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ARTICLE

Technology, TFPG and Employment: A Panel Data Analysis

Sameer Malik[1] · **Arup Mitra**[2]

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Abstract

This paper based on the United Nations Industrial Development Organization (UNIDO) panel data set makes an attempt to estimate total factor productivity growth (TFPG) across countries. Productivity convergence over time is evident when countries are divided across regions which could be attributed to a greater degree of association of countries in a given region pursuing joint efforts for infrastructural development, ICT coverage and advancement, trade negotiations, technology acquisition and innovation, and inflow of FDI. In terms of efficiency estimates for select years, most of the countries are seen to be operating much below the frontier. This is indicative of the fact that countries are keen to pursue resource-driven growth in an attempt to maximize it. Based on the inter-temporal data, we observed that a number of countries registered either a negative or a positive but low correlation between labour productivity growth and TFPG. Evidently, countries are engaged in greater mechanization which may be raising labour productivity without ushering in much success in terms of TFPG. From panel data regression, the impact of technology perceived in terms of TFPG, on employment, is seen to be negligible though it is important to note that none of the groups, income or region-wise, recorded a statistically significant negative effect except the least developed countries (LDCs), while the significant cases (howsoever scanty) reveal a positive association. Appropriate incentives may motivate firms to experience technological progress and employment growth both.

Keywords Technology · Innovation · Productivity · Growth · Employment

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✉ Arup Mitra
arupmitra@sau.int

Sameer Malik
smalik.dse@gmail.com

[1] University of Houston, Houston, USA

[2] South Asian University, New Delhi, India

1 Analytical Framework

Non-resource-driven growth is the key to sustainable development in the long run, else resource intensive economic growth can result in crisis in the future years. Technological advancement is endemic to economic growth, and growth in output which is more than proportionate increase in inputs is attributed to total factor productivity growth (TFPG), after controlling for returns to scale. Therefore, decomposing growth in terms of resource-driven and non-resource-based components, the endogenous growth models can be relooked to identify the major determinants of the latter part, i.e. TFPG. Endogenous growth models urge that research and development (R&D) expenditures taken as a broad proxy for innovative moves contribute directly to firms' productivity enhancement, and indirectly through their industry-wide spill-over effects (see Grossman & Helpman 1990; Romer; 1986). Similarly, import of technology and foreign direct investment (FDI) can also result in technological advancement, contributing to TFPG.

At the global level, TFPG has witnessed a deceleration in the recent past which is a matter of serious concern. In the light of Kuznets' (1966) modern economic growth, while the developing countries may be trying to catch up with the developed countries by investing in factors that contribute to productivity and growth, the gap between the two sets of countries may not actually disappear. This is likely to happen only when the developed countries are able to pursue technological progress in a continuous manner, translating into shifts in higher levels of productivity. However, the productivity decline in the recent past is indicative of poor performance both from the point of view of the developed as well as developing countries. Investment growth has slowed down in both developed and developing countries with implications on innovation, skills and infrastructure, and through these factors on productivity (Das 2018). The technological progress among the leaders has decelerated, while the developing countries are not able to raise their performance in terms of productivity. Even when factor input contributions remained relatively strong, TFPG declines occurred in the emerging market economies (Erumban & Ark 2018). The contribution of ICT has reached a saturation point (Erumban & Ark 2018) as the cost of capital for the price of IT capital input is very large relative to the cost of capital comprising non-IT input (Jorgenson 2018). Though the labour share is on the decline, the share of intangible capital is on the rise and the globalization process with its consequent effect on value chain has possibly resulted in productivity declines in the developed countries without commensurate increase in productivity growth in the developing countries as their growth is resource intensive. Besides, the cost of knowledge workers using ICT might have been on the rise, reducing the TFPG (Jorgenson 2018).

The other issue relates to the effect of technology on employment. A large number of studies have argued that new technology, particularly when it is imported from the labour scarce developed countries, is capital and skill intensive, which may be reducing the pace of employment creation, particularly from the point of view of the unskilled variety of labour (Berman and Machin 2004; Acemoglu 2003). The import of capital and skill intensive technology from the

developed to the developing world results in sluggish employment growth though UNIDO (2005) urged that such technology mobility should be facilitated by other means of reforms on the macro-front. Globalisation and the economic reforms pursued by most of the countries at the behest of World Bank-IMF initiation did witness a sharp decline in the effective rate of protection and other trade barriers all of which encouraged import of technology. The adoption and adaptation of these international technologies are indeed costly because of tacit knowledge and circumstantial sensitivity of technology (Evenson & Westphal 1995). Further, unless an importing country has significant technological capability, it cannot fully utilize the imported technology**.** Besides, imported technology may require more skilled than unskilled workers, while developing countries usually have an abundant supply of the latter type. Acemoglu and Zilibotti (2001) argued that due to the difference in skill scarcity, technology in developed countries tends to be skill intensive and is inappropriate for developing countries. Though UNIDO (2005) argues that it is still cheaper for a latecomer to buy the technology already invented by others than to re-invent the wheel, there can be serious implications in terms of employment loss.

On the other hand, a number of reasons are cited to suggest that new technology in developing countries can still create new employment opportunities. Vivarelli (2013) for example argues that the new technology may enhance profitability, resulting in new investment with job avenues. The displacement and compensation mechanisms which are at work have been discussed with great details by Vivarelli (2013). He reminds that labour-saving and deskilling effects of capital-intensive technology have been a concern since the Luddite movement of the early 19th century. However, he also draws attention to the theoretical debate, which identifies a range of compensation mechanisms that may alleviate such concerns. Labour-saving effects of technology can be offset through: (i) additional employment in industries producing the new machines; (ii) higher demand for goods/services due to lower prices; (iii) new investments made using extra profits; (iv) decreases in wages resulting from price adjustment mechanisms; (v) higher income resulting from redistribution of innovation gains; and (vi) new products created using new technologies. Mitra and Jha (2015) further noted that innovation of new technology may lead to an expansion in the activities of firms such as processing of by-products, without any proportionate increase in capital. All this is expected to raise employment in absolute terms though labour to value added ratio may not increase in comparison with its pre-innovation magnitude.

The paper uses the UNIDO data for the organized manufacturing across 132 countries for the period ranging from 1990 to 2010. The definition of the organized sector may be different across the countries, and hence, the interpretation needs to be made carefully. The study proposes to estimate TFPG and technical efficiency (TE) for several countries (relatively more number of developing countries) and decipher patterns, if any. It also examines the relationship between TFPG and labour productivity growth (LPG) in order to throw light on the dampening effect of TFPG. The effect of technology perceived through changes in TFPG/TE and the number of patents, on employment, comprises another important dimension of the paper.

Information on patent and per capita income in constant prices is taken from the World Bank data set. The variables such as value added, wage rate and capital in different countries are given in nominal terms by UNIDO, and they are subjected to the influence of foreign exchange movement and domestic inflation. In order to convert them into real terms, we have considered the figures in international currency (dollar) based on the average exchange rate prevailing over 1990–2010 and then deflating the figures by the country-specific implicit price deflator. The methodology adopted to estimate TFPG and TE from panel data is due to Cornwell et. al. (1990), where TFPG is estimated as a combination of technological progress (regress) and the change in technical efficiency. From the production function estimated on the basis of the panel data (across countries and over time), the coefficient of time trend is taken as the pace of technological progress (regress).

In the second stage using the residuals as a quadratic function of time for each country separately, TE and the change in TE (dTE/dt) have been estimated. Then, the estimated values of the residual from all the country specific regressions, using the inter-temporal data, have been pooled and relative to the maximum value the efficiency index for each country and for every year has been generated: **exp(residual—max residual)**. Thus, though the technological progress is perceived to be common for all countries over a given time period, which in a globalizing world is quite a realistic assumption, the change in technical efficiency over time is perceived to be different across countries. Hence, TFPG over time and across countries is likely to have considerable variations (for details on the methodology see appendix).

