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This paper is part of the IDRC sponsored project on *Globalisation of Innovation: Its manifestation, determinants and implications for the emerging economies of China and India.* Earlier versions of the paper have been presented at three different China-India conferences at the Tsinghua University, the University of Edinburgh and at the Institute of Development Studies, Kolkata. I am grateful to the participants at these seminars for their comments and suggestions. It is also hoped that the paper will be revised and updated jointly with the other members of the Indian and indeed the Chinese teams. I also thank V S Sreekanth for research assistance. The usual disclaimer applies.

ABSTRACT

China and India are definitely on a higher economic growth path, although the contribution of technology to economic growth is still not very clearly estimated. There is evidence to show that innovative activities in the industrial sector in both the countries have shown some significant increases during the post reform process. Knowledge content of both domestic output and exports are increasing in both the countries. The Chinese NSI is dominated by the SSI of the electronics and telecommunications industries and in the case of India it is led by the SSI of the pharmaceutical industry. In both the countries, increasingly much of the innovative activities are contributed by MNCs. In other words both China and India have become important locations for innovative activities. There is even some macro evidence to show that the productivity of R&D investments in India is higher than in China, although this proposition requires careful empirical scrutiny before firm conclusions can be reached. However continued rise in innovative activity is limited by the availability finance and of good quality scientists and engineers. Although the available supply appears to be very productive, its important that to sustain this on a long term basis and also to spread the innovation culture to other areas of the industrial establishment concerted efforts will have to be made to increase both the quantity and quality of scientific manpower. Fortunately the governments in both the countries are aware of this problem and have started initiating a number of steps towards easing the supply of technically trained personnel. But the governments still have to rethink its financial support schemes by reducing as much as possible the distortions that are currently in this area.

Key words: India, innovation, R&D, patents, total factor productivity growth, high-tech industry, financing of innovation, HRST, R&D personnel.

JEL Classification: O31; O32; O34

Introduction

China and India are two of the fastest growing economies of the world. Their continued surge in economic growth both before and after the recent (2008) global financial crisis has further lent credence to the hypothesis that the economic growth registered by the two countries is sustainable as it is based more on technological improvements rather than by using more factor inputs such as labour and capital. Recent estimates of total factor productivity growth lend some empirical support to this hypothesis. Both the countries have also been receiving sizeable chunks of FDI in R&D by MNCs. There are also press reports of a number of innovations emanating from the two countries although systematic empirical evidence on this issue is found wanting in the literature[1]. One of the avowed objectives of economic reforms in both the countries (embracing of market socialism in China since 1979 and economic liberalization in India since 1991) was to promote competition between firms. Along with the possibility of increased competition, one also sees that both the countries have become increasingly integrated with the rest of the world although on these counts China has a better record than that of India. All these factors may pave the way for both the economies

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1 For a detailed count of these see, Business Week, http://www.businessweek.com/magazine/toc/05_34/B3948 chinaindia.htm (accessed April 5 2010)

to invest in innovative activities as the firms in both the countries are no longer concerned with competition in their respective domestic economies, but internationally as well. In the context, the purpose of the present chapter is to compare the two economies with respect to their innovation record since the onset of the reforms in the two countries which, as argued, earlier should have facilitated this process to flourish.

The chapter is structured into four sections. The first section maps out the larger context in which this study is conducted. The second section marshals a fair amount of quantitative evidence on whether the two economies are becoming innovative. The third section identifies some disquieting features that may act as an impediment to the process in the two countries. The fourth and final section concludes the arguments presented in the chapter.

I. The context

In this I present the larger context against which one may analyse the nature and extent of innovative activities in these two fast growing economies in the world. The context has four components: (i) China and India are the fastest growing economies in terms of efficiency of resource use; (ii) There has been considerable improvement in China and India's rank summary measures of global innovation; (iii) There has been a perceptible increase in the knowledge-intensity of China and India's manufactured and service exports; and (iv) Both the countries have achieved international competitiveness in high technology areas such as astronautic technology. I now elaborate on these four areas.

(i) Fastest growing economies in terms of efficiency of resource use: Productivity growth is well recognised as a measure of an economy's health. This is because an economy may show rapid growth by increasing the level of investments in the key factor inputs of capital and labour. But what is more important is the efficiency with which these factor inputs are combined to produce an increasing level of output. Economists usually measure this efficiency of resource by computing a summary measure such as total factor productivity growth (TFPG) although the empirical measures of TFPG is subject to the quirks of methodology and the type of data used. Among the various empirical exercises comparing TFPG in China and India, two of the recent and more systematic studies are by Bosworth and Collins (2008), examines the sources of economic growth in the two countries over the 25 year period 1978-2004 using a simple growth accounting framework that produces estimates of the contribution of labour, capital, education, and total factor productivity for the three sectors of agriculture, industry, and services as well as for the aggregate economy. Their analysis incorporates recent data revisions in both countries and includes extensive discussion of the underlying data series. The growth accounts, derived by the authors, show a roughly equal division in each country between the contributions of capital accumulation and TFP to growth in output per worker over the period of analysis, and an acceleration of growth when the period is divided at 1993. However, the magnitude of output growth in China is roughly double that of India at the aggregate level, and also higher in each of the three sectors in both sub-periods. In China the post-1993 acceleration was concentrated mostly in industry, which contributed nearly 60 percent of China's aggregate productivity growth. In contrast, 45 percent of the growth in India in the second sub-period came in from services. A second study is by Cates cited in Economist (2009)who computed the TFPG in emerging economies over the period 1990-2008. See Figure 1 for the results of this study. According to this study, China had the fastest annual rate of TFP growth at around 4 per cent per annum closely followed by India at around 2.5 per cent per annum during this period. Now the important question is to explain the determinants of this fast productivity growth. The three determinants that Cates identify are: (i) rate of adoption of existing and new technologies; (ii) the pace of domestic scientific innovations; and (iii) changes in the organisation of production. Using a composite index of technology diffusion and innovation, Cates finds a strong correlation between the rate of increase in an economy's technological progress and its productivity growth. In other words, the study also points to an increase in the rate of innovations in the two countries although this is not exactly probed in to in detail in the study.

