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Technology Development Policies in Brazil, China, India, Russia and South Africa

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Abstract: Solow's work showed that productivity increases are more important than increases in capital intensity to achieve a higher per capita income. Whereas in the early stages of development productivity gains arise mainly from shift in labour from low productivity activities to higher productivity activities, at a still later stage countries need to develop their own technologies. The paper points to the vagueness of the concept of technical change which then raises measurement issues. The vagueness of the concept also leads countries to adopt a variety of policies that they think will foster productivity growth. A major feature of changes in policies in theBRICS countries is to strengthen the linkages between research bodies, whether universities or specialised sector institutions, and industry so that the research is more likely to be useful to industry and picked up by it.

A number of attempts have been made to devise innovation indices. They all suggest that China and India lag behind the other three. But when actual productivity growth is measured China and India usually fare better than the others which raises doubts about the appropriateness of these indices. Part of the problem maybe that these indices use both input and output indicators and combine them into one composite index. The effectiveness of the inputs might already be incorporated in the output measures and then there is little effect on productivity growth.

Keywords: Development Policy, Technology, BRICS, Education.

Section I

Solow (1957) demonstrated the importance of productivity growth in generating increases in per capita income; almost 80 per cent of the increase in income in GDP in the US was because of productivity increase.

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This was in sharp contrast to the work in development economics at that time that had stressed investment and growth of capital. For instance, Lewis stressed that the task of development policy was to raise the savings rate from 5 per cent of national income to 10 per cent. Similarly, Rostow had stressed the need to raise investment rates. Rosenstein-Rodan and Nurkse had emphasised the difficulty of raising the investment rate, Rosenstein-Rodan because of the lumpiness of capital investment and Nurkse because of the lack of adequate demand by income earners from a single project.

Countries in their development policies concentrated on increasing savings rates and were successful in doing this. By the mid-1960s most developing countries had been able to raise their savings rates to about 20 per cent. Growth rates did increase. But the economies experienced considerable fluctuations caused by either inflation or current account deficits or the interaction between these two. There was, however, a more basic structural problem in their growth story. The growth was based on factor accumulation and transfer of workers from low productivity activities to higher productivity ones. The question was how long this process could continue and what would happen once growth because of factor accumulation came to an end.[1] While countries had been developing policies for improving technologies, these were initially concentrated on how to successfully integrate technologies they had purchased from the more advanced countries, i.e. on technology transfer. Now they came to stress upon the generation of new technologies. In these endeavours they adopted national science and technology policies very often following the example of the US which was seen to have been very successful in generating new technologies through collaboration between universities and research laboratories and industry. For instance, after the Second World War, Germany and Japan adopted a national innovation policy framework (Sylvia Ostry and Richard R Nelson, 1995). Currently, many developing countries, including BRICS, are following this path. But difficulties are faced because of the vagueness of the concept of technical progress.

An important issue in devising policies is that the concept of technical progress is vague as in the original paper of Solow productivity growth was a residual after the effect of factor accumulation had been taken account of. It was more a measure of our ignorance. The vagueness of the concept vitiates its measurement sometimes in terms of inputs, e.g. R&D expenditures, number of scientists etc., or in terms of outputs, e.g. patents, scientific papers, etc. Furthermore, governments keen to boost productivity and growth adopt a variety of policies in an attempt to influence innovation.

In this paper we analyse the policies adopted by the BRICS countries to foster technical change. First in Section II we examine some of the conceptual issues that arise in the measurement of technical change and how the nature of productivity growth varies among developing countries depending on their level of development.

Section II Conceptual and measurement issues in calculating rate of technical progress

While Solow demonstrated formally the importance of technical change in explaining growth, Schumpeter had earlier stressed the role of innovation, which formed the basis of change within his system. Schumpeter defined 'innovation' in the sense of encompassing both product and process innovation, as well as the discovery of new markets and raw materials, and a transformation in organizational structure.[2]In Solow's work as in Schumpeter technical change is exogenous. With regard to Schumpeter's perception of innovation as a sudden, exogenous phenomenon, Piore (2007), in his work based on three specific sectors of industry, namely cellular phones, medical devices and branded denim jeans, asserts that new innovations find a market for themselves not by acting as a destabilizing force in otherwise stagnant conditions, but by creating a niche demand for the product through a subtler process involving several feedback mechanisms. In many modern treatments innovations are produced by a sector using various factors of production.[3] Another way of conceptualising technical change is to view it as learning by doing (Arrow 1962, Sheshinski,1967).

But economists have recognised that important new innovations such as the introduction of electric power required significant changes in work procedures and even office and factory layouts before their full benefits could be reaped (Abramovitz and David, 1973). Assuming neutral technical progress to calculate total factor productivity (TFP) growth calculations can lead to surprising results. For instance, Abramovitz and David (1973,) find very little TFP growth in the late nineteenth century despite the large number of world-class innovations of the period. They attribute this phenomenon to biased technical change.

Furthermore, the calculation of productivity growth as a residual implies that productivity growth depends on the specification of the production function. For example, if one assumes vintage capital rather than homogeneous capital the contribution of the capital factor in US growth increases from about 12 per cent to 19 per cent and that of productivity growth declines (Solow, 1959).[4] In Taiwan the contribution of productivity growth to income growth seems to be about 43 per cent if homogeneous capital is assumed and 31 per cent if vintage capital is assumed, (Singh and Trieu, 1999). In South Korea, estimates of the contribution of productivity growth to income growth range from about 25 per cent (Dahlman and Andersson, 2000) to as high as 54.4 per cent (Kim and Han, 2001, referring to the period between 1980 and 1994). It also matters whether intermediate goods are included or not. For instance, changes in the price of oil can significantly influence the measurement of productivity growth when there are significant changes in the price of oil (Moro, 2007, Bruno and Sachs, 1985).

In China, productivity growth's contribution to income growth traditionally has been very low, but since 1993 it has accounted for about 28 per cent (Ozyurt, 2007). In India, productivity growth's contribution was about 20 per cent in the period between 1950 and 1979 but increased to about 40 per cent in the period between 1980 and 2003 (Virmani, 2004). The main driver of productivity growth in low income countries is shift of workers from being unemployed, underemployed or in low productivity lobs to higher productivity jobs. It is mainly when industry becomes important that the capacity to absorb new technologies becomes important.[5] Countries seem to be able to reach middle income levels without very high technological capabilities. It is in the shift from upper-middle income class, as defined by the World Bank, to high income category that requires a jump in technological capabilities. A major feature of this divide is that the majority of patent applicants in upper middle-income countries are usually foreigners, whereas in high income countries they are nationals (Patarapong, 2018).