The rest of the paper is structured as follows: Section 2 focuses on the TFPG estimates across countries over different time constellations and tries to verify if the cross-sectional variations in productivity estimates are converging in a broad sense. Section 3 turns to the relationship between labour productivity and TFPG in order to reflect on whether the contribution of non-resource-driven growth is driving the factor productivity or whether the rise in productivity of one factor (labour) is mainly related to capital accumulation without improvement in the overall performance. Section 4 turns to the relationship between technology and employment. Improvements in technology may raise productivity which in turn tends to reduce the utilizations of all factors including labour. Alternately, technological progress makes technology cheaper, improves the accessibility of all types of firms, expands the scale of production and encourages the processing of by-products, all resulting in rise in employment. Finally, Section 5 summarizes the major findings.

2 TFPG Estimates

Though the year-to-year estimates of TFPG and TE have been derived for the period 1990–2010 depending on the availability of data, in the appendix table 2, we present the estimates for a few select years only, which is again not available uniformly for each of the countries due to missing information. In Table 1, we have tried to present a summary of TFPG estimates based on the figures for the 1990s and the 2000s. The number of countries in Table 1 has dropped considerably in comparison with the table in the appendix due to the lack of data. However, the pattern suggests that

Table 1 Total Factor Productivity Growth over the Years

1990's				
	Negative	Low	Medium	High
2000s				
Negative	Cyprus	China, Macao SAR	China, Hong Kong SAR	
	Ethiopia	Japan	Luxembourg	
	Iran (Islamic Republic of)	Morocco	Republic of Korea	
	Kuwait			
	Philippines			
	Spain			
	Turkey			
	Uruguay			
Low		Austria	India	
		Norway	Israel	
			Malaysia	
Medium	Germany	Finland	Belgium	Ecuador
	Italy	Oman	Netherlands	
	Malta	United States of America		
	Portugal			
	Romania			
High	Denmark	Ireland		United Republic of Tanzania
	Eritrea	Sri Lanka		
	Hungary	Sweden		
	Jordan	United Kingdom		
	Latvia			
	Malawi			
	Mexico			
	New Zealand			
	Poland			
	Singapore			
	Slovakia			
	Slovenia			
	Viet Nam			

Low, medium and large refer to range of values in terms of growth rates. Low (0–2%), Medium (2–5%), High (5% & above)

Source: Based on UNIDO Data

quite a few countries, many of which belong to the developed world, experienced a rise in TFPG in the 2000s, while they had recorded either a negative or a low TFPG in the 1990s (Table 1).

Based on the year-to-year estimates, the cross-sectional variations are measured after dividing the countries into various income groups. From the results, for all countries combined, a significant decline is evident in the standard deviation of TFPG estimates, which may be interpreted as a sign of sigma convergence. Across various groups of countries, however, such a pattern is not evident. For example, among the least developed countries (LDCs), the long-term pace of decline in the variation is mild though the humps of the early nineties and late nineties and early 2000s were not repeated thereafter. Similarly, in the case of low-income countries, again the cross-country variation in TFPG seems to have become less volatile in the 2000s though the extent of long-term decline in the sigma is mild. Among the lower middle income, upper middle income and high-income countries, the drop in the sigma magnitude is prominent though, for the last group, the country experiences tend to widen sharply during 2007–2010 (Fig. 1).

Looking at the sigma value (the standard deviations) after dividing the countries across regions East Asia and Pacific, Europe and Central Asia and Latin America and Caribbean, countries seem to have registered a steady fall, indicating convergence in the productivity growth experience of the countries. Middle East and North Africa on the other hand unfold a rising tendency in the productivity growth witnessed across countries within the group. South Asia, with missing data for the years between 2002 and 2005, reveals a rise in the country-wide variation in productivity growth towards the end of the 2000s, though between 1990 and 2001, sigma convergence was taking place. Sub-Saharan countries after experiencing a sharp increase in the productivity growth variation during the nineties witnessed a major decline in the sigma value which is also less fluctuating on year-to-year basis. On the whole, in several regions in the world, there is a tendency of productivity convergence, though the value around which countries in each region are converging may itself vary from region to region. This could be attributed to a greater degree of association of countries in a given region pursuing efforts jointly for infrastructural development, ICT coverage and advancement, trade negotiations, technology acquisition and innovation, and inflow of FDI.

Looking at the efficiency estimates for select years (appendix table), most of the countries are seen to be operating much below the frontier. This is indicative of the fact that countries are keen to pursue resource-driven growth in an attempt to maximize the growth strategy in the wake of globalization. Without bothering to use the resources optimally or to exploit the existing capacity to the maximum possible extent, countries are in a mad rush to raise the growth magnitude which would indeed show up in the future years, resulting in its non-sustainability. The standard deviation computed from the TE magnitudes across countries seems to be declining except in the case of lower middle income countries, high-income countries and region-wise, East Asia and Pacific, South Asia, and Sub-Saharan Africa (Fig. 2). In other words, in some of the groups of countries, the competitiveness is high, and hence, efforts are on to catch up in terms of the utilization of resources. Countries which were lagging behind have tried to get closer