(ii) Improvements in global innovation ranking: A number of composite indices of global innovation are available these days. One such index is the 'EIU Innovation Index' by the Economist Intelligence Unit[2]. Between 2002-06 and 2004-08, China rose from 59th to 54th in this index. This is most impressive as the prediction was that this sort of a moving up in the ranking will occur only within five years. One reason for the jump is that China is making a concerted effort to build a more innovative economy by investing heavily in R&D and education. India, on the contrary, is advancing at a steady pace up the innovation ranks as the number of patents granted increases and both innovation-specific and broad environmental factors improve. From 58th in 2002-06 it advanced to 56th in 2004-08. In 2009-13, it is forecast to reach 54th.

2 The Economist Intelligence Unit's Innovation Index analyses the innovation performance of 82 economies. It is based on countries' innovation output, as measured by the number of patents granted by the patent offices of the US, European Union and Japan, and innovation inputs, based on the Economist Intelligence Unit's Business Environment Ranking (BER) model. The Index measures the following direct innovation inputs: R&D as a percentage of GDP, the quality of local research infrastructure, the education of the workforce, technical skills, the quality of information and communications technology infrastructure and broadband penetration. The innovation environment includes political conditions, market opportunities, policy towards free enterprise, policy towards foreign investment, foreign trade and exchange controls, taxes, financing, the labour market and infrastructure.

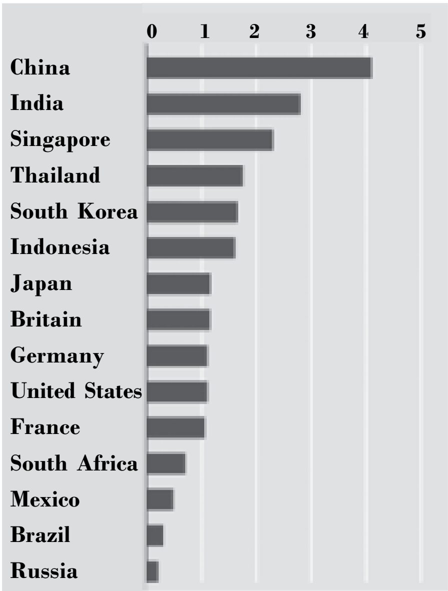

Figure 1: Total factor productivity growth in China and India, 1990-2008

Source: Cates cited in Economist (2009)

(iii) Increasing technological intensity of exports: By applying the UNIDO (2009) definition of high technology products to the UN Comtrade data (according to the SITC, Rev. 3 classification system) on manufactured exports from China and India during the period 1988-2008, I derived the manufactured exports from China and India. This is presented in Table 1. It shows that the high tech export intensity of both the countries have doubled during the period under consideration. If one undertakes a detailed decomposition of the components of these high technology exports then it can be seen that China is specialising in electronics and telecommunications equipments, while in the case of India the most important high technology manufactured product are pharmaceutical products.

Table 1: High-technology intensity of manufactured exports from China and India, 1988-2008

(High technology exports as a per cent of manufactured exports)

	China	India
1988		7.32
1989		10.12
1990		9.17
1991		9.16
1992	20.09	6.86
1993	22.76	7.21
1994	23.91	7.50
1995	25.77	8.95
1996	30.59	10.16
1997	32.44	10.23
1998	36.19	9.15
1999	38.68	9.28
2000	39.59	9.59
2001	40.92	12.34
2002	43.71	12.17
2003	47.33	12.04
2004	48.16	11.90
2005	48.42	11.12
2006	47.65	13.41
2007	46.72	14.54
2008	44.59	16.94

Source: Computed from UN Comtrade

China has in fact become the largest exporter of telecommunications equipments in the world: its share of the world market has actually increased from 2.36 per cent in 1992 to about 23 per cent in 2008. The above focus on manufactured products may actually underestimate the technological content of exports as far as India is concerned as the country is now increasingly diversifying into exports of services. Approximately 40 per cent of India's exports is in the form of services. Within the service exports, I denote the following four as knowledge-intensive services, namely (i) IT services; (ii) R&D services; (iii) Architectural, engineering and technical services; and (iv) Communications services. The combined share of these four in India's services exports have increased from about 55 per cent in 1999-2000 to about 80 per cent in 2007-08.

A mere increase in the technology content of exports and especially manufacturing does not necessarily mean that the country is becoming innovative if this increased exports are merely based on imported components and if the country in question does not have a clear record with respect to objective definitions of innovative activity in these products. It may well be the case that the country is merely importing components and parts, assembling them and exporting the finished product with very little local value addition.

(**iv) International competitiveness in certain high technology areas such as astronautic technology:** Both China and India have an active space research programme, spends considerable amount of public funds on space research and have increasingly demonstrated technological capability in designing satellites and satellite launch vehicles and even undertaking commercial launches of satellites on behalf of other countries. In order to measure the external competitiveness of the astronautic sector of China and India among other space-faring nations, I rely on the space competitiveness index (SCI) computed by Futron Corporation (2009). The SCI evaluates the space faring nations across 40 individual metrics that represent the underlying economic determinants of space competitiveness. These metrics assess national space competitiveness in three major dimensions: government, human capital, and industry. The ranks obtained by the ten major space faring nations are presented in Table 2.

