fixed capital per person employed, Fig. 11.3 presents the relation between natural logarithm of fixed capital per person and natural logarithm of ratio of emoluments to rent and interest. We depict a

Table 11.6 Correlation between select variables—auto component industry (NIC-2008 4 digit 2930)

Variable	Firm age	Net value added	Profit	Total manufacturing days	Average number of persons worked	Daily wage rate	Value of fixed capital	Value of plant and machinery	Value of computer hardware and software
Age of firm	1	0.114**	0.07*	0.192**	0.189**	0.016	0.07*	0.084*	0.051
Net value added		1	0.982**	0.654**	0.648**	0.35**	0.55**	0.473**	0.457**
Profit			1	0.545**	0.543**	0.29**	0.43**	0.341**	0.425**
Total manufacturing days				1	0.995**	0.18**	0.65**	0.622**	0.370**
Average number of persons worked					1	0.19**	0.62**	0.586**	0.383**
Daily wage rate						1	0.291**	0.258**	0.340**
Value of fixed capital							1	0.963**	0.371**
Value of plant and machinery								1	0.316**
Value of computer hardware and software									1

**Correlation is significant at the 0.01 level (two-tailed)

*Correlation is significant at the 0.05 level (two-tailed). Number of Responses as given in Table 11.4

Source Computed from Unit records of Annual Survey of Industries 2012–2013

Table 11.7 Correlation between ratios—auto component industry (NIC-2008 4 digit 2930)

Variable	Emolument as percentage of NVA	Profit as percentage of NVA	NVA per person employed	Fxed capital per person employed	Profit as percentage of gross sales	Value of computer hardware and software per person employed
Emolument as percentage of NVA	1	**−0.964****	−0.048	−0.029	0.003	−0.016
Profit as percentage of NVA		1	0.047	0.009	0.002	0.006
NVA per person employed			1	**0.143****	**0.069***	**0.203****
Fixed capital per person employed				1	**−0.118****	**0.269****
Profit as percentage of gross sales					1	−0.051
Value of computer hardware and software per person employed						1

**Correlation is significant at the 0.01 level (two-tailed)
*Correlation is significant at the 0.05 level (two-tailed). Number of Responses as given in Table 11.4
Source Computed from Unit records of Annual Survey of Industries 2012–2013

three-dimensional relation between natural logarithm values of NVA, persons employed, and fixed capital (Fig. 11.4). Figure 11.5 delineates the relation between natural logarithm of NVA and natural logarithm of profit. Except Fig. 11.4, we segregate patterns with respect to type of organisation. Quite important, we found no discernible divergence between these figures and the results of descriptive and inferential analysis.

Next, we posit four functional relations. model 1 puts natural logarithm of output as a function of natural logarithm of input, natural logarithm of fixed capital, natural logarithm of employed persons, having ISO certification, dummies to capture fixed effects that emanate from type of organisation, and for states, as well. Model 2 retains the same dependent variables in model 1, three independent variables, and dummies to capture fixed effects. However, we drop natural logarithm of fixed capital. Instead, we bring natural logarithm of value of plant and machinery and

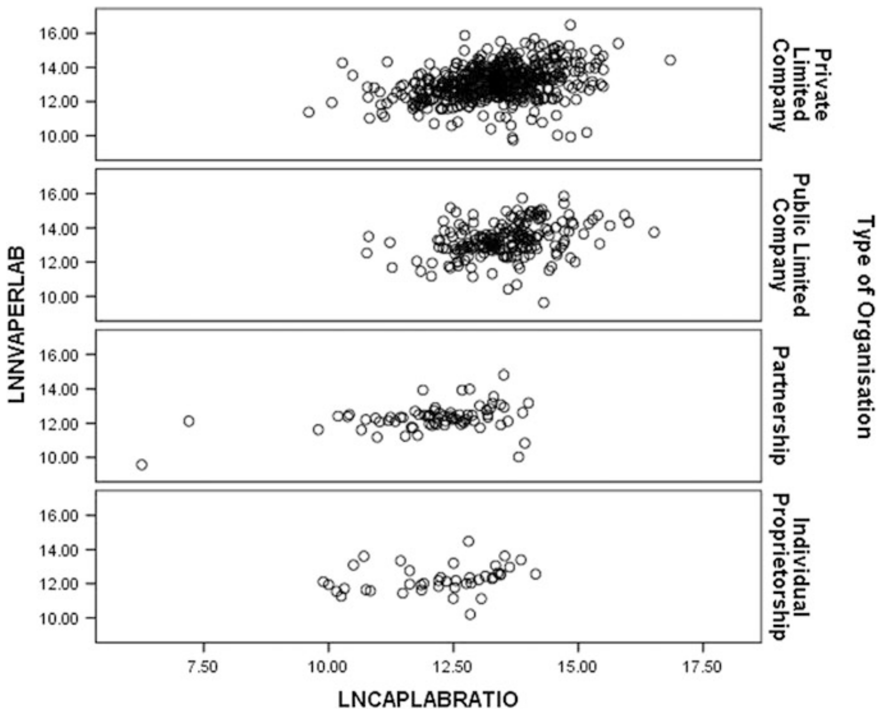


Fig. 11.2 Logarithm of NVA per person employed (LNNVAPERLAB) and fixed capital per person employed (LNCAPLABRATIO) (NIC-2008 4 digit 2930). *Source* Computed from Unit records of Annual Survey of Industries 2012–2013