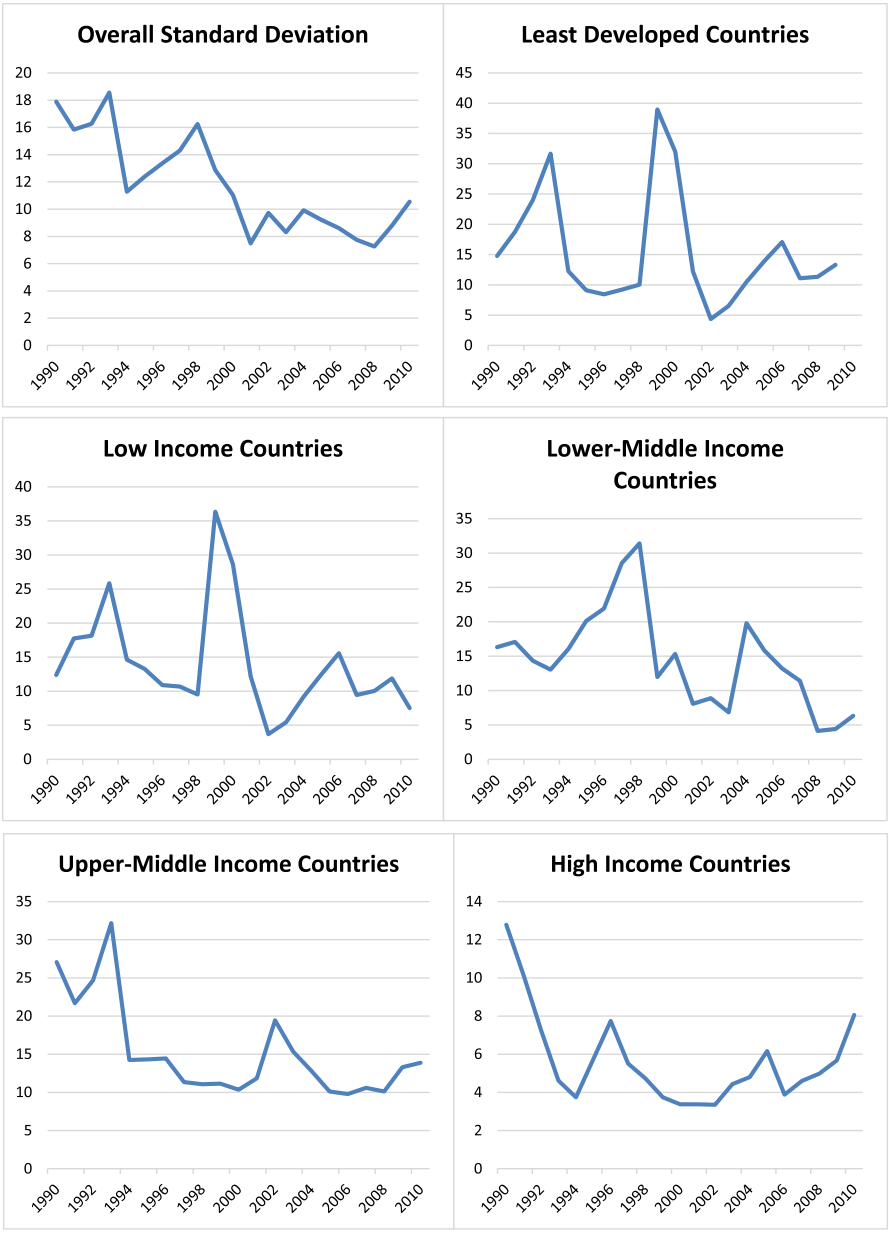

Fig. 1 Sigma Convergence:TFPG (Based on year-to-year TFPG) [Trend in Standard Deviation of TFPG]

to the relatively better performers though most of them may still be operating much below the frontier. In other words, there is enormous scope to utilize the resources efficiently.

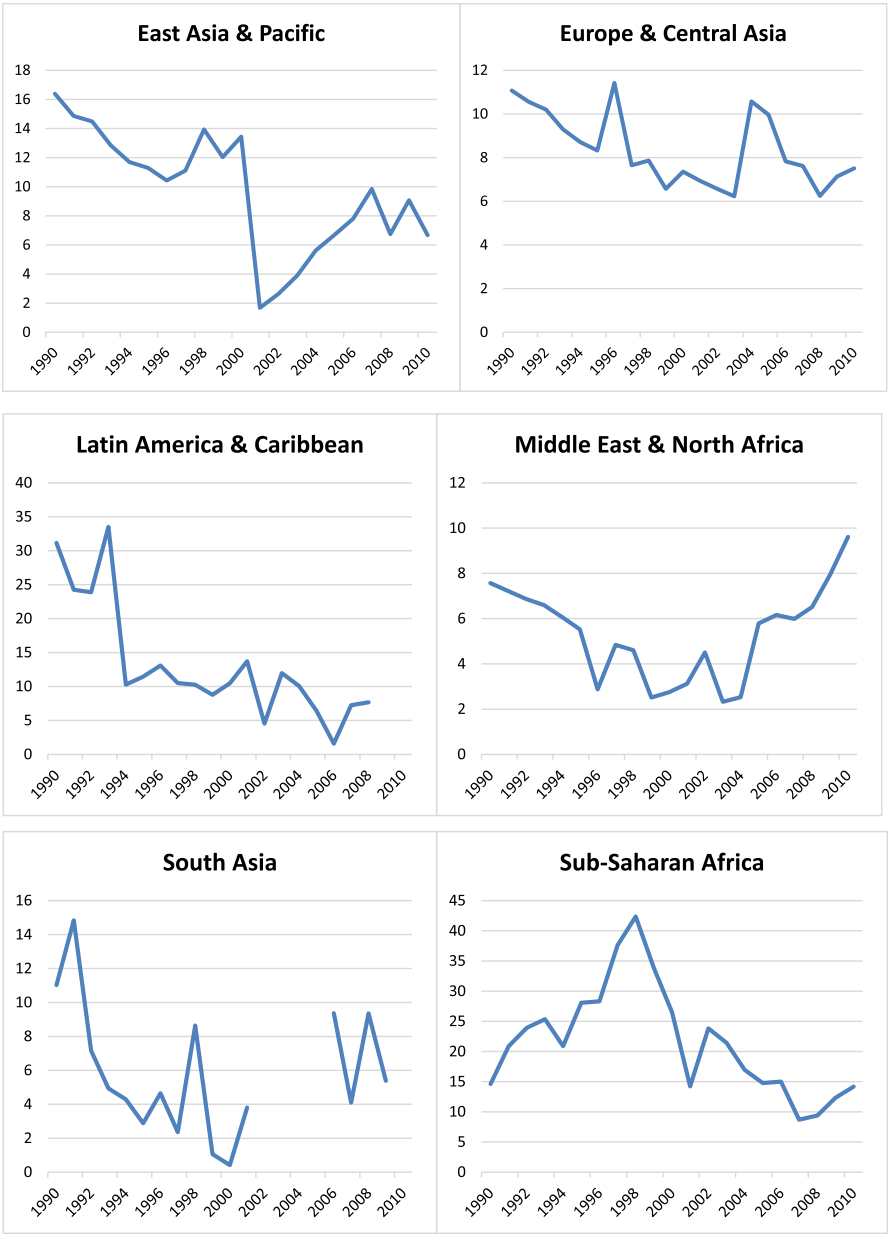

Fig. 1 (continued)

3 Labour Productivity and TFPG

As mentioned in Sect. 1, there has been a productivity decline (in terms of TFPG) across the globe since the advanced countries are not able to raise it steadily while

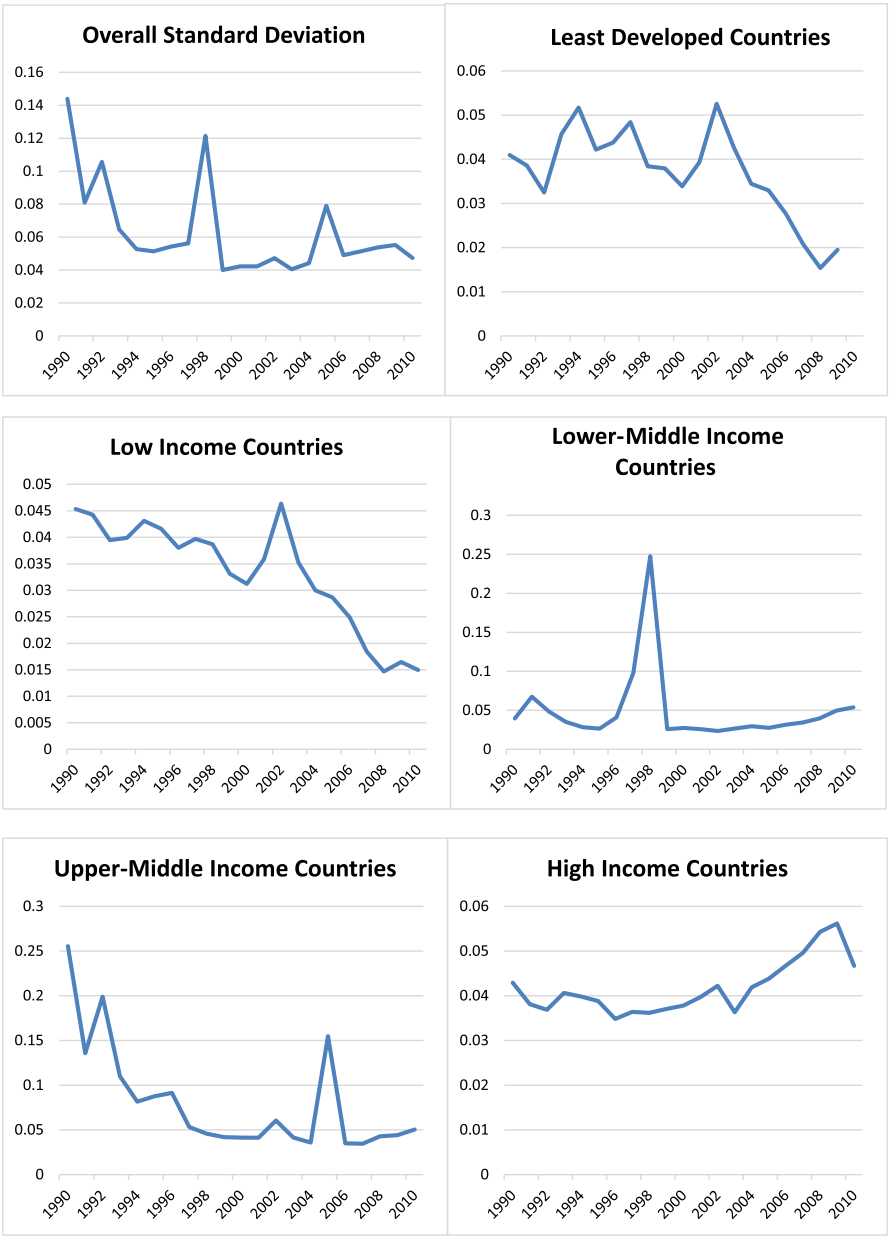

Fig. 2 Sigma Convergence: Technical Efficiency (Based on year-to-year TE) [Trend in Standard Deviation of TE]