Part of the problem of assessing the importance of productivity growth is that, despite the belief that innovations play a major role in generating productivity growth, it is difficult to define an "innovation". The image most people likely have is of some new scientific discovery or the production of a new product — indeed, most analyses of the spread of innovations conceive of them along these lines. But innovation can also be changes in management practices, an area that so far seems to have escaped analysis.[6] Further, innovations have both a technical aspect and an economic aspect: the technical difficulty of an innovation might be greater than the value of its technical potential or economic benefit, and no innovation will be produced unless there is adequate demand for it. Another difficulty with assessing the importance of productivity growth is that it is not always possible to correlate it tightly with innovation: as Solow (1987) remarked, "I see computers everywhere but in the productivity statistics." Indeed, experience with earlier so-called general purpose technologies such as electricity shows that the benefits are considerably lagged.[7]

One can look at innovations from the point of view of either outputs or inputs. From the output side, we are interested in new combinations of existing knowledge to produce new products and devices for use in production. Very often in analysis, innovations are measured by patents, associated royalties and licence fees and so on, but many innovations are not patented. Furthermore, all patents are not equal. Even more important, although patents might describe innovative activity in the developed countries, they do not describe the process of productivity growth in developing countries, which is based more on learning to operate technologies already used in the developed countries.

From the input side, the usual practice is to look at either expenditures on research and development (R&D) or the number of people engaged in research or the number of skilled workers.[8] But much of what is described as R&D expenditures in company reports and accounts is actually adjustments to make the product more suitable for the market and is driven more by tax rules. In addition, such expenditures are relevant only for large research establishments, not for individual innovators, despite their considerable importance.[9] Also, it is difficult to differentiate people who are actively engaged in research from other skilled workers or innovative activity from basic research. There is also the question of how to account for the employment hours of non-technical people who provide necessary services to the technical people. In short, the connection between R&D expenditures or the number of people engaged in research, on the one hand, and innovation, on the other, is quite loose.

There are also considerable analytical difficulties with the concept of "technology transfer." The literature distinguishes between the explicit transfer of technology — such as the physical transfer of templates and design plans for new processes — and the implicit transfer of technology and know-how embodied in workers as they acquire knowledge and technique (particularly in enterprises that receive foreign direct investment, FDI) and eventually relocate to domestic firms. The vagueness of these terms creates difficulties in defining what the policy challenges are, as we discuss below.

In fact, we argue that innovation and technology transfer have become de facto policy catchalls for a wide range of measures. Policies may be targeted towards input measures, such as expenditure on Research and Development (R&D) and employment in Science, Technology, Engineering and Mathematics(STEM), or output measures, such as number of patents, citations etc.

Policies may include extensive use of R&D tax credits for investment policies aimed at innovation-related activities; prioritization in credit rationing and financial allocation to firms deemed to be involved in innovative activities; large increases in tertiary education expenses related to the sciences (particularly in China); the use of geographical zones for various kinds of preferential measures such as trade policy and financial regulation; and financial innovation as a mechanism to internalize the spillover effects from externalities particularly associated with inward FDI. Governments have also implemented mega projects deemed central to innovation activities.

We find extensive and large-scale government intervention in policies aimed at generating productivity growth, with the resources allocated largely through central direction in the name of ITT policy. This policy nexus is extremely important in terms of overall resource allocation and may run counter to a policy of growth through a decentralized, market-based process focused on the emergence of small, rapidly growing firms.

Section III: BRICS and their position on the Innovation Ladder

Several organisations are involved in attempting to examine innovation policy in different countries and to devise measures to examine their effectiveness. According to the Knowledge Economy Index (KEI) developed by the World Bank (2012), Russia has, among the BRICS, the highest knowledge economy ranked at 55, followed by Brazil, South Africa, and China, with India having the lowest rank (110). China, however, leads among the BRICS nations in the Global Innovation Index (2016) with a rank of 25, with Russia, South Africa, India and Brazil at ranks 43, 54, 66 and 69 respectively. The overall index ranking is based on some partial indices based on a large number of indicators. The partial indices show that Russia leads on all counts, except for the Economic Incentive Regime (EIR) index in which it has the lowest score out of all the BRICS nations (Table 1). Brazil is second in rank, both in terms

Table 1: Indicators of Knowledge Economy

	Knowledge Economy Index	Knowledge Index	Innovation Index	Economic Incentive Regime Index	Education Index	Information and Communication Technologies Index	Knowledge Economy Rank
Brazil	5.58	6.05	6.31	4.17	5.61	6.24	60
Russia	5.78	6.96	6.93	2.23	6.79	7.16	55
India	3.06	2.89	4.5	3.57	2.26	1.9	110
China	4.37	4.57	5.99	3.79	3.93	3.79	84
S. Africa	5.21	5.11	6.89	5.49	4.87	3.58	67

Source: Knowledge Economy Index, World Bank (2012)

Table 2: BRICS R&D Indicators

	Internet Users per 1000		Mobile Users per 100		Patents granted to Residents per million		Researchers in R&D per million		Tertiary Enrolment per cent of relevant age population		Expenditures on R&D as per cent of GDP	
	2005	Growth	2005	Growth	2005	Growth	2005	Growth	2005	Growth	2005	Growth
Brazil	21	181	46	173.3	4054	14	580.5	20	26	90	1	23
China	8.5	490	29.8	209	93485	936	856.8	30	19.3	124	1.3	55
India	2.4	989	8	876	4721	166	135.3	16	10.7	150	0.8	2
Russia	15.2	360	83.4	92	23644	24	3234.7	-4	72.6	11	1.1	11
S. Africa	7.5	593	70.4	134	1003	-11	357.8	227	15.0*	29	0.9	-15
United States	68	10	68.3	72	207867	39	3718	8	82.1	4	2.5	9

Source: World Bank

of the overall KEI and individual sub-indicators. South Africa performs exceptionally well in indicators such as the Innovation and EIR indices. It is surprising that China and India occupy the last two places as per this ranking, especially given their performance in terms of patents, where they occupy the top two positions among the BRICS nations.

Alternatively, a study on economic power had found that indicators of various aspects of R&D contributed the most to the overall index of economic power (Agarwal and Brahmo, 2018).

Two broad conclusions can be drawn. Russia is almost at the top for most of the indicators, India at the bottom (Table 2). Secondly, there is mild convergence as India is improving very rapidly on most indicators, though China shows a somewhat fast pace of improvement despite starting at a better position. Russia is improving the slowest. Brazil and Russia being among the top in internet and mobile coverage corresponds with the World Bank's information technology index rankings. Again, China and India are the bottom two in tertiary enrolment which would correspond to their rank in the World Bank's education index though these two countries show the fastest increase. Where the two differ is that China has a low rank for innovation index despite its lead in patents granted, high share of expenditure on R&D and in number of researchers.