Table 2: India's rank in the Space Competitiveness Index in 2008 and 2009

Rank	Country	Govern-ment	Human Capital	Industry	2009 Score	2008 Score (Rank)
1	U.S	38.42	13.96	37.94	90.33	91.43(1)
2	Europe	19.32	9.03	18.46	46.80	48.07(2)
3	Russia	18.57	3.04	10.83	32.44	34.06(3)
4	Japan	15.80	1.72	3.65	21.16	14.46(7)
5	China	12.42	2.98	4.06	19.46	17.88(4)
6	Canada	12.89	3.42	1.82	18.13	16.94(6)
7	India	12.24	1.71	1.39	15.34	17.51(5)
8	South Korea	8.39	1.34	2.31	12.03	8.88(8)
9	Israel	6.72	0.56	1.42	8.70	8.37(9)
10	Brazil	6.10	0.49	0.50	7.08	4.96(10)

Source: Futron Corporation (2009)

India was ranked 5 in 2008. Her rank has since slipped to 7 out of 10, although her score is better than Brazil- a country that is very strong in the aeronautical sector.

Thus, on all these four broad indicators of innovation outcomes, both China and India show considerable improvements over time. However, these indicators although suggestive, do not really prove that the two countries are becoming innovative. In order to measure the innovative activity, following Mani (2009), I rely on two of the conventional indicators that economists continue to employ to measure a country's record with respect to innovations. This exercise is the theme of the next section.

II. Evidence on innovative activity in China and India: Of the two indicators that economists usually employ to measure innovation, one is an input indicator, namely R&D expenditures and the second is an output indicator, namely the number of patents granted. Notwithstanding the limitations of these indicators, these are the only ones that are available for both the countries for sufficiently long periods of time. Further the definitions of both the indicators are standard across the two countries.

(i) R&D Expenditure: In order to compare the Gross Expenditure on R&D (GERD) of the two countries, I have converted the GERD in national currencies to US Dollars. Apart from the absolute levels of GERD, I also present the GERD intensities. These are presented in Table 3.

Table 3: Investments in overall R&D in China and India, 1995-2006

(absolute values of GERD are in billions of US $ and relative values are GERD to GDP ratios in percentages)

	GERD China	GERD India	Ratio of China to India	GERD/ GDP China	GERD/GDP India
1995	4.22	2.04	2.07	0.57	0.72
1996	4.89	2.11	2.31	0.57	0.69
1997	6.15	2.45	2.51	0.64	0.71
1998	6.66	2.57	2.59	0.65	0.76
1999	8.21	2.90	2.83	0.76	0.77
2000	10.83	3.20	3.38	0.90	0.81
2001	12.60	3.43	3.67	0.95	0.84
2002	15.57	3.51	4.44	1.07	0.81
2003	18.62	3.86	4.82	1.13	0.80
2004	23.77	4.35	5.46	1.23	0.78
2005	29.63	4.91	6.04	1.33	0.75
2006	37.03	6.35	5.83	1.42	0.88

Source: Chinese data are from OECD (2008); and Indian data are from Department of Science and Technology (2009)

In both absolute and relative terms China's GERD has increased tremendously during the period under consideration. For instance, it has increased at an annual average rate of 22 per cent during the period compared to India's growth rare of 11 per cent. Second, China's research intensity has virtually trebled during this period, while India's has more or less remained constant. Finally, China used to spend two times that of India towards the beginning of the period but this has increased to almost six times now. This better performance of China in terms of R&D investments may be attributable to the country having a more clearly articulated innovation policy with clear targets on R&D investments coupled with institutional changes and instruments to achieve those set targets within the stipulated time horizon. For instance, the Chinese government has set as a goal to increase R&D intensity to 2% of GDP by 2010 and 2.5% by 2020 (OECD, 2008, 111). India too had a target of research intensity reaching 2 per cent by 2006-07[3], but in actuality it is woefully short of this target. Care has to be exercised while interpreting these figures to mean that the overall relative investments in R&D in India have actually declined. This is because of certain peculiarities with respect to India's R&D performance. See Table 4 for a sector-wide distribution of R&D in the two countries. Even now, in India the government accounts for over 63 per cent of the total R&D performed within the country although the share of government has tended to come down over time. This has been accompanied by an increase in R&D investments by business enterprises which now account for about 30 per cent- a significant increase from just 14 per cent in 1991. For China the similar percentage is about 71 per cent by business enterprises and research institutes (read government) account for only 19 per cent: China has actually gone through an elaborate process of paring down the role of governmental research institutes in the performance of R&D by converting a large number of these institutes into business enterprises.

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3 See Government of India, 2003, http://www.india.gov.in/outerwin.php?id=http://dst.gov.in (accessed April 9 2010)

As a result, the number of government research institutes (GRIs) in China reduced significantly from 5867 in 1991 to about 1149 GRIs in 2004[4]. Increase in the share of R&D performed by business enterprises is generally considered to be a desirable trend as business enterprises tends to implement or productionise the results of their research rather quickly than the government sector where much of the research does not fructify into products and process for the country as a whole[5].