many developing countries are not able to exploit the productivity advantages in a sustainable manner. In the backdrop of globalization, many of the developing countries are involved in maximizing the growth strategy without exploring the

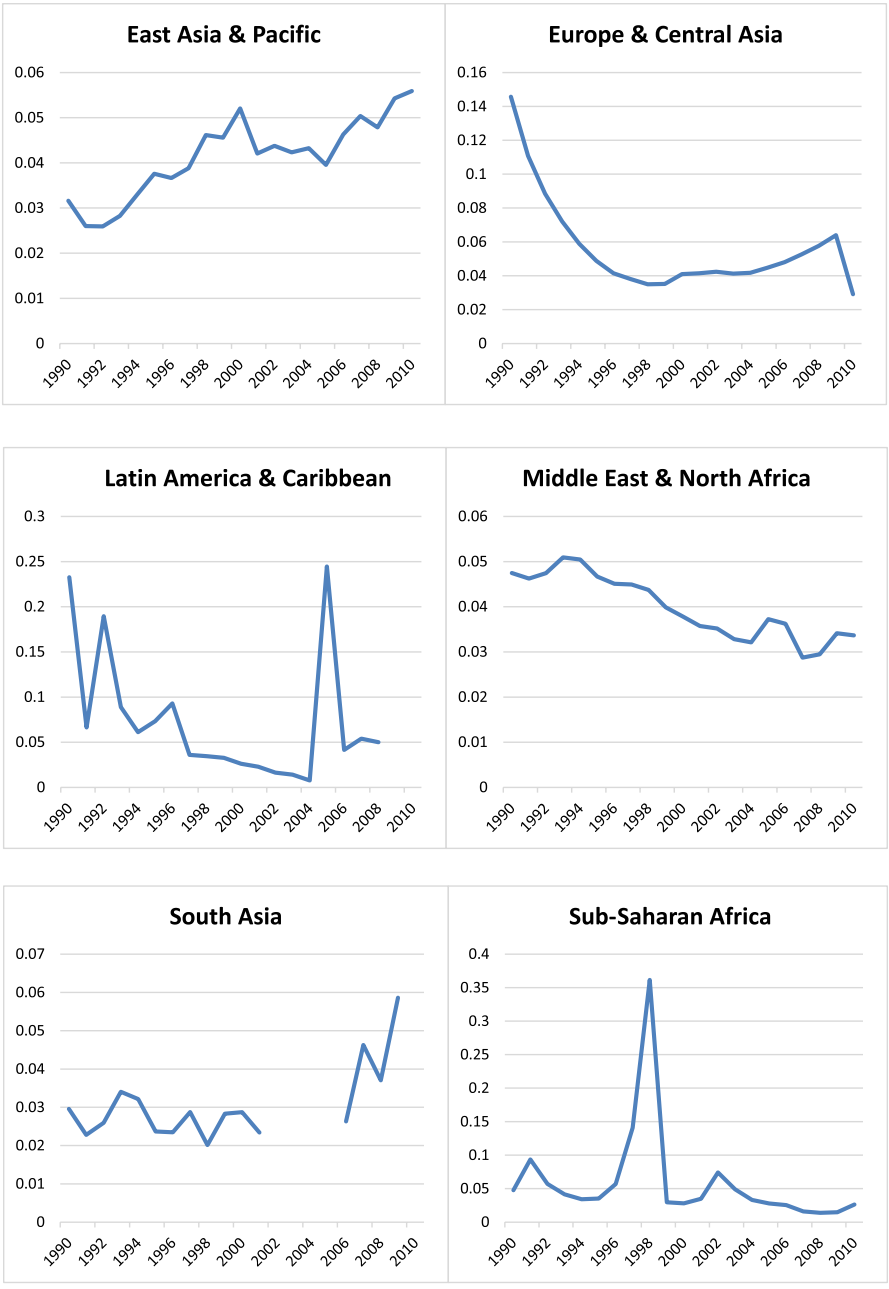

Fig. 2 (continued)

possibilities of raising the non-resource-driven component. Hence, the growth story and the TFPG trajectories may not match in many countries. Labour productivity growth which is in fact much more directly observable and can be closely related to the overall growth experience of the countries can then be assessed in relation to TFPG. In other words, whether the non-resource-driven growth component is translating itself to labour productivity growth or the latter is growing more independently using up the existing resource base? For example, on a priori basis, increased capital per worker may result in rapid labour productivity growth without any major dent on TFPG.

Based on the inter-temporal data for each of the countries, we observe from Table 2 that a number of countries registered either a negative or a positive though low, correlation between labour productivity growth and TFPG. Relatively fewer countries show a positive and medium/high correlation between the two variables. Evidently, countries are engaged in greater mechanization which may be raising the labour productivity without ushering in much success in terms of total factor productivity that tries to conserve all the resources and not one at the expense of the other.

Dividing the time period into two phases, Table 3 indicates that most of the countries which showed a negative or weakly positive correlation between labour productivity growth and TFPG in the nineties continued to remain so in the 2000s as well. Only a handful of countries graduated to unfold a better association between these variables. Only a few countries like Denmark, Malawi, Malta and Ethiopia moved from negative correlation to medium-/high-correlation category and France, Denmark and Sri Lanka improved from low-to-medium correlation category. So, on the whole, the countries' strategy to catch up in terms of growth does not seem to be based on resource-saving approach which is indeed a key to sustainable development.

The regression results[1] which in addition to TFPG include the number of patents as a determinant of labour productivity are suggestive of the fact that patents are insignificant in the LDCs and the low-income countries, while it is significant in lower middle income, upper middle income and high-income countries. Region-wise, the Latin American and Caribbean and South Asian countries again unravel a significant impact of patents on labour productivity (Table 4). TFPG, on the other hand, is a significant determinant in a number of groups of countries including the aggregate results (all countries combined). In terms of income, the least developed and low-income countries and region-wise East Asia and Pacific, Middle East and North Africa, North America and Sub-Saharan African countries show TFPG as an insignificant determinant of labour productivity growth. In other words, many of the countries in regions largely corresponding to the developing world are not engaged in resource-saving pursuits. The production processes in these countries adhere to resource intensive growth, which in future can pose serious challenges.

[1] Three sets of estimates—OLS, Fixed Effect (FE) and Random Effect (RE)—were generated, and based on the test statistic, the appropriate model has been retained.