Most nations are increasingly realising the need to promote innovation through productivity gains, as also for dismantling regulatory barriers that dampen the ease of innovating and doing business. For example, according to the Global Competitiveness Report (2015), China has seen a stagnation in its index over the previous six years and needs to strategically implement policies to counter the challenges of an aging population, rising costs of production and low returns on investment. Russia has improved on the counts of regulatory business environment and import tariffs; however structural and financial market inefficiencies in the domestic economy seem to be holding it back from reaching its potential. Similarly, South Africa fares quite well in terms of several sub-categories, such as the quality of financial markets (rank 12) and transport infrastructure(rank 29), but its overall position is significantly affected by the levels of corruption and bureaucratic inefficiency.

Table 3: Global Indices for Competitiveness and Innovation

Country	Global Competitiveness Index (GCI)		Global Innovation Index(GII)	
	2006-07	2015-16	2007	2016
Brazil	66	75	40	69
Russian Federation	62	45	54	43
India	43	55	23	66
China	54	28	29	25
South Africa	45	49	38	54

Source:GCI, GII reports (various years).

Section IV: Policies affecting science and technology

Education Policies

Education policy — in particular, higher education policy, sometimes called human resource policy — is a central element in the ITT policy mix. India has lagged behind the other countries at all levels of education. Primary education in India is still not universal, though it is getting there. Gross tertiary enrolment rates in Brazil, China, India, Russia, and South Africa are 25, 22 and 12, 76 and 19 per cent respectively.[10] In 2015, the literacy rate for those of ages 15 and above was 93, 96, 72, 100 and 94 per cent, respectively, in Brazil, China, India, Russia and South Africa. While there is no significant difference among the four other countries the literacy rate is significantly lower in India. The World Bank's KAM project (2008), using an education index as a population-weighted aggregate indicator, assigns marks of 5.6, 3.9 and 2.3, 6.8 and 5.5 respectively, to Brazil, China, India, Russia and South Africa. China and India get a low value with India being lower while the other three get somewhat similar values.

Brazil

Brazil has put significant resources into developing its higher education system over the past three decades and some institutions have achieved recognizable excellence in teaching and research. However, more generally, a majority of the institutions struggle to provide relevant, quality education at reasonable cost.

Federal policy toward higher education, until recently, did not attempt to control costs or correlate funding and productivity. Other legislation and regulations, outside the control or influence of MEC (Ministério da Educação e do Esporto), created built-in cost increases independently of access, quality or relevance of higher education. Brazilian universities traditionally have concerned themselves more with obtaining resources from the federal government than with managing the resources effectively within their institutions.

To improve higher education the federal government has sought to change the sector's legal framework; develop a performance-based funding system that supports MEC's policy goals of improved access, quality and efficiency; and improve the capacity to evaluate quality of instruction and performance of institutions.

Prior to 1994 higher education institutions had limited autonomy, were not allowed to define curricula including opening new courses and intake into various courses. They could not determine hiring or firing for academic, technical or administrative staff or setting their salaries. They also could not transfer budget resources among expenditure categories. The 1996 National Education Law created a new category of institutions, "university centres," which enjoy most of the same legal privileges as universities but have greater autonomy over curricula and enrolment and a mandate to concentrate on undergraduate teaching instead of research. The law also allowed universities to define their own personnel policies, including hiring and firing staff and to manage their budgets without centralized bureaucratic mandates. The law further created the framework for a national evaluation system, through which the federal government can monitor and guarantee the quality of higher education. Other legislative changes allowed the creation of new, shorter courses, similar in some respects to U.S. community college degree programmes, as well as two-year professional master's degrees for areas of high demand, such as business administration and economics. Instead of a restrictive "minimum curriculum" for each course or career, institutions are now required only to follow broad curriculum guidelines and can determine the type and amount of education they offer. Slowing the implementation of these legislative changes, however, is resistance to autonomy and inertia within universities themselves.

As a second prong of the strategy, to improve accountability, the government plans to fund federal institutions through block grants, on the basis of performance contracts. Each institution's allocation would be derived using a simple, transparent formula that rewards "behavioural changes" and improved productivity that advance MEC's policy goals of greater access, quality and efficiency. For the private system, the government would provide loans targeted at students who could not otherwise afford to pay tuition. Students would be able to use their loans only at private institutions that demonstrate their ability to produce proficient students.

Finally, an integral part of MEC's strategy is to transform its role from a provider of funds for inputs to that of a guarantor of a minimal standard of quality of output. This goal is to be achieved through an evaluation and accreditation system. Brazil has a long and successful experience with evaluating and accrediting graduate courses; that system has been recently revised to increase the relevance and quality of its criteria and to apply them to undergraduate programmes.

Brazil is making efforts to improve its tertiary education attainment level. The World Bank data show that Brazil allocates about six times more resources per student to tertiary education than to primary education; by comparison, the Organisation for Economic Cooperation and Development (OECD) countries allocate, on average, 29 per cent more to tertiary education (without considering R&D activities) than to primary education. Yet it is still insufficient: from 1995 to 2005, expenditures on tertiary-level educational institutions increased by 51 per cent, but the number of students increased by about 80 per cent. Today, 8 per cent of Brazilians in the age group 25 to 34 and 9 per cent of in the age group 35 to 54 have tertiary education, compared with 4 per cent of those in age group 55 to 64; 13 per cent of graduates are in science-related fields.

China

China has made great efforts, particularly since the 1980s, to enhance the educational level of its population to upgrade technology and improve productivity. The average number of years of schooling of the population aging between 15–64 increased from 4.10 in 1980 to 5.96 in 2000 (Cohen and Soto, 2001). During this period, the proportion of the population finishing junior secondary education increased from 15 per cent to 34 per cent, those with senior secondary education increased from 6 per cent to 11 per cent and those with tertiary education increased from 1 per cent to 4 per cent (Hu, 2003). These policies have increased the number of highly skilled workers in China substantially (see Li *et al.*, 2008).

Despite this skill enhancement, there are shortages in several segments of the labour market such as a shortage of competent managers or highly qualified researchers in industry-relevant fields. This creates human resource bottlenecks in the innovation system. Also, the supply-driven tertiary education expansion has led to an abundance of highly educated labour while technicians and technical workers seem to be in short supply in many industries because of insufficient investment in vocational training.