Table 4: Evolution of the Chinese and Indian National Systems of Innovation, 1991-2007

(Sector-wide performances of GERD, Figures are percentage share of each sector in total GERD)

	Government		Business Enterprises		Higher Education	
	China	India	China	India	China	India
1991	51.6	86.16	39.8	13.84	8.6	
1996	44.9	78.26	43.2	21.74	11.8	
2000	31.2	77.21	60.3	18.46	8.6	4.33
2007	19.2	67.91	72.3	27.71	8.5	4.38

Source: OECD (2008) and Department of Science and Technology (2009)

The business enterprise sector in both the countries is now emerging as the core of the NSI in both the countries although it is much more pronounced in the case of China than in India. In China, the business sector has become the largest R&D performer in terms of S&T inputs and outputs. According to these indicators, the business sector plays a dominant role in the S&T development of China. However, due to various historical and structural reasons, the efficiency and the innovation capacity of the

4 For detailed account of this see Gu and Lundavall (2006) and Schaaper (2009)

5 Governmental R&D in India is expended by atomic energy, defense, space, health and agricultural sectors. The spillover of government research to civilian use is very much limited in the Indian context although in more recent times conscious efforts have been made by the government is slowly beginning to produce results. This especially so in the area of astronautic research. For details see Mani (2010 b).

business sector is still insufficient, despite a large and rapid increase in scale and scope. While S&T activities in government research institutes and the higher education sector have some similarities, the business sector is different from the previous two sectors in several aspects.

The R&D expenditure of the business enterprise sector of both the countries have risen, once again, the Chinese annual growth rate at 31 per cent is much higher than that is recorded for India and as a result the R&D expenditure of Chinese enterprises is almost 16 times its counterparts in India (Table 5). It must however be noted that both Chinese and Indian firms spent only less than a per cent of their sales turn over on R&D.

It looks as if the business enterprises in both China and India are becoming the core of both country's NSI. However, OECD (2008) remarks that "it would be wrong to conclude that firms already form the backbone of the Chinese NIS. To a significant extent, the rapid increase in business sector R&D has resulted mechanically from the conversion of some public research institutes into business entities often without creating the conditions for them to become innovation oriented firms''.

Table 5: Business enterprise R&D expenditures in both China and India, 1999-2006 (Values are in billions of US $)

	China	Growth rate (%)	**India**	Growth rate (%)	Ratio of China to India
1999	4.07		0.61		6.64
2000	6.49	59	0.59	-3.59	10.98
2001	7.62	17	0.62	4.75	12.30
2002	9.53	25	0.68	9.36	14.06
2003	11.61	22	0.75	10.85	15.46
2004	15.89	37	0.99	31.38	16.10
2005	20.24	27	1.37	38.79	14.78
2006	26.33	30	1.64	19.92	16.03

Source: OECD (2008) and Department of Science and Technology (2009)

If both Chinese and Indian business enterprises have increased their investments in intramural R&D, it will also be interesting to see the relationship between these investments and the costs incurred in importing technology from abroad. Combining the two aspects, I define a ratio called the average propensity to adapt. This is defined as the ratio of intramural R&D in business enterprises to cost incurred in technology purchases from abroad (Figure 2). If this ratio is greater than unity, it could be argued that under *cetris paribus* conditions, firms are developing local technological capabilities.

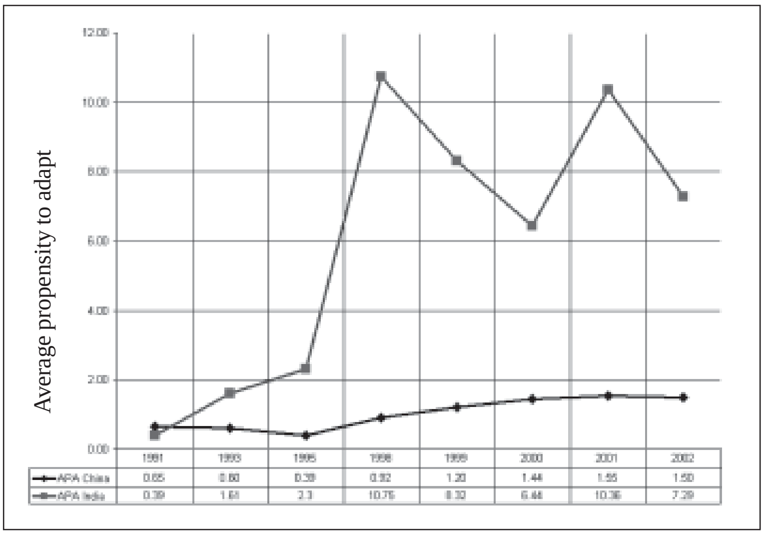

Figure 2: Average propensity to adapt in Chinese and Indian business enterprises, 1991-2002

Source: Computed from OECD (2008) and Department of Science and Technology (2009)

From the above, it could be seen that Indian business enterprises despite their lower levels of investments in R&D have a better propensity to adapt and thereby develop local capabilities compared to their Chinese counterparts. Although it must be said that both Chinese and

Indian companies are increasingly improving their propensity to adapt. The exercise is admittedly very limited in terms of its scope. Further studies of a case study nature are very much required before one can draw strong conclusions or inferences of this type.

R&D outsourcing: Another interesting aspect of R&D in business enterprises is the fact that both China and India have become important recipients of R&D outsourcing deals. R&D offshoring started in India way back in 1984 with Texas Instruments setting up its first R&D centre in Bangalore. China's R&D offshoring trend began in the early 1990s with Motorola being the first company to take advantage of the local talent and low cost in China. No precise estimates of the size of this sector in both the countries exist. According to some private estimates[6] that are available there exist 920 MNCs having 1,100 R&D centres in China. The number till December 2008 for India was about 671 MNCs with 781 R&D centers. Data on receipts under R&D services are lacking in the case of China, but in the case of India it has increased from US $ 221 million in 2004-05 to US $ 1385 million in 2008-09 (Reserve Bank of India, 2010, p. 580). Availability of high quality scientists and engineers and the lower costs of performing R&D are identified as the main reasons for the growth of these R&D outsourcing. Most of these R&D outsourcing is actually confined to certain high technology industries such as telecommunications equipment, information technology, pharmaceuticals and biotech industries. Available studies in the case of China (Lan and Liang, 2006) has shown that foreign R&D centres are hardly connected with the national system of innovation of China as their linkages are often enough with their own parent firms abroad. This is likely to be the same for India as well.