Table 2 Inter-temporal Correlation between Labour Productivity and TFPG in Each of the Country

Correlation between Annual Growth of Labour Productivity & TFPG (Over the Period 1990–2010)			
Negative	Low	Medium	High
Albania	Austria	Azerbaijan	Australia
Armenia	Bahamas	Denmark	Barbados
Bangladesh	China, Hong Kong SAR	Eritrea	Belarus
Belgium	Ecuador	Estonia	Botswana
Bolivia (Plurinational State of)	Georgia	France	Bulgaria
Cameroon	Germany	Hungary	Chile
Central African Republic	Indonesia	Kenya	Czech Republic
China, Macao SAR	Ireland	Kuwait	Egypt
Colombia	Italy	New Zealand	Greece
Cyprus	Jordan	Panama	Nigeria
El Salvador	Latvia	Poland	Peru
Ethiopia	Luxembourg	Slovakia	Romania
Fiji	Madagascar	Slovenia	Thailand
Finland	Malawi	United Kingdom	The f. Yugosl. Rep. of Macedonia
Iceland	Malaysia	Uruguay	Trinidad and Tobago
India	Malta		
Iran (Islamic Republic of)	Netherlands		
Israel	Norway		
Japan	Oman		
Lithuania	Portugal		
Mauritius	Spain		
Mexico	Sri Lanka		
Mongolia	Sweden		
Morocco	Venezuela (Bolivarian Republic of)		

Table 2 (continued)

Correlation between Annual Growth of Labour Productivity & TFPG (Over the Period 1990–2010)			
Negative	Low	Medium	High
Niger			
Philippines			
Republic of Korea			
Republic of Moldova			
Singapore			
Swaziland			
Tunisia			
Turkey			
Ukraine			
United Republic of Tanzania			
United States of America			
Viet Nam			

Low is less than and equal to 0.3; medium is greater than 0.3 and up to 0.6, and high is greater than 0.6

Table 3 Correlation between Labour Productivity and TFPG in the 1990s and 2000s

Correlation between Annual Labour Productivity Growth & TFPG:				
1990s				
	Negative	Low	Medium	High
2000s				
Negative	Austria	Finland	Chile	Kuwait
	Belgium	Greece		Poland
	Cameroon	Israel	Fiji	
	China, Macao SAR	Italy	Japan	
	Hungary	Jordan	United Republic of Tanzania	
	Iran (Islamic Republic of)	Malaysia		
	Oman	Mexico		
	Slovakia	Morocco		
	Sweden	Republic of Korea		
	United States of America	Tunisia		
		Turkey		
Low	Estonia	Cyprus	China, Hong Kong SAR	Indonesia
	India	Ecuador	The f. Yugosl. Rep. of Macedonia	Slovenia
	Latvia	Ireland		
	New Zealand	Portugal		
	Norway	Spain		
	Singapore			
Medium	Denmark	France		Bulgaria
	Malawi	Netherlands	Luxembourg	Eritrea
	Malta	Sri Lanka	United Kingdom	Romania
High	Ethiopia		Panama	Egypt
			Trinidad and Tobago	

Low is less than and equal to 0.3; medium is greater than 0.3 and up to 0.6, and high is greater than 0.6

4 Technology and Employment

In the previous section, we noted that the contribution of TFPG to labour productivity growth is not substantial and much of the labour productivity growth has accrued due to capital accumulation. In this section, we turn to a more fundamental question: is the modern technology itself averse to employment creation? In other words, effect of technology on employment is an important concern. Whether technological growth tends to reduce employment or it can be conducive to employment growth is a pertinent issue. If technological development means lesser utilization of all the factors of production for the same level of output, then naturally, it tends to reduce employment per unit of output as well. But, if it reduces the utilization of some of the factors of production and not labour, then both technology and employment can go hand in hand. In support of this view, it may be argued that output growth is faster than the growth of some of the inputs such as capital but not labour because the

Table 4 Regression Results for Annual Labour Productivity Growth (Dependent Variable)

VARIABLES	(1) All Countries (RE)	(2) LDC	(3) Low Income	(4) Lower Middle Income (RE)	(5) Upper Middle Income (RE)	(6) High Income (RE)	(7) East Asia & Pacific	(8) Europe & Central Asia	(9) Latin America & Caribbean (RE)	(10) Middle East & North Africa	(11) North America	(12) South Asia (RE)	(13) Sub-Saharan Africa (RE)
TFPG	1.104***	− 1.051	− 1.051	0.166**	2.166***	0.769***	− 0.0568	1.889***	1.160***	0.167	− 1.505	0.258***	0.228
	(0.342)	(1.741)	(1.843)	(0.0654)	(0.339)	(0.220)	(0.358)	(0.453)	(0.434)	(1.046)	(9.687)	(0.0812)	(0.264)
Patents	2.20e–05	− 0.134	− 0.553	0.00218**	0.00166**	7.60e–06***	1.29e–05	0.000284	− 0.0544***	0.00126	1.49e–05	0.00183***	− 0.392
	(1.65e–05)	(0.193)	(0.339)	(0.000997)	(0.000742)	(2.73e–06)	(3.36e–05)	(0.00290)	(0.0193)	(0.00103)	(0.000207)	(0.000124)	(1.445)
Constant	− 4.676**	− 24.10	− 26.01	− 4.734	− 8.683**	0.183	− 1.614	− 1.823	− 3.228	− 4.417	1.375	− 6.748***	− 17.25
	(2.088)	(10.47)	(14.72)	(4.644)	(4.411)	(0.645)	(1.870)	(9.688)	(4.653)	(2.985)	(19.01)	(0.569)	(14.12)
Observations	854	25	23	149	162	520	149	460	81	85	14	37	28
R-squared		0.048	0.050				0.000	0.194		0.019	0.042		
Number of id	79	4	3	19	17	40	13	36	13	7		4	5

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

labour contracts may involve rigidity. Labour might have been hired on a long-term basis, which can be treated as a sunk cost (fixed or variable)—a retrospective cost that has already been incurred and cannot be recovered. Besides, the operation of the new technology is not necessarily automated which involves labour displacement.

A related point is also of great interest. Even if technology leads to lesser utilization of all the factors (including labour) for a given level of output, the rise in the quantum of production certainly contributes to employment generation, i.e. the scale effect. Modernization of technology may lead to its large-scale application in various sectors of the economy, and hence, the quantum of production and employment both may increase simultaneously even when the new technology gets more capital intensive. Though labour per unit of output may be declining in absolute terms, the increase in employment can still be substantial. These issues of employment increase at the aggregate level due to wider application of the advanced technology prompted by the profit motive and are certainly of great relevance, particularly in the context of the developing economies confronted with the compulsion of maximizing growth and generating employment opportunities for the vast supplies of labour.

Nevertheless from another angle, there can be a negative effect of technology on employment. Since technological innovations largely take place in developed countries, they are made to suit these economies and their factor endowments. Incidentally, these countries are primarily labour scarce, and thus, the new technology tends to become increasingly labour saving (Pack & Todaro 1969). In other words, the developed countries are faced with a severe shortage of labour ready to pursue mechanical jobs, and thus, the innovations relating to technical progress are usually pursued with an objective of reduction in labour requirement in the production process. So technical progress and rising capital intensity proceed synonymously, which do not conflict with the labour market situation in the developed countries.[2] However, with import liberalization if the developing countries import this sort of technology at a cheaper cost, it restricts their employment growth particularly in the high productivity formal sector. Thus, the labour-saving technical change is a definite disadvantage to developing economies (Kelley et al. 1972) though UNIDO (2005) argues that it is still cheaper for a latecomer to buy the technology already invented by others than to re-invent the wheel. Similar is the case with innovation which is believed to be highly capital intensive.

So one hypothesis in this section is that the import of technology and innovation both being capital intensive may reduce employment. Alternately, technological progress and employment both can be positively associated due to the scale effects prompted by the reductions in technology price. This may lead to a greater accessibility and adoption of the technology and also processing of by-products which may not result in proportionate increase in capital but require greater magnitude of labour in absolute sense.