In the face of global competition for talent (OECD, 2007), China has loosened restrictions on returning by, for example, granting special permits for entry and exit to enable returnees to work both abroad and in China; they are also allowed to remit their after-tax earnings, a right otherwise reserved for foreigners working in China.[11] Establishment of development parks and incubators dedicated to returned overseas scholars,and provision of tax incentives and project funding have encouraged returnees, as also interregional competition, especially among Beijing, Shanghai, Shenzhen and Guangzhou, to attract returnees.[12] Another element of the strategy is the ministry of education funding programmes to recruit Chinese research talent around the world to work in China.

The results of these initiatives are mixed, and it is questionable whether the recent increase in the number of returnees can be attributed to government incentives. In any case, the number still falls short of that required to reduce significantly current and prospective shortages of certain types of skills. In the foreseeable future, the main determinants of inflows and outflows of highly qualified Chinese labour will continue to be international differences in wages, working and living conditions and entrepreneurial opportunities.

India

India has sought to develop its scientific education system believing it to be necessary for growth of technology (Aggarwal, 2001). To develop a skilled labour force and achieve self-sufficiency in the generation of new technology, the government set up in 1942, even before achieving independence, the Council of Scientific & Industrial Research (CSIR) with many institutions under it undertaking research in various areas. Several Indian Institutes of Technology (IITs), modelled on the Massachusetts Institute of Technology were established in the 1950s with foreign help in devising courses and systems of study. The government signed agreements with governments of many countries to provide access to Indian students in foreign universities.[13] Imports of technology were severely restricted to encourage entrepreneurs to adopt technology developed by domestic institutions.

School enrolment was greatly expanded in the 1950s and 1960s. In subsequent decades, however, school enrolment grew very slowly, and India lagged behind other countries. In the past two decades, however, the Indian government has made an intense effort to expand primary education. In 2009 the Right to Education Act which provided for universal primary education was passed. Now primary enrolments are almost 100 per cent. Recently, to absorb the large number graduating from primary schools and to meet increased labour market demand for qualified workers attention has shifted to secondary and tertiary education.

Growth in the supply of tertiary-educated workers slowed between 1993 and 1999 and was virtually stagnant between 1999 and 2004 (Azam, 2009a).The government entrusted the task of establishing new institutions for tertiary education to the private sector. But the high fees charged by these institutions limited access to them. The government has more recently shifted its policy to raise tertiary enrolment from 10 per cent in 2007 to 21 per cent by 2016-17 and 30 per cent by the year 2020. It has sought to establish an IIT, and an Institute of Management and at least one Central University in each state. The Ministry has identified 374 districts that are educationally backward and will set up Model Degree Colleges in these districts.

In urban India, the returns to tertiary education are increasing: a tertiary-educated regular worker was paid wages that were 82 per cent higher than those of a below-primary-educated regular worker in 1993 and 101 per cent higher in 2004 (Azam, 2009b).The tertiary education system is large. In the 2006/07 academic year, there were 369 universities with 1.43 million students and 18,064 colleges with 9.6 million students (Azam and Blom, 2008). As well, in 2004, there were 1,265 engineering and technology colleges, 320 pharmacies, 107 architecture schools and 40 hotel management institutes. The aggregate supply of skilled science and engineering graduates is steadily rising, but they are still only a tiny fraction of India’s huge population.

A major issue with Indian educational institutions at all levels is the poor quality of the instruction and the students. A large number of teaching posts are vacant in the institutions of higher learning.

Russia

Russia has traditionally had high education levels, especially in science and Mathematics. There has been a steady rise in public expenditure on education as a percentage of GDP in recent years as well, from 3.7per cent in 2005 to 4.3per cent in 2013. According to the Global Innovation Index 2015, education (rank 20) is an area of strength for Russia; it is interesting to note, however, that in the PISA scale outcome for reading, science and maths, it has a much lower rank at 35. Gross tertiary enrolment stands at 76.1per cent, with 28.1per cent of graduates belonging to science and engineering streams. Russia faces an imbalance in terms of the composition of the people employed in research, with a large proportion of workers being support staff and not actual scientists and engineers, employed more out of a demand for labour intensive mechanisms by the citizens, than other factors. Another issue has been the numerical majority of older research personnel which has led to concerns of a shortage of skilled scientific manpower in the near future. However, in recent years, the population of 60-plus researchers has stabilised and there has further been a favourable trend in researchers below the age of 30, lessening the gravity of this problem. (UNESCO, 2015)

Several initiatives have been put in place to continue the trend of quality education and to reap the rewards of innovation. These include the identification of National Research Universities, as well as the State Programme for Development of Education (2013-2020). The intent of such programmes is to bridge the gap between the domestic appraisal of innovation and knowledge creation, in terms of a high score in patent applications and citable documents by residents, and a lower score based on royalty receipts, percentage of high technology exports and Patent Cooperation Treaty (PCT) compliant patent applications.

South Africa

Educational reforms have been a priority since the change of the government in 1994 in South Africa and in fact are a valuable instrument of social restructuring in terms of redressing the excesses of Apartheid. As per the 2013 data from UNESCO, the economy spends 6.23per cent of its GDP on public expenditure on education, out of which 0.8per cent is on tertiary education.In terms of student-teacher ratio in secondary education it lags behind considerably at a rank of 95 out of the 120 countries for which data is available.(GII, 2015). Gross tertiary enrolment also fares poorly at only 19.7per cent, with around 818 researchers per million of the population in 2012.

Given the history of Apartheid, the research sector in South Africa was dominated by older, white males and there was an overall scarcity of qualified scientists and researchers. Measures like the Technology and Human Resources for Industry Programme (THRIP) which primarily encourages industry-academia interaction, seek to rectify this by prioritising the entry of black and female students in technological and engineering streams. South Africa is 11^{th} among host countries worldwide in terms of inflow of foreign students, owing to good educational infrastructure. Indeed, it ranks higher than India and China in terms of the Education Index of the World Bank's KEI index, with a score of 4.87.

The primary challenges for South Africa are to raise the quality of its tertiary education and make it more inclusive in terms of age and composition.

Research Policy

In most countries, ITT policies tend to focus on the public sector, but the BRICS countries have started to foster innovation and technology transfer in the private sector. We discuss the ITT policy in both sectors and some other special policies. In addition, the countries are seeking closer tie ups between research organisations and industries.

Brazil

> Brazil's development stages were similar to India's, from the early emphasis on "science and technology" to a later focus on "science, technology and innovation."

Changes in Public Sector and General Sectoral Policies

Until the mid-1950s, during a period of import substitution, Brazilian governments built a network of institutions involved in scientific, technological and industrial projects. Among others, it is worth mentioning the Aerospace Research Center, founded in 1947, which played an important role in the development of the Brazilian aircraft industry; the National Council for Scientific and Technological Research, established in 1951 and originally focused on atomic technology but still an important institution for financing public research, especially in the federal universities; and the Brazilian Development Bank, created in 1953 with funds generated by workers' forced savings and still the most important institution for financing long-term investment in Brazil.