Industry-wide distribution: In both the countries**,** R&D by business enterprises is concentrated in about ten industries (Table 6) although the degree of concentration is slightly higher in India. Another

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6 http://zinnov.com/blog/?p=160 (accessed on April 6 2010)

Table 6: Industry-wide distribution of business-wide R&D expenditures in China and India

China (RMB 100 million)	**2000**			**2003**	**2004**		
Electronics and telecommunication equipment	79.82			163.54	226.21		
Transport equipment	42.27			95.65	127.47		
Electrical machinery	29.49			74.49	93.43		
Share of top 5 (%)	**55.53**			**61.76**	**63.23**		
Share of top ten (%)	**74.95**			**80.27**	**80.51**		
India (INR Millions)	**1999-00**	**2000-01**	**2001-02**	**2002-03**	**2003-04**	**2004-05**	**2005-06**
Drugs and Pharmaceuticals	478.98	554.15	739.63	1026.79	1441.43	2237.12	2826.86
Transportation	431.37	451.96	528.61	434.27	546.50	862.80	1047.20
Electricals and Electronics Equipment	186.34	178.63	227.30	170.54	197.68	290.42	375.40
Information and Technology	110.36	156.10	173.60	110.02	194.28	221.24	306.63
Chemicals (Other than Fertilisers)	273.64	308.06	218.08	194.75	213.18	238.62	300.87
Total for top 5	1480.69	1648.90	1887.22	1936.38	2593.08	3850.20	4856.96
Share of top 5 (%)	67.98	68.44	67.70	69.54	71.19	75.85	77.48
Biotechnology	54.97	50.32	53.78	108.72	136.84	187.51	277.74
Metallurgical Industries	83.89	80.11	42.29	82.61	104.43	131.83	142.87
Mis.Mechnical Engineering Industries	36.46	41.96	35.12	74.89	86.67	110.86	137.31
Soaps, Cosmetics Toilet Preparations	56.45	44.52	112.12	142.64	155.40	173.88	137.22
Telecommunications	30.51	69.13	76.57	55.04	92.18	81.81	98.67
Total for top 10	**1810.95**	**2003.38**	**2274.80**	**2469.81**	**3239.78**	**4611.94**	**5728.26**
Share of top 10 (%)	**83.14**	**83.15**	**81.61**	**88.69**	**88.94**	**90.86**	**91.38**

Source: OECD (2008), p. 117 and Department of Science and Technology (2009) interesting issue brought out by the table is the fact that China appears to specialize in the creation of electronics and telecommunications technologies while in the case of India it is the pharmaceutical technologies. In fact both the countries have become very important world players in these two industries. In other words, based on this data, it may not be incorrect to state that the NSI of the two countries are to a certain extent dominated and shaped by the Sectoral System of Innovation (SSI) of the two industries, electronics and telecommunications in the case of China and pharmaceutical in the case of India. However, there is one manufacturing industry where both the countries are concentrating on, namely the transport equipment industry. This is also an industry where a number of high profile new product launches by domestic manufacturers have occurred[7].

Productivity of R&D: It is seen that China invests far greater amounts on R&D compared to that of India.

Table 7: Productivity of R&D investments: China vs India, 1995-2006
(GERD is in US $ Billions, Patents granted are in numbers; Productivity is US $ billion per patent granted)

	GERD China	GERD India	Patents China	Patents India	China Productivity	India Productivity	Ratio of China to India
1995	4.22	2.04	62	37	0.07	0.06	1.233
1996	4.89	2.11	46	35	0.11	0.06	1.760
1997	6.15	2.45	62	47	0.10	0.05	1.901
1998	6.66	2.57	72	85	0.09	0.03	3.059
1999	8.21	2.90	90	112	0.09	0.03	3.527
2000	10.83	3.20	119	131	0.09	0.02	3.723
2001	12.60	3.43	195	178	0.06	0.02	3.350
2002	15.57	3.51	289	249	0.05	0.01	3.828
2003	18.62	3.86	297	342	0.06	0.01	5.549
2004	23.77	4.35	404	363	0.06	0.01	4.907
2005	29.63	4.91	402	384	0.07	0.01	5.767
2006	37.03	6.35	661	481	0.06	0.01	4.245

Source: Table 3 and USPTO

7 For instance the launch of the small car, TATA Nano in the case of India.

So it will be instructive to analyse the productivity differential in R&D investments in the two countries. Admittedly, this is a complex issue to be tackled. Nevertheless a first attempt is made in terms of relating R&D investments in the two countries to their respective output in terms of patents granted. However there are different types of patents, national, foreign and Triadic. Further there are utility and design patents: utility patents are for new inventions where design patents are for ornamental changes in existing products. Given the fact that both national and Triadic patents are very specific and depend on the norms adopted individual patents, following the usual practice in the literature, I analyse the US utility patenting behaviour of Chinese and Indian inventors. These are then related to the GERD in both the countries to arrive at the amount of GERD per US utility patent (Table 7). The resulting exercise point to two important results: firstly, China's productivity has virtually remained constant over the years while India's productivity show a definite increase over time and secondly, the productivity differential between the two countries have actually increased over time with India's productivity being more than the Chinese one. However, given the rudimentary nature of this exercise, one has to be very careful in drawing strong conclusions about the productivity differential between the two giants, especially when the earlier results on TFP presents a better picture for China. Needless to add this is an important issue that needs a further empirical probe at much disaggregated levels.