In order to test this, hypothesis log of employment is taken to be a function of log of value added and log of wage rate and the number of patents. The performance

[2] Different mechanisms of technological change and effects on jobs emerge in the work of Bogliacino and Pianta (2010).

indicator (TFPG/TE) is included to test if productivity growth or better utilization of resources results in higher output growth relative to input growth including labour or alternately and does not affect employment though reduces the use of other inputs.

Based on panel data across countries, it is observed that the elasticity of employment with respect to value added is positive across regions and various income groups though there are considerable variations in the magnitude (Table 5). The same is true in relation to wage elasticity of employment.

TFPG is an omnibus measure of technological change. It incorporates productivity growth arising from all kinds of technological change (could involve modern technologies such as robotics, artificial intelligence, or earlier generations of technologies). The concern about employment has been with reference to modern technologies. Our results show that the impact of performance indicator (TFPG) is negligible (statistically insignificant) in most of the cases except in the low and lower middle income countries and region-wise, North America. It is important to note that none of the groups, income or regions, recorded a (statistically significant) negative effect of TFPG on employment, except the LDC, while the significant cases (howsoever scanty) reveal a positive association.[3] However, the effect of patents, wherever statistically significant, is seen to reduce employment when countries are divided as per income. On the other hand, different regions decipher differential impact: East Asia & Pacific, North America and South Asia are indicative of a negative effect, while Europe & Central Asia, Latin America & Caribbean and Middle East & North Africa show a positive impact of patents on employment.

5 Conclusion

This paper based on UNIDO panel data makes an attempt to estimate TFPG across countries and over time. Though inter-temporal comparison was not possible for a number of countries, among the ones for which a comparison could be made, many belonged to the developed world and experienced a rise in TFPG in the 2000s, while they had recorded either a negative or a low TFPG in the 1990s. However, in the case of the developing countries, such improvements were rather limited.

Productivity convergence is not evident among some of the groups of countries. For example, among the least developed countries, the long-term pace of decline in the variation is mild though the humps of the early nineties and late nineties and early 2000s were not repeated thereafter. Similarly in the case of low-income countries, again the cross-country variation in TFPG seems to have become less volatile in the 2000s though the extent of long-term decline in the sigma (standard deviation) is mild. On the other hand, among the lower middle income, upper middle income and high income countries, the drop in the sigma magnitude is prominent. Looking at the sigma value after dividing the countries across regions, East Asia and Pacific, Europe and Central Asian and Latin America and Caribbean countries seem to have registered a steady fall, indicating convergence in the productivity growth

[3] As we replace TFPG by TE (Table 6) the effect of performance index remains mixed: lower middle income and high income countries show a positive and negative effect respectively.

Table 5 TFPG and Employment-Dependent Variable: Log of Number of Employees

Variables	(1) All Countries	(2) LDC	(3) Low Income (RE)	(4) Lower Middle Income	(5) Upper Middle Income	(6) High Income	(7) East Asia & Pacific	(8) Europe & Central Asia	(9) Latin America & Caribbean	(10) Middle East & North Africa	(11) North America (OLS)	(12) South Asia	(13) Sub-Saharan Africa
Log (value added)	0.690***	0.483***	0.528***	0.651***	0.335***	0.819***	0.823***	0.733***	0.388**	0.611***	0.571***	0.818***	0.505***
	(0.101)	(0.0447)	(0.0177)	(0.0894)	(0.113)	(0.0910)	(0.0973)	(0.167)	(0.151)	(0.113)	(0.108)	(0.107)	(0.0886)
Log (wage rate)	− 0.698***	− 0.653***	− 0.702***	− 0.629***	− 0.348**	− 0.789***	− 0.855***	− 0.765***	− 0.344*	− 0.583***	− 2.191***	− 0.583**	− 0.649***
	(0.103)	(0.0385)	(0.0179)	(0.0885)	(0.128)	(0.0827)	(0.108)	(0.176)	(0.172)	(0.0841)	(0.175)	(0.129)	(0.0658)
Patents	− 1.51e–06***	− 0.00185	− 0.00851	− 4.89e-05***	2.79e− 05	− 1.63e–06***	− 1.30e–06***	2.24e–05**	0.000530**	4.33e–06*	− 1.56e–06**	− 7.43e–05**	− 0.00376
	(2.72e–07)	(0.00182)	(0.0128)	(1.40e–05)	(1.96e–05)	(2.09e–07)	(1.41e–07)	(9.50e–06)	(0.000218)	(2.00e–06)	(6.94e–07)	(1.70e–05)	(0.00918)
TFPG	0.000326	− 0.00210	− 0.00627***	0.00321**	− 0.00141	− 0.00303	− 0.000516	− 0.00323	0.000728	− 0.0105	0.0653*	0.00511	0.00249
	(0.000954)	(0.00207)	(0.000812)	(0.00113)	(0.00214)	(0.00237)	(0.00280)	(0.00245)	(0.00190)	(0.00718)	(0.0359)	(0.00483)	(0.00134)
Constant	3.463**	6.852***	6.036***	3.585**	8.490***	1.422	1.793	3.127	6.289***	3.973*	23.90***	− 0.325	6.241**
	(1.507)	(0.669)	(0.219)	(1.346)	(1.690)	(1.481)	(1.403)	(2.334)	(1.948)	(1.826)	(3.239)	(1.898)	(1.377)
Observations	920	28	23	172	185	540	164	478	96	91	17	46	28
R-squared	0.700	0.924		0.766	0.331	0.867	0.789	0.740	0.500	0.855	0.975	0.876	0.896
Number of id	78	4	3	19	17	39	12	36	13	7		4	5

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

FE/RE model is selected on the basis of LM and Hausman statistic. It may be noted that while TFPG is a flow variable others are not so

Table 6 TE and Employment-Dependent Variable Log of Number of Employees

VARIABLES	(1) All Countries	(2) LDC	(3) Low Income (RE)	(4) Lower Middle Income	(5) Upper Middle Income	(6) High Income	(7) East Asia & Pacific	(8) Europe & Central Asia	(9) Latin America & Caribbean	(10) Middle East & North Africa	(11) North America (OLS)	(12) South Asia	(13) Sub-Saharan Africa
Log (value added)	0.696***	0.527***	0.584***	0.679***	0.363***	0.818***	0.763***	0.740***	0.410**	0.544***	0.588***	0.787**	0.521***
	(0.0995)	(0.0521)	(0.0976)	(0.0995)	(0.105)	(0.0837)	(0.112)	(0.151)	(0.166)	(0.0543)	(0.0791)	(0.153)	(0.0622)
Log (wage rate)	− 0.682***	− 0.653***	− 0.726***	− 0.667***	− 0.345**	− 0.698***	− 0.764***	− 0.674***	− 0.345*	− 0.581***	− 1.767***	− 0.622**	− 0.676***
	(0.0967)	(0.0233)	(0.0465)	(0.1000)	(0.124)	(0.0720)	(0.132)	(0.163)	(0.171)	(0.0477)	(0.294)	(0.177)	(0.0425)
Patents	− 1.34e–06***	− 0.00114	− 0.00705	− 5.41e–05***	2.93e–05	− 9.37e–07***	− 5.77e–07	1.87e–05**	0.000556**	7.26e–06**	1.57e–07	− 7.45e–05*	− 0.00568
	(2.64e–07)	(0.00236)	(0.00979)	(1.60e–05)	(1.99e–05)	(2.31e–07)	(6.08e–07)	(7.55e–06)	(0.000235)	(1.97e–06)	(6.53e–07)	(2.44e–05)	(0.0116)
Technical Efficiency	− 0.520	− 3.291	− 1.974	0.145**	− 0.575	− 2.070***	− 2.697	− 1.794***	− 0.273	2.837	− 1.499	0.391	0.293
	(0.390)	(4.835)	(1.947)	(0.0639)	(0.517)	(0.511)	(2.239)	(0.437)	(0.274)	(1.578)	(1.729)	(0.618)	(0.166)
Constant	3.202**	6.081***	5.188***	3.253**	7.856***	0.715	2.569	2.226	5.806**	5.282***	19.01***	0.718	6.103***
	(1.508)	(0.867)	(1.603)	(1.466)	(1.521)	(1.438)	(1.624)	(2.081)	(2.286)	(0.934)	(2.860)	(2.658)	(1.009)
Observations	920	28	23	172	185	540	164	478	96	91	17	46	28
R-squared	0.706	0.927		0.746	0.340	0.881	0.805	0.755	0.502	0.851	0.972	0.863	0.899
Number of id	78	4	3	19	17	39	12	36	13	7		4	5

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

experience of the countries in these regions. This could be attributed to a greater degree of association of countries in a given region pursuing jointly infrastructural ventures, ICT coverage and advancement, trade negotiations, technology acquisition and innovation, and inflow of FDI.