During the period of military governments from 1964 to 1985 and following the end of the stagnation of the Brazilian economy that began in the early 1960s, large investment projects were implemented that loosened bottlenecks in the infrastructure and basic industries, especially intermediate goods producing industries (Castro and Souza, 1985). The military governments heavily preoccupied with scientific and technological development established in 1964, two funds to financethe introduction of new technologies: one to train personnel involved in basic research in the universities and the other to aid the acquisition of machinery and industrial equipment. In 1965, the Agency for Financing Studies and Projects was established, still an important public enterprise for financing innovative activities.

Throughout the 1970s, successive scientific and technological plans appeared, to increase the financial resources for S&T, and to fund R&D for new technologies, new sources of energy, microelectronics and the aerospace industry. Institutional modernization reached its peak in 1972 with the creation of the Secretary of Industrial Technology, which coordinates S&T programmes, promotes technological development in both private and public firms, manages Brazil's system of intellectual property rights (patents and trademarks) and regulates the transfer of technology through the National Institute of Industrial Property Rights (Dahlman and Frischtak, 1993).

Despite rapid growth rate of Brazilian real GDP between 1950 and 1980 (7.5 per cent annual average) and development of a large and diversified industrial base, R&D expenditures were relatively low (around 0.63 per cent of GDP) compared with those in industrialized countries or even some later industrializing Asian countries such as South Korea. Moreover, the state was responsible for most (62.6 per cent) of the R&D expenditures, which were highly concentrated in a narrow group of firms (Dahlman and Frischtak, 1993). Also, research in the universities proceeded quite independently of the needs of industry.

Important institutional developments have sought to rectify weaknesses. The National System of Scientific and Technological Development, an umbrella organisation for entities that used government funds to conduct scientific and technological research, was created in 1975. The Ministry of Science and Technology was established in 1985 as the central body in the Federal S&T system. In turn, a National Council for Science and Technology, chaired by the Brazilian president, is responsible for harmonizing the policies of the various ministries that also work in these areas.

Recent Initiatives in the Private Sector

The commercialization of innovation is long overdue in Brazil. Even compared with those of countries such as China and India, Brazil's innovation system is far from market oriented. The government, accordingly, has started to adopt measures to modernize Brazil's NIS. In 2006, for example, it passed an Innovation Law to provide major transmission networks of knowledge from basic research – especially by public institutions and federal universities – to the applied technologies of firms.

China

China's ITT policies have evolved substantially over time, in roughly four stages. In the first stage (1956-77) China set up its basic industrial capability, especially in precision instruments, large machines and large engineering projects. During the second stage (1978-91), after the initial "open-door policy," the Chinese government stressed transfer of scientific and technological innovations to the economic field and moving S&T activities from a planning orientation to a market orientation. In the third stage (1992-2000), China built up a base for its high-tech industry and realized significant achievements in those areas. Furthermore, innovation rather than pure science and technology became the goal, and China began to use its scientific and technological resources to set up a national innovation system (NIS). In the fourth stage (2001–present) since China's accession to the World Trade Organization in 2001– stress has been on policies such as high-tech parks and new R&D policies. There has also been a large-scale transformation of R&D institutions (Huang *et al.*, 2004).

China's ITT policies clearly show the role of government-funded, project-based programmes, but they always had a strong private sector and enterprise component – FDI was expected to bring in new technologies that would be diffused to domestic enterprises. Recently, however, China has shifted its focus to encouraging innovative firms and institutions to achieve more commercialization.

Major Government Programmes and Reforms of Public R&D Institutions

A key element in China's post-1980 ITT policies is a plethora of major government-oriented programmes and mega projects. The government has funded a series of programmes to strengthen national technological innovation capability. For instance, such programmes absorbed 17 per cent of total public S&T expenditure during the 2000-05 period.

These programmes included in 1982 a "national technological revise plan," a "national key technology development projects plan," and a "national long-term S&T plan. A "S&T breakthrough plan" was added in 1983 and a "key technology R&D program" in 1984 (Huang et al., 2004). In the 1990s, there were the "national science and technology long-term plan," focused on developing Chinese research and production capabilities in atomic energy, electronics, semiconductors, automation, computer technology and rocket technology (Kondo, 1997). "The national middle-and-long-term S&T program," of the State Science and Technology Committee of China in 1992, to bridge by 2000 the gap between China and the industrialized countries in the 1970s and 1980s and by 2020 that at the beginning of the twenty-first century (Kondo, 1997; Wen and Kobayashi, 2002). These programmes had specific sectoral goals.[14]

Apart from central funds, 17per cent of public S&T expenditures (OECD, 2007),[15] local governments and enterprises were also important contributors, e.g. in the Torch Programme and the Spark Programme.[16] The Torch programme is an entrepreneurial programme that has four components: Innovation Clusters, Technology Business Incubators, Seed Funding (Innofund) and Venture Guiding Fund. Spark aims to revitalize the rural economy by focusing on farming techniques and processing technologies. The main objective of such programmes is to promote the diffusion of applied technologies, rather than to conduct basic scientific research, and unlike publicly funded basic research programmes, they receive funding mainly from bank loans and enterprises' own capital.

Recently, the new energy, resources and environmental technologies have received more emphasis, with one program now focusing on promoting technical upgrading and restructuring of industries to promote sustainable social development. Another, the "973 Program," encourages cutting-edge scientific research and work on other important issues in S&T fields.

Progress in the Private Sector

The private sector plays an important role in fostering business innovation and commercialization. The government's share of funding varies from nearly 90 per cent for basic research to around 50 per cent for applied research and to just 20 per cent for technology innovation and merely 2 to 5 per cent for Programmes such as Torch and Spark that support the commercialization of research. Local governments and enterprises typically provide larger shares of funding for programmes related to innovation and the dissemination of technologies (Agarwal, Li and Whalley, 2015). In 2006, 69.1 per cent of the funds for gross domestic expenditure on R&D (GERD) in China came from business enterprises, 24.7 per cent from central and local governments and 6.2 per cent came from abroad and other sources (China, 2007).

In the late 1990s, the government began to provide technological innovation funding for scientific middle and small enterprises, which have become the main source of innovation, development, investment and risk taking. At the same time, hundreds of large-scale government-owned R&D institutions were transformed into enterprises, non-profit organizations and intermediary organizations or merged into universities. This transformation improved the economic performance of public R&D institutions. Patent applications, employee average salary, revenue and other economic performance indicators all went up during this period. Several R&D institutions even went public in the stock market.

Among China's goals is the establishment of a venture capital system to support technology-based small and medium enterprises.