So based on this analysis of R&D expenditures it is somewhat clear that Chinese electronics and telecommunications sectors and the Indian pharmaceutical sectors have become more innovative since the onset of reforms. I propose to follow this argument through with an analysis of the patenting behaviour of the two countries.

(ii) **Patenting behaviour**: R&D investment is basically an input measure of innovation while patents are an output measure. There are three different types of patents, namely patenting by Chinese and Indian inventors in the US, Triadic patents and national patents in both China and India. I examine the record of the two countries in each of these. I begin with the US patenting record of the two countries as for reasons seen above are one of the most important indicators about innovative activity. Both the countries have improved their US patenting record since the onset of reforms (Table 8), again China having more patents than India. In fact the difference between the two countries record with respect to patenting has increased over time. But there is an important difference between the two countries. India has, relatively speaking, more utility patents (defined as those for new inventions). Increasingly most of the Chinese patents are design patents accounting for as much as one third of the total patents. Finally both China and India together account for much of the patents that inventors from the BRICs have secured in the USA.

Technology-wide distribution of these patents (Table 9) also shows some important differences between the two countries although at the very same time it supports the finding that the analysis of R&D expenditure had indicated (in Table 6 above). Two important differences are discernible. Firstly, Chinese inventors have focused more on developing electrical, electronic and telecommunications technologies while Indian inventors have been focusing much more on pharmaceutical and chemical technologies. Secondly, Indian inventors are, relatively speaking, more specialized (as the country has a much higher concentration on fewer technologies) than their Chinese counterparts. Finally of the top fifteen classes of technologies emphasized by Chinese and Indian inventors there are only three classes in which both the countries have common interest. These are in pharmaceuticals (Class 424), telecommunications (Class 370) and software (class 707). Of these three in the former, India has a lead while in the latter two classes both the countries have the same level of patents.

Table 8: Trends in US patenting by Chinese and Indian inventors
(Number of patents granted by the USPTO)

	Utility patents			Design patents			Total Patents			Ratio of utility to total patents		
	Total world	China	India	Total world	China	India	Total world	China	India	Total world	China	India
1979	48854	0	14	3119	0	0	51973	0	14	0.94		1
1980	61819	0	4	3949	0	0	65768	0	4	0.94		1
1981	65771	2	6	4745	0	0	70516	2	6	0.93	1	1
1982	57888	0	4	4944	0	0	62832	0	4	0.92		1
1983	56860	0	14	4563	0	0	61423	0	14	0.93		1
1984	67200	2	12	4938	0	0	72138	2	12	0.93	1	11
1985	71661	1	10	5066	0	0	76727	1	10	0.93	1	1
1986	70860	7	18	5518	0	0	76378	7	18	0.93	1	1
1987	82952	23	12	5959	0	0	88911	23	12	0.93	1	1
1988	77924	47	14	5679	1	0	83603	48	14	0.93	0.98	1
1989	95537	52	14	6092	0	1	101629	52	15	0.94	1.00	0.93
1990	90365	47	23	8024	1	0	98389	48	23	0.92	0.98	1.00
1991	96511	50	22	9569	2	1	106080	52	23	0.91	0.96	0.96
1992	97444	41	24	9269	0	0	106713	41	24	0.91	1.00	1.00
1993	98342	53	30	10630	0	0	108972	53	30	0.90	1.00	1.00
1994	101676	48	27	11095	0	1	112771	48	28	0.90	1.00	0.96

cont'd.....

	Utility patents			Design patents			Total Patents			Ratio of utility to total patents		
	Total world	China	India	Total world	China	India	Total world	China	India	Total world	China	India
1995	101419	62	37	11712	1	1	113131	63	38	0.90	0.98	0.97
1996	109645	46	35	11410	2	1	121055	48	36	0.91	0.96	0.97
1997	111984	62	47	11414	4	1	123398	66	48	0.91	0.94	0.98
1998	147517	72	85	14766	16	7	162283	88	92	0.91	0.82	0.92
1999	153485	90	112	14732	9	1	168217	99	113	0.91	0.91	0.99
2000	157494	119	131	17413	42	0	174907	161	131	0.90	0.74	1.00
2001	166035	195	178	16871	70	1	182906	265	179	0.91	0.74	0.99
2002	167331	289	249	15451	101	6	182782	390	255	0.92	0.74	0.98
2003	169023	297	342	16574	127	7	185597	424	349	0.91	0.70	0.98
2004	164290	404	363	15695	192	9	179985	596	372	0.91	0.68	0.98
2005	143806	402	384	12951	163	16	156757	565	400	0.92	0.71	0.96
2006	173772	661	481	20965	309	19	194737	970	500	0.89	0.68	0.96
2007	157282	772	546	24062	462	24	181344	1234	570	0.87	0.63	0.96
2008	157772	1225	634	25565	647	37	183337	1872	671	0.86	0.65	0.94

Source: Computed from USPTO

Table 9: Technology-wide distribution of US patents granted to Chinese and Indian inventors (Cumulative total number during 1963-2008)

China Patent Class	Class Title	Cumulative total	India Patent Class	Class Title	Cumulative total
439	Electrical Connectors	571(11.06)*	532	Organic Compounds (includes Classes 532-570)	707(17.33)*
361	Electricity-Electrical Systems and Devices	246 (4.77)	424	Drug, Bio-Affecting and Body Treating Compositions (includes Class 514)	591 (14.49)
424	Drug, Bio-Affecting and Body Treating Compositions(includes Class 514)	240 (4.65)	435	Chemistry: Molecular Biology and Microbiology	218 (5.64)
382	Image Analysis	114 (2.21)	520	Synthetic Resins or Natural Rubbers (includes Classes 520-528)	132 (3.24)
502	Catalyst, Solid Sorbent, or Support Therefor : Product or Process of Making	101 (1.96)	370	Multiplex Communications	89 (2.18)

cont'd.....