In terms of efficiency estimates for select years, most of the countries are seen to be operating much below the frontier. This is indicative of the fact that countries are keen to pursue resource-driven growth in an attempt to maximize the growth strategy in the wake of globalization. Without being concerned to use the resources optimally or to exploit the existing capacity to the maximum possible extent, countries are in a mad rush to raise the growth magnitude which would indeed show up in the future years, resulting in its non-sustainability.

Based on the inter-temporal data for each of the countries, we observed that a number of countries registered either a negative or a positive but low correlation between labour productivity growth and TFPG. Relatively fewer countries show a positive and medium/high correlation between the two variables, be it developing or developed. Evidently, countries are engaged in greater mechanization which may be raising the labour productivity without ushering in much success in terms of overall productivity (TFP). Even with real technological change, there may not be a rise in TFPG, particularly if tangible capital cost is excessive. From panel data, it is observed that the elasticity of employment with respect to value added is positive across regions as well as various income groups though there are considerable variations in the magnitude. The same is true in relation to wage elasticity of employment. However, the impact of technology perceived in terms of performance indicator (TFPG) is negligible (statistically insignificant) in most of the cases, though it is important to note that TFPG does not necessarily tell us about the kind of technological change. But it is important to note that none of the groups, income or region, recorded a (statistically significant) negative effect of TFPG on employment, except the LDCs, while the significant cases (howsoever scanty) reveal a positive association. On the whole, TFPG has been weak, while capital deepening has been significant. Considering TFPG as a very broad proxy of technological change, we may infer that modern technology is not necessarily employment saving in absolute sense at least. The scale effect and the scope to process by-products resulting in the expansion of activities of firms may contribute to employment creation. Hence, appropriate incentives may motivate firms to experience both technological progress and employment growth.

Appendix

Country	Year	TE	TFPG	Country	Year	TE	TFPG
Albania	2000	0.01	5.36	China, Hong Kong SAR	1995	0.11	5.05
Albania	2005	0.02	9.53	China, Hong Kong SAR	2000	0.14	3.04
Albania	2010	0.04	13.70	China, Hong Kong SAR	2005	0.16	1.03
Armenia	2005	0.06	− 38.21	China, Hong Kong SAR	2010	0.17	− 0.98

Country	Year	TE	TFPG	Country	Year	TE	TFPG
Australia	1990	0.12	− 11.84	China, Macao SAR	1990	0.09	3.07
Australia	2005	0.10	7.29	China, Macao SAR	1995	0.11	2.03
Austria	1990	0.08	1.34	China, Macao SAR	2000	0.13	0.98
Austria	1995	0.09	1.49	China, Macao SAR	2005	0.14	− 0.06
Austria	2000	0.10	1.64	China, Macao SAR	2010	0.14	− 1.11
Austria	2005	0.12	1.79	Colombia	1990	0.10	27.35
Azerbaijan	2005	0.05	5.98	Colombia	1995	0.30	16.69
Azerbaijan	2010	0.06	− 6.16	Colombia	2005	0.60	− 4.64
Bahamas	1990	0.06	30.63	Cyprus	1990	0.09	2.60
Bahamas	1995	0.11	− 7.88	Cyprus	1995	0.10	0.77
Bangladesh	1990	0.04	17.97	Cyprus	2000	0.10	− 1.06
Bangladesh	1995	0.07	− 1.68	Cyprus	2005	0.10	− 2.89
Barbados	1990	0.05	51.92	Cyprus	2010	0.08	− 4.72
Barbados	1995	0.11	− 19.89	Czech Republic	1995	0.04	− 1.88
Belarus	2005	0.01	0.50	Czech Republic	2005	0.06	8.71
Belgium	1990	0.06	4.47	Denmark	1990	0.12	− 7.21
Belgium	2000	0.10	3.25	Denmark	1995	0.10	− 3.34
Belgium	2005	0.12	2.64	Denmark	2000	0.09	0.52
Bolivia	1990	0.11	− 0.15	Denmark	2005	0.11	4.39
Bolivia	1995	0.09	− 10.84	Ecuador	1990	0.03	9.66
Brazil	1990	0.90	36.48	Ecuador	1995	0.05	8.21
Bulgaria	2000	0.02	− 7.53	Ecuador	2000	0.07	6.75
Bulgaria	2005	0.03	14.94	Ecuador	2005	0.11	5.30
Cameroon	1990	0.04	7.13	Egypt	1990	0.06	− 16.90
Cameroon	1995	0.05	− 1.32	Egypt	1995	0.03	− 14.49
Cameroon	2000	0.04	− 9.76	Egypt	2005	0.01	− 9.68
Central African Republic	1990	0.07	− 10.90	El Salvador	1995	0.07	− 7.10
Chile	1990	0.12	− 0.67	Eritrea	1995	0.06	− 20.31
Chile	2005	0.17	2.57	Eritrea	2000	0.03	− 6.47
China, Hong Kong SAR	1990	0.08	7.06	Eritrea	2005	0.03	7.37

Country	Year	TE	TFPG	Country	Year	TE	TFPG
Eritrea	2010	0.07	21.21	Indonesia	1990	0.12	− 42.94
Estonia	1995	0.04	− 3.46	Indonesia	1995	0.02	− 22.75
Estonia	2005	0.05	8.03	Indonesia	2000	0.01	− 2.57
Ethiopia	1990	0.11	− 1.96	Indonesia	2005	0.02	17.62
Ethiopia	1995	0.11	− 2.79	Iran (Islamic Republic of)	1990	0.16	− 3.00
Ethiopia	2000	0.10	− 3.63	Iran (Islamic Republic of)	1995	0.14	− 3.37
Ethiopia	2005	0.08	− 4.47	Iran (Islamic Republic of)	2000	0.13	− 3.74
Fiji	1990	0.04	19.72	Iran (Islamic Republic of)	2005	0.11	− 4.11
Fiji	2000	0.13	− 0.11	Ireland	1990	0.16	− 5.92
Fiji	2005	0.11	− 10.03	Ireland	1995	0.14	− 1.53