A number of factors have supported China's strong economic performance and increased national innovation capability since 1978 :

- FDI (see Buckley *et al.*, 2002; Liu and Wang, 2003).
- High-tech Development Zones (HTDZs), sometimes called Science and Technology Industrial Parks, which provide business incubators and innovation support structures and offer various preferential policies on, for example, taxation to entice enterprises to locate there. HTDZs have become a major driving force of China's strong economic growth (Qian, 2008).
- Encouragement of science and technology business incubators (STBIs). They mainly focus on commercialization of R&D outputs and provide linkages among universities, research institutes, high-tech small and medium enterprises and markets.

India

Upon independence, the Indian government set itself the task of the socio-economic transformation of the country through a process of central planning. Because of a recognition of its significance, science was given considerable importance in development planning. As mentioned above even before independence the government took steps to strengthen he country's technological capabilities. In its first S&T policy document, the government stated that the most important aims of the policy were "to foster, promote, and sustain, by all appropriate means, the cultivation of science, and scientific research in all its aspects — pure, applied, and educational; to ensure an adequate supply, within the country, of research scientists of the highest quality" (Government of India, 1958). The government pursued these aims by offering good conditions of service to scientists, according them an honoured position and associating them with policy formulation.[17]

India adopted a policy of import substitution in basic and heavy industries. Technology for these had to be imported. Given the negligible R&D base, flows of foreign technologies were required and, indeed, encouraged. FDI, technology licensing and financial and technical collaborations were allowed over a wide range of industries. Foreign collaborations increased six-fold between the 1948-55 period and 1964–70, while the FDI stock more than doubled between 1948 and 1964. But government sought to ensure that this went hand in hand with training Indian personnel so that Indian capabilities were built up.[18] But learning did not always take place. In the absence of any need to improve competitiveness, there was little or no incentive to learn, absorb, assimilate and upgrade foreign technologies to create capabilities (Desai,1980).

In the late 1960s, in light of a foreign exchange crisis and cut-off of aid, technological self-reliance became important, and it was felt that technology should not be imported to the detriment of local development effort based on R&D structures created earlier (Sandhya, Jain and Mathur, 1990). Consequently, earlier policies on technology acquisition were reversed and the emphasis shifted from "science and scientific development" to "technology and technological development" (Aggarwal, 2001). Foreign collaborations were severely restricted and FDI was allowed only in core industries where no alternative local technologies were available. To deal with the situation arising from the restrictions on technology acquisition, a Department of Science and Technology was set up, and in the Fifth Plan (1974-79), S&T planning was made part of the overall planning process.

As a result of these policies, technology transfers declined drastically between 1968 and 1980 as also FDI. Growth of royalty payment slowed from 22.3 per cent annually between 1970 and 1976 to 15.2 per cent between 1977 and 1985. Some positive benefits did accrue, however: R&D expenditures in private companies increased more than eightfold between fiscal years 1970/71 and 1980/81. This led to near self-sufficiency in standard technologies; indeed, India began to export technology.

Policy Changes in the Private Sector

A major weakness in the system was the disconnect between the technologies developed in the CSIR units and industry. Rarely were the domestic technologies used. The Technology Policy statement of 1983, for the first time, recognized the need to establish linkages among scientific, technological and financial institutions to promote the effective transfer of technology from institutions to industry. In 1985, a fully-fledged Ministry of Science and Technology was created, and in 1986 a high-level post of scientific adviser and a science advisory council to the Prime Minister were set up. Also introduced were schemes to strengthen and provide quality assurance of in-house R&D and to grant recognition to scientific and industrial research organizations in the private sector.

The Indian government also began to provide soft loans and help raise venture capital funds to foster its NIS through project-based programmes. For example, the Home Grown Technology Programme supports commercialization of technologies developed by indigenous research and development by providing soft loans (generally not exceeding 50 per cent of the project cost) for technology development, repayable in user-friendly instalments after the completion of the project. India's traditional financial institutions have also stepped up, with initiatives such as ICICI Bank's Technology Support and Services Programmes.[19]

In addition, to correct the lack of direct financial support for R&D in the private sector, the Indian government has created a multitude of schemes to support the absorption of imported technologies by industry and to develop, implement and commercialize indigenous innovations (see Krishnan, 2003: 7). India now offers many fiscal incentives for R&D, such as exemption from income tax for ten years for businesses whose main aim is R&D.

Toward a National Innovation System

In 1991, India undertook sweeping reforms to open the country to foreign investment and competition and to deregulate most industry to foster domestic competition. The tempo of liberalization has continued: every budget since that of 1991 has included further reform of the financial, infrastructure, information technology, telecommunications and foreign trade and investment sectors. Inward flow of FDI has been progressively liberalised with greater FDI participation allowed if the technology imported is more sophisticated. Also import of technology has been liberalised.

In this progressive environment, the promotion of R&D has re-established its importance, not only for exploiting inward technology but also for improving the efficiency of technology transfer. A new draft of the Technology Policy, enacted in 1993, emphasized strengthening linkages among industry, R&D institutions and financial institutions to encourage commercial exploitation of technologies developed in laboratories. It recommended a consortium approach to R&D and technology development involving academic institutions and national research laboratories for goal-oriented programmes and new product development.

Among the initiatives emerging from this new focus have been the restructuring of public institutions and the strengthening of India's role in international organizations. In particular, India now plays an active role in the work of the World Trade Organization, including the thorny issue of trade-related intellectual property rights.

In short, the Indian experience post-1991 has focused on liberalization strategies on the one hand, and active industrial and technology policies on the other, as mutually supportive. The government realizes there is an urgent need to revitalize the country's scientific enterprise and raise the standards of S&T in Indian institutions to meet the challenges of an increasingly technological world. In effect, India plans to integrate science and technology into all spheres of national activity and to gear the generation of S&T developments to poverty alleviation and the improvement of the quality of life. That philosophy is reflected in its Science and Technology Policy 2003, which emphasizes the importance of adapting the national innovation system to the rapidly changing world order. One concrete, declared objective is "to promote international science and technology cooperation towards achieving the goals of national development and security, and make it a key element of our international relations" (Government of India, 2003).[20]

Russia

The Russian Federation has an interesting history when it comes to innovation and technology transfer, owing to two features; the first is that a large proportion of research and development has always been publicly-funded, and the second is that innovation has predominantly evolved from the defence sector. The course of technology transfer in the erstwhile USSR and present-day Russia can be delineated into three broad periods, from 1960-80, 1980-late 90s and late 1990s onwards. The decades 1960-1980 were marked by innovation in isolation, stemming primarily from space research, largely separated from the day-to-day economic life. From the 1980s however, there was a growing interaction between the civil and military sectors, and this was encouraged in light of the economic and ancillary benefits, or "dual use" benefits that accrued (Pankova, 2002). There was a growing freedom of operation of enterprises within the domain of innovation and research; however, the system was still riddled with inefficiencies that prevented a smooth channel of technology transfer within the economy as well as from other nations. There was insufficient university-industry interaction, especially in terms of the contribution of the Russian Academy of Sciences (RAS) and its affiliated institutions.