natural logarithm of value of computer hardware and software. However, in models 3 and 4, we replace natural logarithm of output as dependent variable by natural logarithm of NVA. Moreover, in both the models, we remove natural logarithm of input. Except these changes, model 3 retains the same independent variables in model 1, while model 4 retains the same independent variables in model 2. We began the analysis by applying ordinary least squares (OLS) regression to these models. The results were subject to post-estimation analysis for variance inflation factor, testing the hypothesis of homoscedasticity, and testing the hypothesis of no omitted variables. We did not find any discernible violation of assumptions, excepting models 1 and 2 report heteroscedasticity. However, we found evidence, by plotting leverage[2] and normalised residual square, for perceptible impact of outliers in the distribution of variables. So, we adopted the robust

[2]'An observation with an extreme value on a predictor variable is a point with high leverage. Leverage is a measure of how far an independent variable deviates from its mean. High leverage points can have a great amount of effect on the estimate of regression coefficients'. http://www.ats.ucla.edu/stat/stata/dae/rreg.htm.

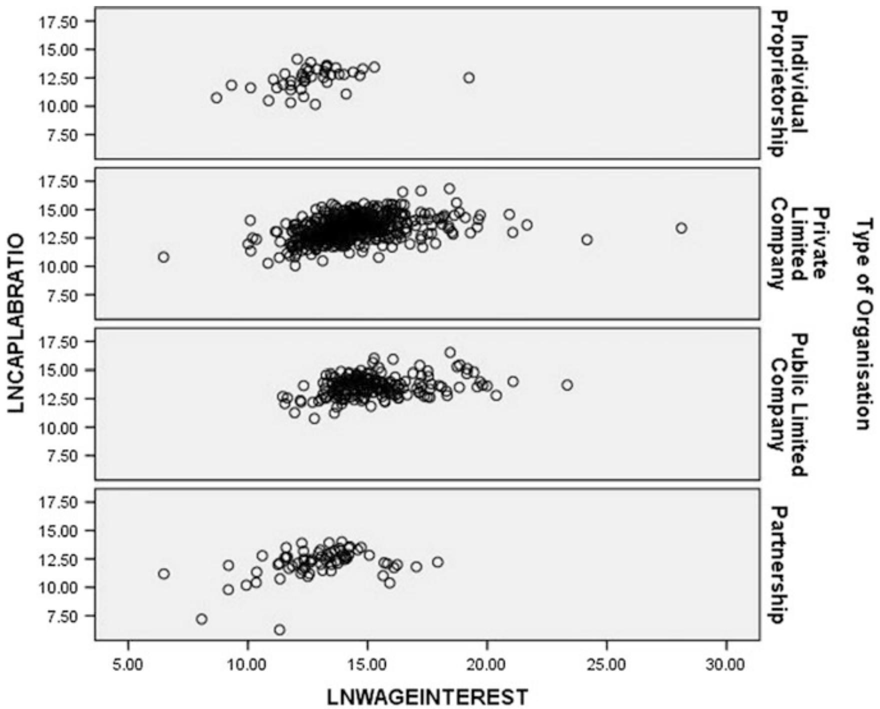
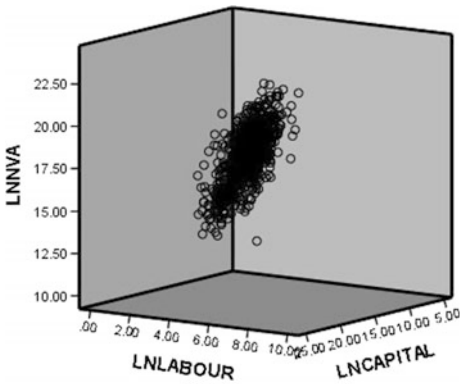


Fig. 11.3 Logarithm of ratio of emoluments to interest and rent (LNWAGEINTEREST) and fixed capital per person employed (LNCAPLABRATIO) (NIC-2008 4 digit 2930). *Source* Computed from Unit records of Annual Survey of Industries 2012–2013

Fig. 11.4 Logarithm of NVA (LNNVA), logarithm of fixed capital (LNCAPITAL), and logarithm of person employed (LNLABOUR) (NIC-2008 4 digit 2930). *Source* Computed from Unit records of Annual Survey of Industries 2012–2013