China Patent Class	Class Title	Cumulative total	India Patent Class	Class Title	Cumulative total
532	Organic Compounds (includes Classes 532-570)	98 (1.90)	327	Miscellaneous Active Electrical Nonlinear Devices, Circuits and Systems	88 (2.16)
370	Multiplex Communications	82 (1.59)	707	DP: Database and File Management or Data Structures (Data Processing)	75 (1.84)
435	Chemistry: Molecular Biology and Microbiology	80 (1.55)	709	Multi computer Data Transferring (Electrical Computers and Digital Processing Systems)	75(1 .84)
520	Synthetic Resins or Natural Rubbers (includes Classes 520-528)	75 (1.46)	341	Coded Data Generation or Conversion	70 (1.72)
707	DP: Database and File Management or Data Structures (Data Processing)	75 (1.46)	711	Memory (Electrical Computers and Digital Processing Systems)	70 (1.72)
455	Telecommunications	74 (1.43)	423	Chemistry of Inorganic Compounds	66 (1.62)

cont'd.....

China Patent Class	Class Title	Cumulative total	India Patent Class	Class Title	Cumulative total
704	DP: Speech Signal Processing, Linguistics, Language Translation and Audio Compression/ Decompression	73 (1.4)	326	Electronic Digital Logic Circuitry	63 (1.54)
438	Semiconductor Device Manufacturing: Process	69 (1.34)	502	Catalyst, Solid Sorbent, or Support Therefor : Product or Process of Making	61 (1.50)
375	Pulse or Digital Communications	68 (1.32)	717	DP: Software Development, Installation, and Management (Data Processing)	60 (1.47)
362	Illumination	66 (1.29)	714	Error Detection/Correction and Fault Detection/Recovery	59 (1.45)
	Cumulative total of the top 15	2032 (39.36)		Cumulative total of the top 15	2424 (59.41)
	Cumulative total of all patent classes	5162 (100)		Cumulative total of all patent classes	4080 (100)

Note: *Figures in parentheses indicate percentage share of the total
Source: Computed from USPTO

A still another important issue is of the ownership of these patents. See Table 10. Although there are some differences between the two countries, there are some important common points. In both countries much of the US patents are held by foreign companies, their level being much higher in China due essentially to the larger number of foreign companies in the two countries. Domestic enterprises in both the countries have similar levels of patenting. There, however are two important differences: firstly, Indian Govern Research Institutes (GRI's) and universities (actually almost entirely GRIs) have a higher share than their Chinese counterparts and secondly Chinese individuals have a higher patenting record than Indian individuals. The higher share of Indian GRI's is due to two reasons. Firstly, the CSIR network of laboratories had an explicit strategy of increasing their patent portfolio and this strategy was set into motion since the late 1990s although this does appear to be tapering off since 2003 (Mani, 2009). Secondly, I had noted earlier that Chinese NSI had gone through a massive reorganisation although the 1990s wherein a number of hitherto GRIs were converted to business enterprises. The exercise thus shows that increasingly the surge in US patenting by both China and India are largely contributed by foreign R&D centres which are operating from the two countries and as such the surge in patents need not necessarily imply that the two countries are becoming more innovative. Rather, the more correct inference may be that the two countries have indeed become important locations for innovative activities. The business press is replete with a large number of innovations that MNCs were able to carry out from the countries.

Table 10: Ownership of US Patents, Cumulative 1963-2008 (percentage shares)

	China	India
Foreign	53.56	40.26
Individually Owned Patents	27.96	9.95
Domestic business enterprises	13.21	14.14
GRIs and Universities	5.28	35.67
Total	100	100

Source: Computed from USPTO

I continue the analysis with Triadic patents from China and India. These patents being taken for the same family of technologies from three different patent offices (namely, the US, European and Japanese) signify a very high level of quality as it is more difficult and costly not just to secure these patents but also to maintain them[8]. Consequently firms and research institutes will in all probability self select their best inventions to patent. So an increase in the number of Triadic patents secured indicates not just your ability to innovate but also the quality of it. See Table 11.

Table 11: Triadic patents granted to Chinese and Indian Inventors, 1990-2006

(Number of Triadic patents)

	Brazil	Russian Federation	China	India	South Africa	World
1990	10	21	12	12	13	32417
1991	6	36	12	8	18	29786
1992	13	45	17	7	33	29922
1993	22	34	16	8	32	30794
1994	12	51	17	6	21	32414
1995	17	60	21	11	25	35731
1996	18	58	23	14	29	39098
1997	29	69	43	22	34	41515
1998	29	94	47	34	35	42878
1999	31	60	62	40	31	45507
2000	33	69	84	45	35	47162
2001	47	56	114	85	24	45565
2002	44	48	178	106	28	46120
2003	51	51	252	120	30	48093
2004	51	55	290	122	33	50727
2005	56	64	384	133	31	50569
2006	65	63	484	136	30	51579
Growth rate (%)	18.77	10.38	27.86	20.98	8.39	3.04

Source: OECD (2009)

8 Triadic patent families are defined at the OECD as a set of patents taken at the European Patent Office (EPO), the Japan Patent Office (JPO), and granted by the US Patent and Trademark Office (USPTO), to protect the

China and India has the highest growth rate and also accounts for the largest share among the BRICS.

National Patents: In both the countries there has been a tremendous surge in national patents. See Table 12. But in both the countries most of the national patenting is still dominated by foreign inventors although the share of domestic inventors has been showing some fluctuations. Of the two, the share of domestic inventors is higher in China and in the case of India although the share of domestic inventors kept on rising (with some fluctuations) until 2005, it has started declining since that year. My hypothesis is that with the TRIPS compliance of Indian patent regime since January 1 2005, MNCs have shown a rush to patenting in India so that Indian companies and especially the pharmaceutical ones may find it difficult to do incremental innovations.