In the late 1990s and the period that has followed, the Russian economy has evolved to incorporate the modern structural framework of technology transfer, albeit gradually. According to the STI outlook

(OECD-STI, 2012), a majority of R&D in Russia is still carried out under the State's purview, disconnected from the private firms. Only 26 per cent of the GERD for 2010 was funded by the business enterprises. Despite policy measures being undertaken in this regard, such as initiatives for clusters, SMEs, a stifling atmosphere of regulatory checks, weak ICT infrastructure and a lack of competition are among the factors that lead to Russia's comparatively poor performance in promoting a viable environment for entrepreneurship.

It is puzzling to note that the period of prosperity before 2008 led to a rather lax attitude towards innovation, promoting an overwhelming dependency on imported technology and know-how. The global crisis of 2008 only served to intensify the domestic challenges in the form of the structural barriers that the economy faced. The growth rate particularly slowed down since 2012 and was further pushed downward from 2014 onwards due to the influence of oil prices. (UNESCO, 2015) In this scenario, the Russian government seems to have recognised the need for innovation-driven growth and has initiated several targeted policies over the past few years in this regard. In 2012, President Putin highlighted the need for restructuring the economy, and as recently as June 2016, his agenda indicates that Russia is to be established as a champion of barrier-free technology transfer, in a bid to reverse the outflow of capital. (RBTH, 2016)

Since 2011, several official policies such as the Presidential Decree on the Approval of the Priority Areas for the Development of Science and Technology and the List of Critical Technologies (2011), the Strategy for Innovative Development to 2020, the Federal Goal-oriented Programme on Research and Development and the National Technology Initiative have been brought into effect. Tax benefits, apart from the usual deductions, are available to companies engaging in developing software, or associated with the Skolkovo Innovation Centre (Deloitte, 2015). Further, several initiatives have been launched in the sphere of

‘Green’ industries and energy-efficient innovations, as it was recognized as an area of weakness for the Russian economy, which ranked 114 out of 141 countries on ecological sustainability (GII, 2015).

However, a low share of the private sector in R&D, institutional and legal bottlenecks, and the near-absence of a start-up culture are persistent issues that would require concerted policy efforts by the Russian government.

South Africa

Largely resource-driven, South Africa is the leading economy in the African sub-continent. Its national system of innovation has been subject to a pluralistic form of governance, depending, to a great extent, on the enterprise of the individual departments involved in research and innovation-oriented policy making (Pouris, 2012).

While technology transfer has existed since the 1980s, South African innovation policy in this regard was properly structured only after 1994 when democratic elections took place. A National System of Innovation was recognised in a 1996 White Paper on Science and Technology and Technology Transfer Offices (TTOs) were established from the late 1990s onward to augment linkages between industry and academia, that is, universities (Wolson, 2007).

Policies were put in place to enhance competitiveness, doing away with the erstwhile mechanism of import substitution that prevailed in the Apartheid era. Research grants were instituted; however, given the low number of researchers, they failed to be effective in driving the rate of innovative activity and patents. (Mani, 2001)

There have been other programmes like the Support Programme for Industrial Innovation (SPII) which targets the Small, Medium and Micro-Enterprise (SMME) sector, and the Advanced Manufacturing

Technology Strategy (2002),which identifies critical technologies in terms of product and production technologies, ICT use in manufacturing, etc. Another key initiative is the Centres of Excellence initiative by the DST which is divided into seven centres, namely, the Centre of Excellence in Biomedical TB Research, the Centre of Excellence in Invasion Biology, the Centre of Excellence in Strong Materials, the Centre of Excellence in Birds as Keys to Biodiversity Conservation at the Percy Fitzpatrick Institute; the Centre of Excellence in Catalysis; The Centre of Excellence in Tree Health Biotechnology at FABI and the Centre of Excellence in Epidemiological Modelling and Analysis. The DST also apportioned resources for the South African Nanotechnology Strategy in the mid-2000s. (Pouris, 2012) There has also been an attempt to tap the biotechnology potential by facilitating a conducive environment for such start-ups, e.g. Biosciences Park (OECD-STI, 2012).

The Technology Innovation Agency (TIA) aims to cement the links between STI policy and industrial regulations. As per the Ten-year Innovation Plan (2008-18) five focus areas or challenges have been defined, namely,biotechnology and pharmaceuticals, space, energy security, climate change, and understanding of social dynamics. (OECD-STI, 2012). Concomitantly, some of the industries that have been considered eligible for super deductions are pharmaceuticals, energy and utilities, mining, natural resources, etc.

Apart from the above-mentioned challenge areas, there is a growing need to address gaps in manpower and human capital, and the National Human Resources Development Strategy (2010-20) focuses on this aspect. Further, there is a need for the South African economy to step up its manufacturing potential in terms of remedying both its ailing industrial environment and the low returns to innovation in terms of patents and technology transfers.

Section V: Evaluation of the ITT policies

The effectiveness of the policies can be evaluated in terms of patents received or citations. More directly one could calculate the rate of growth of productivity in the economy.

We had seen above in Table 2 that BRICS had been increasing expenditures on R&D and raising access to high technology areas, such as mobile or internet use tertiary enrolments and patents. In Table 4 below we compare the position in the BRICS with that of the US to see whether they have been able to close the gap. Relative to the US, the BRICS countries, except China, are spending considerably less on R&D as per cent of GDP. The share is also increasing only very slowly, again except for China

Table 4: State of Technology Relative to US (per cent)

	Patents to national Per million population		Researchers per million		Tertiary Enrolment of relevant age group		R&D expenditures as per cent of GDP	
	1995	2015	1995	2015	1995	2015	1995	2015
Brazil	2.2	1.6	n.a.	17.4	n.a.	57.4	n.a.	45.8
China	8.1	335.8	14.2	27.7	5.7	50.6	23.5	75.8
India	1.2	4.4	4.9	3.9	7.1	31.3	26.2	30.5
Russia	14.2	10.2	121.6	77.2	55.1	93.7	40.2	44.2
S. Africa	0.7	0.3	6.4	29.1	19.1	22.6	24.3	27.1

Source: Authors' calculations from data in World Bank World Development Indicators.