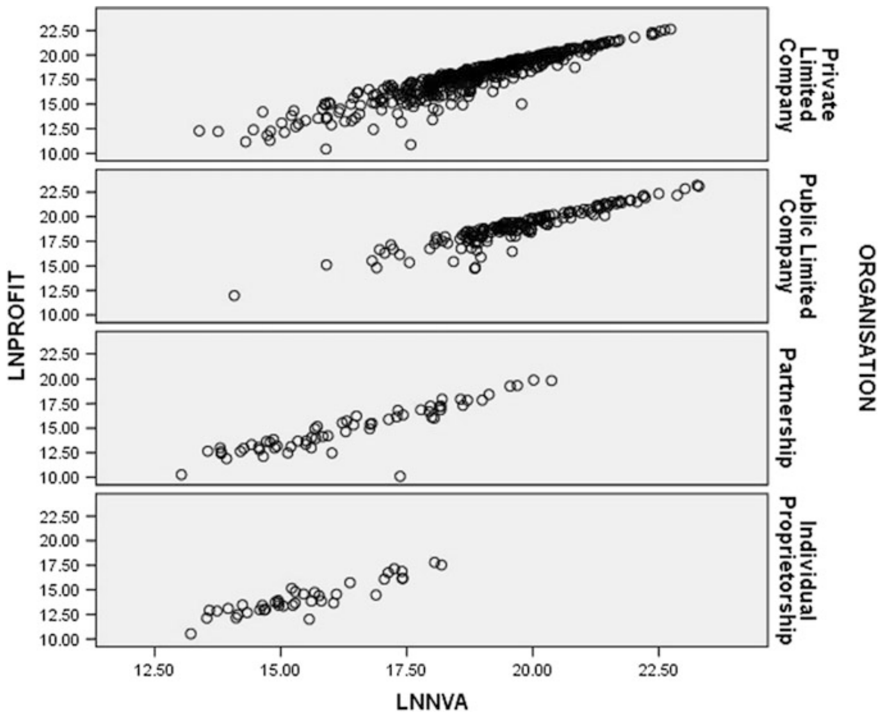


Fig. 11.5 Logarithm of NVA (LNNVA) and logarithm of profit (LNPROFIT) (NIC-2008 4 digit 2930). *Source* Computed from Unit records of Annual Survey of Industries 2012–2013

regression[3] method that precludes leveraging power of outliers, to estimate these models. Across four models, constants are positive and statistically significant (Table 11.8). However, dummies for state and type of organisation are not statistically significant. However, across these models, not having ISO certificate, statistically significant at 0.01 level, pulls output and NVA down. The magnitude of relation between the dummy for ISO and NVA is relatively higher than the magnitude of relation between the dummy for ISO and output.

For models 1 and 2, input captures largest chunk of variation in output (elasticities of 0.88 and 0.87, respectively). What makes model 1 distinct from model 2 is while model 1 treats fixed capital as an aggregate, in model 2, we use two constituents of capital—plant and machinery and computer hardware and software. Quite important, in models 1 and 2, leaving aside input, labour (i.e. employed persons) reports the second highest statistically coefficient (0.10 and 0.11, respectively). In model 1, however, coefficient of fixed capital is of lower magnitude (0.04), although the coefficient is statistically significant. In model 2, we retain the

[3]See Verardi and Croux (2009). Robust regression in Stata. *The Stata Journal*, *9*(3), 439-453. http://www.stata-journal.com/article.html?article=st0173.

Table 11.8 Determinants of output and NVA (robust regression) (NIC-2008 4 digit 2930)

Independent variables	Dependent variable							
	Model 1		Model 2		Model 3		Model 4	
	Natural logarithm of output		Natural logarithm of output		Natural logarithm of NVA		Natural logarithm of NVA	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Constant	1.37**	0.13	1.64**	0.14	8.71**	0.5	10.3**	0.46
Natural logarithm of input	0.88**	0.01	0.87**	0.01			–	–
Natural logarithm of fixed capital	0.04**	0.01	–		0.32**	0.03	–	–
Natural logarithm of employed	0.1**	0.01	0.11**	0.01	0.79**	0.04	0.78**	
Natural logarithm of the value of plant and machinery	–	–	0.02**	0.01	–	–	0.16**	0.03
Natural logarithm of the value of computer hardware and software	–	–	0.02**	0.00	–	–	0.14**	0.02
Having ISO certification: No (reference category: yes)	(−) 0.07**	0.01	(−) 0.08**	0.02	(−) 0.3**	0.07	(−) 0.3**	0.07
Type of organisation dummies	Yes		Yes		Yes		Yes	
State dummies	Yes		Yes		Yes		Yes	
Analysis of variance	$F(28,797) = 2831.95^{**}$		$F(29,752) = 2347.79^{**}$		$F(27,759) = 132.01^{**}$		$F(27,716) = 132.01^{**}$	
Number of responses	826		782		787		787	

**Significant at the 0.01 level (two-tailed)

Source Computed from Unit records of Annual Survey of Industries 2012–2013

same Pecking order of coefficients is as in the case of model 1. Interestingly, in model 2, coefficients in respect of plant and machinery and computer hardware and software turn out to be quite weak, however, statistically significant.