Country	Year	TE	TFPG	Country	Year	TE	TFPG
Finland	1990	0.08	0.47	Ireland	2000	0.15	2.85
Finland	1995	0.09	1.29	Ireland	2005	0.20	7.24
Finland	2000	0.10	2.11	Israel	1995	0.07	2.49
Finland	2005	0.12	2.93	Israel	2000	0.08	1.96
France	1990	0.08	0.49	Italy	1990	0.09	− 2.44
France	2005	0.11	0.67	Italy	1995	0.08	− 1.10
Georgia	2000	0.00	21.88	Italy	2000	0.08	0.23
Georgia	2005	0.01	12.84	Italy	2005	0.09	1.56
Georgia	2010	0.01	3.80	Japan	1990	0.10	3.13
Germany	1990	0.11	− 4.38	Japan	1995	0.12	1.87
Germany	2000	0.10	0.14	Japan	2000	0.13	0.62
Germany	2005	0.11	2.39	Japan	2005	0.14	− 0.64
Greece	1990	0.10	− 4.36	Japan	2010	0.14	− 1.90
Greece	1995	0.09	− 2.03	Jordan	1990	0.13	− 9.68
Greece	2005	0.10	2.64	Jordan	1995	0.09	− 5.74
Hungary	1995	0.05	− 7.15	Jordan	2000	0.08	− 1.81
Hungary	2000	0.04	− 0.44	Jordan	2005	0.08	2.13
Hungary	2005	0.05	6.28	Jordan	2010	0.11	6.06
Iceland	2000	0.14	4.98	Kenya	1995	0.10	49.77
Iceland	2005	0.08	− 28.78	Kuwait	1995	0.15	− 1.30
India	1990	0.02	4.10	Kuwait	2000	0.13	− 5.94
India	1995	0.03	3.14	Kuwait	2005	0.09	− 10.59
India	2000	0.03	2.18	Kuwait	2010	0.05	− 15.23
India	2005	0.04	1.22	Latvia	1995	0.05	− 9.78
Latvia	2005	0.03	0.60	Morocco	2010	0.05	− 2.72
Latvia	2010	0.04	5.80	Nepal	1990	0.02	− 5.06
Lithuania	2000	0.04	− 3.83	Netherlands	1990	0.08	1.97
Lithuania	2005	0.04	5.65	Netherlands	1995	0.09	2.23
Lithuania	2010	0.07	15.13	Netherlands	2000	0.11	2.48
Luxembourg	1995	0.08	6.54	Netherlands	2005	0.13	2.74
Luxembourg	2005	0.11	− 0.31	New Zealand	1995	0.11	− 4.66
Madagascar	2005	0.00	− 17.36	New Zealand	2000	0.10	0.14
Malawi	1990	0.08	− 22.80	New Zealand	2005	0.12	4.94
Malawi	1995	0.03	− 11.18	Niger	2000	0.05	53.76
Malawi	2000	0.03	0.44	Nigeria	1995	0.10	− 7.54
Malawi	2005	0.04	12.05	Norway	1990	0.11	− 0.76
Malaysia	1990	0.03	7.43	Norway	1995	0.11	− 0.14
Malaysia	1995	0.04	5.92	Norway	2000	0.12	0.48
Malaysia	2000	0.06	4.40	Norway	2005	0.13	1.10
Malaysia	2005	0.08	2.89	Oman	1995	0.02	0.59

Country	Year	TE	TFPG	Country	Year	TE	TFPG
Malaysia	2010	0.09	1.38	Oman	2000	0.02	1.75
Malta	1990	0.10	− 6.79	Oman	2005	0.02	2.90
Malta	1995	0.08	− 3.56	Oman	2010	0.02	4.06
Malta	2000	0.07	− 0.33	Panama	1990	0.13	− 32.81
Malta	2005	0.08	2.89	Panama	2000	0.07	19.52
Mauritius	2005	0.06	− 22.12	Peru	1990	0.41	− 57.80
Mauritius	2010	0.10	38.64	Peru	1995	0.12	7.05
Mexico	1990	0.17	− 13.41	Philippines	1990	0.07	− 1.27
Mexico	1995	0.11	− 7.01	Philippines	1995	0.07	− 0.92
Mexico	2000	0.09	− 0.60	Philippines	2005	0.07	− 0.22
Mexico	2010	0.18	12.21	Poland	1990	0.09	− 9.93
Mongolia	1990	0.04	− 12.36	Poland	1995	0.06	− 5.64
Mongolia	1995	0.02	− 25.67	Poland	2000	0.05	− 1.35
Mongolia	2000	0.00	− 38.97	Poland	2005	0.06	2.94
Morocco	1990	0.04	3.44	Portugal	1990	0.06	− 2.89
Morocco	1995	0.05	1.90	Portugal	2000	0.06	0.30
Morocco	2000	0.05	0.36	Portugal	2005	0.06	1.89
Morocco	2005	0.06	− 1.18	Republic of Korea	1990	0.05	5.98
Republic of Korea	1995	0.06	4.00	Spain	1990	0.12	− 3.97
Republic of Korea	2000	0.08	2.03	Spain	1995	0.10	− 3.00
Republic of Korea	2005	0.09	0.05	Spain	2000	0.10	− 2.04
Republic of Moldova	2000	0.02	− 7.85	Spain	2005	0.09	− 1.07
Republic of Moldova	2005	0.01	− 3.35	Sri Lanka	1990	0.08	− 5.62
Republic of Moldova	2010	0.01	1.14	Sri Lanka	1995	0.07	− 2.02
Romania	1990	0.35	− 38.58	Sri Lanka	2000	0.07	1.59
Romania	1995	0.07	− 27.67	Sri Lanka	2010	0.13	8.80
Romania	2000	0.02	− 16.77	Swaziland	1990	0.13	15.96
Romania	2005	0.01	− 5.87	Swaziland	1995	0.06	− 49.44
Singapore	1990	0.08	− 5.12	Sweden	1995	0.08	0.53
Singapore	1995	0.07	− 2.39	Sweden	2000	0.09	2.27
Singapore	2000	0.07	0.34	Sweden	2005	0.11	4.01
Singapore	2005	0.08	3.07	Thailand	1990	0.04	15.80
Singapore	2010	0.10	5.80	The f. Yugosl. Rep. of Macedonia	1990	0.50	− 32.73
Slovakia	1995	0.03	− 4.05	The f. Yugosl. Rep. of Macedonia	1995	0.13	− 21.18
Slovakia	2000	0.03	0.76	The f. Yugosl. Rep. of Macedonia	2000	0.07	− 9.63
Slovakia	2005	0.03	5.58	The f. Yugosl. Rep. of Macedonia	2005	0.06	1.91
Slovenia	1995	0.15	− 20.48	The f. Yugosl. Rep. of Macedonia	2010	0.09	13.46
Slovenia	2000	0.07	− 10.22	Trinidad and Tobago	1990	0.09	− 19.65
Slovenia	2005	0.06	0.04	Trinidad and Tobago	1995	0.05	− 6.22
Slovenia	2010	0.08	10.30	Trinidad and Tobago	2000	0.05	7.21

Country	Year	TE	TFPG
Tunisia	1995	0.06	3.30
Tunisia	2000	0.06	– 2.56
Turkey	1990	0.56	– 15.91
Turkey	1995	0.26	– 16.57
Turkey	2000	0.12	– 17.23
Turkey	2005	0.05	– 17.89
United Kingdom	1990	0.13	– 6.39
United Kingdom	1995	0.11	– 2.54
United Kingdom	2000	0.11	1.30
United Kingdom	2005	0.13	5.15
United Republic of Tanzania	1990	0.00	11.03
United Republic of Tanzania	1995	0.01	10.91
United Republic of Tanzania	2005	0.03	10.67
United Republic of Tanzania	2010	0.05	10.55
United States of America	1990	0.16	– 0.40
United States of America	1995	0.17	0.60
United States of America	2000	0.19	1.61
United States of America	2005	0.22	2.61
Uruguay	1990	0.27	– 8.96
Uruguay	1995	0.18	– 8.84
Uruguay	2000	0.12	– 8.73
Uruguay	2005	0.08	– 8.61
Venezuela (Bolivarian Republic of)	1990	0.18	– 27.81
Venezuela (Bolivarian Republic of)	1995	0.06	– 20.28
Viet Nam	2000	0.01	– 22.24
Viet Nam	2010	0.01	15.47

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