There has, however, been substantial growth in number of researchers, except for India, and tertiary enrolment and the gap with the US, though still considerable, has been narrowing. But the effectiveness of this increase in number of researchers and tertiary enrolment is questionable as the increase in patents is very small and has actually declined relative to the US in Brazil, Russia and South Africa.

Table 5: STEM Citations 1996-2016

Country	Total citations	STEM citations*	STEM citations (including social sciences)
Brazil	7557916	7083449	7197905
China	32913858	31130409	31501490
India	10839171	10228037	10386159
Russia	5947119	5527117	5581502
S. Africa	2689207	2255713	2438116
United States	240363880	195132199	205386553

*Excluding Arts/Humanities, Business Management and Accounting, Economics, Econometrics and Finance, Multidisciplinary and Social Sciences

Source: SCImago Journal and Country Rank (derived from SCOPUS database).

We now look more directly at productivity growth. Only China and India have seen productivity growth consistently higher than the average for the world (Table 6). Also, the rate of productivity increase, has fallen is lower in 2011-15 compared to 2005-07

Table 6: Annual Growth Rate of Labour Productivity (Output per Worker)

	2005-07	2008-10	2011-15
Brazil	2.2	3.1	0.1
China	11.9	9.7	7.7
India	8.2	7.2	5.3
Russia	6.2	0.9	1.2
S. Africa	2.0	1.7	-0.3
World	3.4	1.7	2.2

Source:Key Indicators of the Labour Market (KILM) 2015, ILO.

Another way to look at productivity increase is to calculate the Solow residual.

Table 7: Average annual growth of productivity

	Manufacturing, 1995-2009		Contribution to Value added		
	Per worker	Per hour	Contribution per cent of		
			Capital	Labour	Solow Residual
Brazil	-0.5	0.1	5	1	-3
China	11.8	11.1	3	4	4
India	4.6	3.6	5	1	1
Russia	5.4	4.9	1	1	3

Source: Authors' calculations from World Input Output Data set.

China again shows the fastest pace of productivity growth (Table 7). But now Russia shows a faster pace of productivity increase than India. Brazil performs very poorly. Except for the reversal between India and Russia the results are similar to those from the ILO. These results on productivity growth are in quite a sharp contrast to the World Bank's innovation index or the Global Competitiveness Index or the Global Innovation Index.

Section VII: Conclusions

Productivity increases because of technical change become increasingly important as countries move up in per capita income. In the early stages of development productivity gains arise mainly from shift in labour from low productivity activities to higher productivity activities. But later choosing the right technologies to import and make improvements in such technologies form the basis for productivity growth. At a still later stage countries need to develop their own technologies.

The paper points to the conceptual and measurement issues that affect calculations of productivity increases. The vagueness of the concept of technical change makes it difficult for countries to formulate precise policies that would foster technical change. Countries, as a consequence, adopt a variety of policies that they think will foster productivity growth. The overall framework is to develop a national innovation framework which binds together the different policies.

A major feature of these changes is to strengthen the linkages between research bodies, whether universities or specialised sector institutions,[21] and industry so that the research is more likely to be useful to industry and picked up by it.

A number of attempts have been made to devise innovation indices. They all suggest that China and India lag behind the other three. But when actual productivity growth is measured China and India usually fare better than the others which raises doubts about the appropriateness of these indices. Part of the problem may be that these indices use both input and output indicators and combine them into one composite index. The effectiveness of the inputs might already be incorporated in the output measures and then there is little effect on productivity growth.

Endnotes

1 Eichengreen, Park and Shin (2014), Agénor and Canuto(2015).

2 In early discussions among economists about how to define innovations, newer methods of organizing work were excluded (see Kuznets, 1962).

3 The theory of endogenous growth is one such attempt to incorporate technical change within the system Lucas, Roemer. Other attempts to have a second innovation producing sector are Shell, Nordhaus.

4 Investments in different years buy capital goods built in different years. One can assume that capital goods built in 2008 are the same as those built in 2007 and the same as those built in 2006, etc. This is assuming that capital goods are homogeneous. The investments in different years can be added to get the total capital stock. However, capital goods built in different years may not be the same. For instance, they might require different amounts of labour or produce different quantities of output. They are then considered heterogeneous and one cannot get the capital stock by simply adding investments in different years. Different techniques of estimation have to be used.

5 Absorption of new technologies seems to be somewhat easier in initial stages in the industrial sector than agriculture. Manufacturing technologies can be bought

on a turnkey basis and the simple technologies may be relatively easy to absorb. Higher productivity in agriculture depends on better quality seeds and even if got from existing technology providing have still to be adapted to local conditions and so require some technological capability.

[6] In early discussions among economists about how to define innovations, newer methods of organizing work were excluded (see Kuznets, 1962).

[7] Major innovations often require major changes in factory layouts and procedures before the full benefits can be reaped, and there might be a considerable lag before the need for change is recognized and implemented.

[8] Usually, employees are separated into skilled and unskilled, the latter including all administrative workers. Such a classification, however, might overstate the number of skilled workers engaged in production. But it does mean that, in practice, organizational efforts are taken into consideration.

[9] For instance, it would be difficult to measure the impact of what is called "*jugaad*" in India and similar innovations in other developing countries.

[10] The gross tertiary enrolment rate refers to the ratio of total enrolment, regardless of age, to the population of the age group that officially corresponds to the level of education shown.

[11] The Indian government has been less successful in attracting Indians living abroad to return, although those with expertise in the IT and biotechnology areas are returning in larger numbers, perhaps attracted by the government's now allowing Indians to own certain types of assets abroad.

[12] For more details see Agarwal, Li and Whalley (2015)

[13] For details see Agarwal (2016).

[14] For details see Agarwal, Li and Whalley 2015.

[15] Of course, as mentioned earlier, it is an open question how effective funds are in generating innovations.

[16] The Spark Program was named for a Chinese proverb, "A single spark can start a prairie fire."It was launched in 1985 to "implement a batch of scientific and technologicalprojects of quick benefit to promoterejuvenation of the regionaleconomy." (OECD, 2007, page 53).

[17] For a detailed analysis of policies in India see Ray(2009)

[18] These can be seen for instance in the iron and steel industry. After the initial import technology import, further capacity expansions were designed and executed by Indians (Parthasarathi, 2015).

[19] The Industrial Credit and Investment Corporation of India was set up in 1954 to provide capital for investment by private enterprises. In 1994 it was transformed into a regular bank.

[20] From http//dst.gov.in/stsysindia/spr1958. It is the first point in item 7 of the report.

[21] Sector specific policies that also seek to tie in with encouragement of GVC to foster productivity growth seem to have been very successful in ASEAN (Patarapong, 2018)

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