Now, we turn to models 3 and 4. In these models, we deduct inputs and depreciation from output, generating net value added (NVA). This means we do not include input as an independent variable. Apart from this, model 1 is replicated as model 3 while model 2 as model 4. In models 3 and 4, natural logarithm of employed accounts for largest variation (reporting partial elasticities 0.79 and 0.78, respectively). While 1 unit proportionate change in fixed capital generates 0.32 unit proportional change in NVA (model 3), in model 4, plant and machinery and computer hardware and software report coefficients 0.16 and 0.14, respectively. In both these models, not having ISO adversely affects NVA (−0.3 apiece). Moreover, fixed effects that originate from identities like state and type of organisation are not statistically significant.

Interestingly, leaving aside the conventional logic of NVA as a function of labour (i.e. persons employed) and fixed capital or plant machinery, quite interestingly, value of computer hardware and software and having ISO account for not an insignificant impact on NVA. Presumably, the inference points to that in auto component industry in India, across locations and type of organisation,[4] while the labour plays pivotal role in explaining variation in NVA, corroborating the extant literature on small and medium enterprises, it appears processes like ISO and resources such as computer hardware and software contribute to 'absorptive capacity' that emerges as the growth driver.

11.4 Unorganised Auto Component Industry in India

Our previous discussion was delimited to the registered/organised manufacturing, while unorganised enterprises also play vital role in the value chain of auto component industry. We delineate patterns from National Sample Survey 67th unit records. To identify enterprises that are engaged in auto component manufacturing, we selected NIC 2008 4 digit code 2930 that captures auto component sector, generating the data of 182 unorganised enterprises. As shown in Table 11.9, while 86% of enterprises are located in the urban, 87% are owned by male proprietors. Two-fifths of enterprise owners belong to schedule tribe (ST)/scheduled caste (SC)/ other backward classes (OBC) categories. 87% of enterprises exist with fixed premises and with permanent structure. Close to one-fifth are own account enterprises. Two-fifths of these units have faced same problem in recent times. Of these,

[4]Type of organisation also captures the scale of operation/employment. While public limited enterprises are larger units, the category of private limited captures medium to large. Other two types—proprietorship and partnership—are mainly formed by smaller enterprises.

Table 11.9 Characteristics of unorganised enterprises in auto component industry (NIC-2008 4 digit 2930)

Area	Percentage (%)	Faced problems	Percentage (%)
Rural	13.8	Yes	39.6
Urban	86.2	No	60.4
Total (*N* = 181)	100	Total (*N* = 182)	100.0
Type of ownership	*Percentage (%)*	*If faced problems, severe problems*	*Percentage (%)*
Proprietor male	87.4	Erratic power supply/power cuts	61.1
Proprietor female	3.8	Shortage of raw materials	4.2
Partnership with members of the same household	4.9	Shrinkage/fall of demand	5.6
Partnership between members not all from the same household	3.8	Non-availability/high cost of credit	6.9
Total (*N* = 182)	100	Non-recovery of financial dues	2.8
Social category of enterprise owner/partners	*Percentage (%)*	Non-availability of labour as and when needed	15.3
Scheduled tribe	2.2	Labour disputes and related	1.4
Scheduled caste	5.5	Others	2.8
Other backward classes	32.4	Total (*N* = 72)	100.0
Others	59.9	*Enterprise status*	*Percentage (%)*
Total (*N* = 182)	100	Expanding	41.2
Location	*Percentage (%)*	Stagnant	25.8
Within household premises	12.6	Contracting	9.9
With fixed premises and	87.4	Operated for less than three years	23.1
With permanent structure			
Total (*N* = 182)	100	Total (*N* = 182)	100.0
Type of enterprise	*Percentage (%)*	*Enterprise's usage of computer and Internet*	*Percentage (%)*
Own account enterprise	18.7	Enterprise used computer (*N* = 182)	9.3
Establishment	81.3	Enterprise used Internet (*N* = 182)	7.1
Total (*N* = 182)	100.0		

Source Computed from Unit Records of NSS 67th Round

three-fifths faced problems due to erratic power supply, while for one-sixth labour scarcity was a major problem. However, a measly 1.4% said they faced problems due to labour dispute. Only two-fifths reported that they had been expanding. While 9% used computers, 7% used Internet.

Table 11.10 Analysis of variance select variables—auto component industry with type of ownership (NIC-2008 4 digit 2930)

Dependent variable	Independent variable	*F*	Sig.
Gross value added (GVA) (rupees) (N = 182)	Type of ownership	0.064	0.979
Value of fixed capital (rupees) (N = 182)	Type of ownership	0.052	0.984
Value of plant and machinery (rupees) (N = 87)	Type of ownership	1.354	0.263
Value of information, computer and telecommunications equipment (rupees) (N = 39)	Type of ownership	0.072	0.975
Net surplus (rupees) (N = 181)	Type of ownership	0.066	0.978
Employed persons (N = 182)	Type of ownership	0.058	0.982

Source Computed from Unit Records of NSS 67th Round

Next, we move to the inferential analysis of select variables: gross value added (GVA), average number employed persons, fixed capital, net surplus, value of information, computer and telecommunications equipment, and value of plant and machinery. Moreover, we transform these variables to natural logarithm scale.[5] We use three tools: analysis of variance (ANOVA), Pearson correlation coefficient, and regression. Table 11.10 presents ANOVA results. In ANOVA, all the select variables are treated as the dependent variables, while type of ownership is the independent variable. We accept the null hypothesis that as we change categories within type of ownership, there is no change in these variables.

We run Pearson correlation for every pair of variables—LNGVA, LNLABOUR, LANCAPITAL, LNSURPLUS, LNICT, and LNPLANT—generating 15 correlation coefficients (Table 11.11). Of these, except one pair (LNICT and LNPLANT), all report positive strong correlation, ranging from 0.49 (LNCAPITAL and LNGVA) to 0.92 (LNGVA and LNSURPLUS). While LNGVA and LNSURPLUS are performance indicators, rests are resources with the enterprise. Among resources that covary strongly with LNGVA, LNLABOUR reports highest magnitude of correlation (0.92), followed by LNICT (0.68). The same Pecking order is valid for LNSURPLUS (correlation with LNLABOUR and LNICT are 0.66 and 0.61, respectively).

The third analysis we explore is the regression. We regress LNGVA on LNCAPITAL, LNLABOUR, dummies with respect to usage of computer by the enterprise and usage of Internet by the enterprise. We have two models. In model 1,

[5]LNGVA = Natural Logarithm of GVA, LNLABOUR = Natural Logarithm of Employed Persons; LNCAPITAL = Natural Logarithm of Fixed Capital, LNSURPLUS = Natural Logarithm of Net Surplus, LNICT = Natural Logarithm of information, computer and telecommunications equipment, and LNPLANT = Natural Logarithm of Plant and Machinery.

Table 11.11 Correlation between select variables (NIC-2008 4 digit 2930)

	LNGVA	LNLABOUR	LNCAPITAL	LNSURPLUS	LNICT	LNPLANT
LNGVA	1	0.809**	0.490**	0.917**	0.684**	0.614**
LNLABOUR		1	0.531**	0.659**	0.721**	0.537**
LNCAPITAL			1	0.508**	0.513**	0.693**
LNSURPLUS				1	0.608**	0.556**
LNICT					1	0.232
LNPLANT						1

**Correlation is significant at the 0.01 level (two-tailed)
LNGVA Natural Logarithm of GVA, *LNLABOUR* Natural Logarithm of Employed Persons *LNCAPITAL* Natural Logarithm of Fixed Capital, *LNSURPLUS* Natural Logarithm of Net Surplus, *LNICT* Natural Logarithm of information, computer and telecommunications equipment, *LNPLANT* Natural Logarithm of Plant and Machinery Number of Responses as given in Table 11.10
Source Computed from Unit Records of NSS 67th Round

Table 11.12 Determinants of GVA (robust regression) (NIC-2008 4 digit 2930)

Independent variables	Dependent variable			
	LNGVA[a]		LNGVA[a]	
	Model 1		Model 2	
	Coeff.	Standard error	Coeff.	Standard error
LNCAPITAL$	0.06**	0.02	0.06**	0.02
LNLABOUR$	0.93**	0.07	0.92**	0.07
Usage of computer by the enterprise (1 = Yes, 0 = No)	0.43**	0.17	–	–
Usage of Internet by the enterprise (1 = Yes, 0 = No)	–	–	0.55**	0.19
Constant	8.67**	0.25	8.20**	0.25
Analysis of variance	$F(3,178) = 141$**		$F(3,178) = 143$**	
Number of responses	182		182	

**Significant at the 0.01 level (two-tailed)
[a]Variable names are explained Table 11.11
Source Computed from Unit Records of NSS 67th Round

we regress LNGVA on LNCAPITAL, LNLABOUR, dummy with respect to usage of computer by the enterprise, while, in model 2, we retain all variables except the dummy. We replace dummy for usage of computer by the enterprise by dummy for usage of Internet by the enterprise. We refrain from using both dummies together since phi correlation[6] of these dummies is strongly positive, thus paving way for multicollinearity. Akin to regression models shown in Table 11.8, we first deployed an OLS model, and subjected results to the post-estimation process. Although we did not find any significant departure from OLS assumptions, we used robust

[6]Phi correlation measures correlation between two nominal variables.

regression to overcome the leveraging power of outliers. As shown in Table 11.12, with respect to model 1, LNLABOUR accounts for highest chunk of variation in LNGVA, while usage of computer makes quite a discernible positive impact on LNGVA. We get more or less similar pattern for model 2, as well. In the case of model 2, leaving resources like labour, usage of Internet appears to make strong positive impact on LNGVA.

Quite unequivocally, what emerges from the descriptive and inferential analysis is that while linking resources with enterprise's performance, two resources stand out in impact: labour and information and communication technology. These two resources, along with technological upgradation, seem to play pivotal role in shaping absorptive capacity of enterprises in auto component industry in India, in particular small and medium enterprises.

11.5 Field Study of Auto Component Custer in Pune

Previous analysis and discussion unravels that it is crucial for enterprises in auto component industry, particularly SMEs, to envisage the creation and fostering of absorptive capacities, primarily through synergising labour and information technology. This is a transformative question, entailing organisation knowledge and learning. To get some sense of how auto component enterprises practice these processes, we did a sample survey of 92 firms during May–June, 2016.

Table 11.13 presents data gathered from Pune automobile cluster which brings out firm characteristics, which manufacture automobile parts and accessories. A sample size of 92 firms is accounted in this analysis. Of all the firms, 40% of the firms had Web presence of some kind which provides them a better visibility. Further, majority of the firms (more than 50%) were of recent origin, i.e. established between the years 2000–2010. A meagre 7.2% of firms were established prior to 1990s. The educational qualification of the owner of the firm was mostly found to be diploma holders (close to 50% of the total owners). Close to 25% of the owners were also found to be undergraduates having technical background. The sample collected also reflects a majority of small proprietorship firms which largely falls within tier 3 of the value chain. In terms of the size of the firm, a large majority were small firms. Medium sized firms were found to be around 15%. A link can be drawn between the type of establishment, size of the firm, and the nature of the firm where as mentioned earlier a large number of enterprises in the sample lay in the tier 3 category. In most instances, the number of workers in the firms was found to be less than twenty. Data was collected from different locations in Pune that included *Bhosari, Chakan, Powna* industrial area, and *Talawade*. Of these different locations, majority of the firms were located in *Bhosari*.

In Table 11.14, we interrogate the usage of technology which transfers into learning outcomes through various internalisation processes. It was found that more than half of the firms were using conventional devices in production. However, a few firms also showed investments done in using latest technological devices.

Table 11.13 Characteristics of factories that manufacture parts and accessories for motor vehicles in Pune (2016)

Firm characteristics	Percentage (%)	Firm characteristics	Percentage (%)
Firm having website (n = 90) (Variable name: WEB)		Size of the firm (n = 92) (Variable name: SCALE)	
Yes	40	Micro	16.3
Year of establishment (n = 83) (Variable name: YEAR)		Small	68.5
Before 1990	7.2	Medium	15.2
1990–2000	9.6	Nature of the firm (n = 89) (Variable name: TIER)	
2000–2010	56.6	Tier 1	25.8
After 2010	26.5	Tier 2	21.3
Educational qualification of the owner (n = 89) (Variable name: EDUCATION)		Tier 3	52.8
12th and below	7.9	Number of workers (n = 91) (Variable name: EMP)	
Undergraduate technical	23.6	Below 10	35.2
Undergraduate non-technical	2.2	10 and below 20	35.2
Diploma	47.2	20 and below 100	25.3
Industrial training Institute (ITI) qualified	7.9	Above 100	4.4
Postgraduate technical	9.0	Location of firm (n = 92) (Variable name: LOCATION)	
Postgraduate non-technical	2.2	Bhosari	45.7
Type of establishment (n = 92) (Variable name: ESTABLISH)		Chakan	18.5
Proprietorship	54.3	Powna industrial area	17.4
Partnership—same family	13.0	Talawade	18.5
Partnership—at least one member from outside the family	15.2		
Private limited company	16.3		
Public limited company	1.1		

Source Survey data

A small portion of firms also used a mix of both conventional as well as latest technology to carry out production. On probing further it came to be known that these devices which are used in the production were largely known from the perspective of experiences of concerned persons, while other sources of learning were also found to be through education, customers, family, and competitors. These experiences which account for learning occur through a mixture of handling iterative processes along with peer learning at work place. However, the knowledge

Table 11.14 Technology, design, and knowledge in factories (auto component industry Pune) (2016)

Variable	Percentage (%)	Variable	Percentage (%)
Devices used in production (n = 91) (Variable name: DEVICES)		Research and development (n = 92) (Variable name: RD)	
Conventional	54.9	Availability of R&D	13.2
Latest technological devices	30.8	Bought R&D	3.3
Both	14.3	Design (Variable name: DESIGN)	
Source of learning about the device used (n = 91) (Variable name: LERANING1)		Source of design (n = 90)	
Experience	64.0	Customers	74.4
Customer	7.9	We design our own products	12.2
Education	23.6	We design together	13.3
Family	3.4	Freedom in design (n = 91) (Variable name: FDESIGN) (yes/no)	48.4
Competitors	1.1	Developed new product (n = 91) (Variable name: NEWPROD) (yes/no)	1.1
Satisfaction in devices (n = 91) (Variable name: SATISFACTION)		Links with training institute (n = 91) (Variable name: TRAINLINK) (yes/no)	11.0
Strongly agree	4.4	Awareness of latest technology (n = 91) (Variable name: AWARETECH) (yes/no)	90.0
Agree	61.5	Source of knowledge about the technology (n = 88) (Variable name: KNOWLEDGE)	
Neither agree nor Disagree	7.7	Internet Variable name: INTERNET) (yes/no)	71.6
Disagree	24.2	Exhibition (variable Name: EXHIBITION) (yes/no)	50.0
Strongly disagree	2.2	Visit companies (Variable name: VISITC) (yes/no)	33.0

Source Survey data

about the latest technology is attributed largely to the usage of Internet and also by attending exhibitions and visiting companies. It was also observed that primarily the source of design had been customers, which depict a strong interface between buyer and supplier. A large majority of the firms were satisfied with the devices that they used for production. Although it was found that they had the freedom to design products, it was rarely such that firms actually took up designing new products. Part of the reason also lay that majority of the firms in the data belonged to tier 3 enterprises which has little expertise of the same.[7] Also, the focus on R&D was bleak.

Next we showcase, in Table 11.15, data on labour and learning processes in firms. Overall it came out that firms did find adequate skilled labour to be used. Close to 70% agreed on finding adequate skilled labour. It was also found that around 65% of the employers organise some kind of training for the workers. This training was mostly supervised and on the job training for the workers. Technology is also seen to be advantageous for the firms where a large chunk of employers believed that the usage of advanced technology would increase their production.

Inclusion of new technology also requires learning for the workers. It was found that the sources of learning for the workers were largely from their own experiences and education. These learning processes developed mostly in learning by doing fashion and to a lesser extent from formal and informal training. Only a meagre percentage of employers provide skill development training to its workers. The firms operate in a much standardised manner which is brought out by the fact that a large chunk of employers have never changed their method of production process. Also since the workers are not much skilled, most of the directions are provided by the employers themselves, and there is not much scope for initiation by the worker. Close to 40% of the firms provide manuals for the usage of technological devices and also document their technological process.

In Table 11.16, it was found that a little less than half of the firms had ISO certification. On assessing whether there has been any possible link between adaption to new technology along with increase in the number of workers, no clear views emerged with some firms agreeing while some others being unsure towards it. Around 76% of the firms reported that over a period of time there has been an increase in the production to the tune of 5–10%. This has appeared with an increase in productivity and which is also reflected positively on the financial performance of the firms. On probed over relationship with the customer and suppliers, a more or less amicable relation was found to exist between the same. Majority of the firms interrogated did not export their products but were to some extent involved in the outsourcing of their activities.

[7]Refer to Table 11.13.

Table 11.15 Labour and learning in factories (auto component industry Pune) (2016)

Variable	Percentage (%)	Variable	Percentage (%)
Adequate skilled labour (***n* = 91**) (Variable name: SKILL)		**Source of learning** (***n* = 90**) (Variable name: LEARNING2)	
Agree	69	Own experience	61
Neither agree nor disagree	7	Education	2
Disagree	21	Education and experience	33
Strongly disagree	3	Family	3
Provide training for labour (***n* = 91**) (Variable name: TRAINING)		**Learning Process** (***n* = 91**) (Variable name: LEARNING3)	
Strongly agree	1	Learning by doing	60
Agree	64	Formal training	7
Neither agree nor disagree	1	Informal training	33
Disagree	34	**Skill development** (***n* = 91**) (Variable name: SKILL)	19
Mode of training (***n* = 87**) (Variable name: MODE)		**Change in production process** (Variable name: CPP) (**n = 91**)	**19**
Direct on job TRAINING	22	**Independence for workers** (***n* = 91**) (Variable name: INDEPENDENCE)	
No training	6	Strongly Agree	1
Supervised training	45	Agree	14
Job training	14	Disagree	79
Hire only experienced workers	11	Strongly disagree	5
Monthly training programme	2	**Incentives for workers for innovation** (***n* = 91**) (Variable name: INCENTIVES)	
Strongly agree		Strongly agree	2
(Variable name: ADVTECH1)			
Strongly agree	13	Agree	14
Agree	81	Neither agree nor disagree	2
Neither agree nor disagree	3	Disagree	76
Disagree	2	Strongly Disagree	5
Use of advanced technologies increased production (***n* = 88**) (Variable name: ADVTECH2)		**Manual for technology** (***n* = 91)** (Variable name: MANUAL)	41
Strongly agree	14	**Documentation of technology** (***n* = 91**) (Variable name: DOC) (yes/no)	40
Agree	80		
Neither agree nor disagree	5		
Disagree	2		
Provision of information (***n* = 91**) (Variable name: INFO)			
Strongly agree	7		
Agree	81		
Neither agree nor disagree	4		
Disagree	8		

Source Survey Data

Table 11.16 Core processes and outcomes in factories (auto component industry Pune) (2016)

Variable	Percentage (%)	Variable	Percentage (%)
ISO certification (*n* = **91**) (Variable name: ISO) (yes/no)	42.9	**Relationship with customer (*n* = 91)** (Variable name: CUSTOMER)	
Increase in number of workers with new technology (n = 91) (Variable name: COMPLI)		Very good	17.6
Strongly agree	2.3	Good	70.3
Agree	40.9	Neither good nor bad	6.6
Neither agree nor disagree	39.8	Bad	5.5
Disagree	17.0	**Relationship with supplier (*n* = 91)** (Variable name: SUPPLIER)	
Status of production process (n = 91) (Variable name: PROCESS)		Very good	16.5
Increased	76.9	Good	81.3
Decreased	7.7	Neither good nor bad	2.2
Remains the same	15.4	Bad	0.0
Increase in production (n = 88) (Variable name: PROD)		**Increase in productivity (*n* = 91)** (Variable name: PROD)	
0–5%	20.0	Increased	83.5
5–10%	61.3	Remains the same	16.5
More than 10%	18.7	Decreased	0.0
Status of financial performance (n = 90) (Variable name: FINANCE)			
Increased	80.7		
Decreased	5.7		
Remains the same	13.6		
Exporting (***n* = 90**) (variable name: EXPORT)	19.0		
Outsourcing (***n* = 91**) (variable name: OUTSOURCE)	45.0		

Source Survey Data

11.6 Conclusion

The auto component industry in India presents a case of a thriving value chain which is poised for growth in the future. In a cursory overview, it encapsulates firms of different sizes working synchronously to achieve targets and in the process constantly upgrading itself. This study had been specifically dedicated towards the study of small and medium enterprises situated in the value chain of the Indian auto component industry.

In the paper, we have used four types of data: recent time series of select indicators that are pertinent to the organised auto component industry, cross-sectional unit records of organised factories in auto component industry for the year 2012–2013, cross-sectional unit records of unorganised enterprises in auto component industry for the year 2009–2010, and sample survey conducted in Pune auto component cluster in 2016. Drawing cues from the time series analysis of select aggregates, while there is discernible trade-off in distributing NVA between wage and profit in the organised sector, irrespective of scale—plant and machinery or employment-, there has been consistent exponential growth in capital per employed per person. However, as per the recent cross-sectional data (for the year 2012–2013), labour emerges to be the most impactful in explaining direct variation in net value added. Adding to this, investment in computers and ISO certification seem to be emerging as critical sources of growth for these enterprises. Interestingly, these findings appear to repeat in unorganised enterprises, as well. From our sample survey, primarily capturing unorganised enterprises in Pune cluster, unequivocally, enterprises seem to see creative synergy in organising skill, learning, knowledge, and firm performance.

This study has brought home the point starkly that labour, as opposed to popular imagination, forms a key resource for an enterprise, in particular the SMEs. In the current climate of rapid technological progress for upgradation, labour forms a cornerstone that channelises these developments into fruition. However, combining the data presented in the paper and the review of the extant literature on absorptive capacity, capabilities of labour may be complemented by the usage of information and communication technology. Labour is seen as a repository of knowledge which acts as an interface between capital and output. While the former represents the inputs for the production process, the latter is represented in the form of net value added. The absorptive capacity of labour hence developed over a period of time is shown to be quite useful in assimilating the utility derived from technological upgradation. There is a need to foster their absorptive capacity by prudently combining skilled labour and information and communication technology, while capital-labour ratio is certain to grow in coming days. Perhaps, this also partly explicates towards the knowledge building in the firms within the value chain.

Quite important, while the auto component industry supplies to one of the world's most technologically sophisticated and business savvy buyers such as original equipment manufacturers (OEMs), the state of technological artefacts may rather be determined by OEM-driven value chains. However, auto component industry, even amidst a monopsonistic market structure, appears to have a plethora of possibilities of innovative management of skilling, learning, and knowledge.

From a policy angle, to transform the auto component industry into an innovative and creative system, in particular those enterprises that are located in a cluster, it makes sense if there are triadic stratagem, bringing enterprises, original equipment manufacturers, and the state, to synergise a shared system of knowledge, skill, learning, and competitiveness. Unequivocally, clusters such as Pune remain, barring a few notable exceptions, averse to basic enterprise upgradation tools like ISO while keeping aloof from exploring the arena of international business. In this milieu, technological acquisition or upgradation alone may not work. What has to be forthcoming is building transformational systems through synergetic processes like learning, knowledge management, and skilling. Ideally, cluster needs to envisage resources and facilities that are open to enterprises. Here, the state also can play the role so as to facilitate such an organisation. Thus, enterprises can be redeemed from contractual complexities and specific assists that are required in building absorptive capacities in the Indian auto component industry.

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