III. Disquieting features: Although Chinese and Indian business enterprises have increased their investments in R&D, the surge in patenting that has occurred since the initiation of reforms is largely attributable to foreign enterprises that are located in the two countries. Domestic enterprises in the two countries, barring notable exceptions are not innovative. Based on our review of the relevant literature and discussions with industry associations, there are two disquieting features or constraints that the NSI of the two countries suffer from, although it may be argued that the intensity of these two as constraints may vary across the two countries. The two constraints are: (i) availability and quality of scientists and engineers of the type that can innovate; and (ii) financing of innovative activity. Of the two, there is now some evidence of the former issue as a constraint in both the countries, while the latter one is a typical constraint more in the case of India.

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same invention. In terms of statistical analysis, indicators on triadic patent families improve the international comparability of patent-based statistics (no ¬home advantage). Furthermore, patents that belong to the family are typically of higher value (as regards additional costs and delays involved in extending protection to other countries).

Table 12: Trends in patenting within China and India: domestic vs foreign inventors

(Number of patents granted by SIPO and IPTO)

China	Domestic	Foreign	Ratio of domestic to foreign	India	Domestic	Foreign	Ratio of domestic to foreign
1995	1530	1863	0.82	1994-95	476	1283	0.37
1996	1395	1581	0.88	1995-96	415	1118	0.37
1997	1532	1962	0.78	1996-97	293	614	0.48
1998	1655	3078	0.54	1997-98	619	1225	0.51
1999	3097	4540	0.68	1998-99	645	1155	0.56
2000	6177	6506	0.95	1999-00	557	1324	0.42
2001	5395	10901	0.49	2000-01	399	919	0.43
2002	5868	15605	0.38	2001-02	654	937	0.70
2003	11404	25750	0.44	2002-03	494	885	0.56
2004	18241	31119	0.59	2003-04	945	1524	0.62
2005	20705	32600	0.64	2004-05	764	1147	0.67
2006	25077	32709	0.77	2005-06	1396	2924	0.48
				2006-07	1907	5632	0.34
				2007-08	3173	12088	0.26

Source: Ministry of Science and Technology (2007) and Controller General of Patents, Designs and Trade Marks (various issues)

Availability and quality of scientists and engineers: Although it is generally held that both China and India have a copious supply of scientists and engineers, the fact is that the real supply of scientists and engineers engaged in R&D and innovative activities is not much. For instance, in the case of China, OECD (2008) estimates that even if the current high levels of growth in the number of researchers is maintained there will be a large gap between the demand for, and supply of, scientific manpower. The OECD (2008, p, 329) argument runs as follows: “the Chinese government aims to raise R&D intensity from 1.34% of GDP (2005) to 2% in 2010 and 2.5% in 2020. Despite the rapid growth of researchers in recent years and the expansion of the tertiary education sector, future needs may not be met. To project the future need for researchers, a simple estimate was made, based on the following assumptions: GDP growth at 8% on average until 2020, ratio of R&D intensity to GDP of 2.5% in 2020, and the wage level and the proportion of labour costs in total R&D expenditure equal to that of Korea in 2005. The result of the simple estimation suggests that raising China’s R&D intensity to 2.5% of GDP may imply that the need for 3.7 million researchers by 2020, *i.e.* an additional 2.6 million researchers from the number in 2005. To meet this demand means an additional 170 000 researchers each year, or average annual growth of 8.3%. From 1998 to 2005 the average annual increase in researchers was 90 457. Therefore, even if the current level of growth in the absolute number of researchers is maintained, there will be a large gap. The average growth rate of researchers was 12.7% a year from 1998 to 2005; this is likely to be difficult to sustain in the future, as the number of researchers increases. However, for this reason, the gap in the supply of additional researchers is expected to be more accurate from 2010".

Similar is the case in India too. The recent growth performance of knowledge-intensive industries in India is prompting many commentators to feel that India is transforming itself into a knowledge-based economy. The copious supply of technically trained human resource is considered to be one of the most important reasons for this growth performance. However, of late, the industry has been complaining of serious shortages in technically trained manpower. For instance a study conducted by the Federation of Indian Chambers of Commerce and Industry (FICCI, 2007) has revealed that the rapid growth in the globally integrated Indian economy has led to a huge demand for skilled human resources. However, lack of quality in the higher education sector has become a hindrance in filling the gap. The survey, based on a study conducted in 25 sectors, also showed that currently there is a shortage of about 25 per cent skilled manpower in the engineering sector.

In order to see the present supply of scientists and engineers for R&D, I introduce three concepts of human resource in science and engineering[9]: Human Resource in Science and Technology (HRST), R&D personnel, and Researchers. These are then estimated for both China and India. I estimate both the total and density as well (Table 13).

Table 13: Stock of scientists and engineers engaged in R&D in China and India

(Full time equivalent basis as of 2005)

		HRST	R&D personnel	Researchers
China	Total (million numbers)	70.34	1.36	1.18
	Density (per 10, 000 labour force)	914.98	17.69	15.35
India	Total (million numbers)	40.20	0.39	0.15
	Density (per 10, 000 labour force)	933.49	9.06	3.48

Source: Computed from OECD (2008), Department of Science and Technology (2009), and National Council of Applied Economic Research (2005).

9 The definition of HRST is broad and covers "people actually or potentially employed in occupations requiring at least a first university degree'' in S&T, which includes all fields of science, technology and engineering. R&D personnel, as defined by the OECD *Frascati Manual* (2002), are "all persons employed directly on R&D", which includes those providing direct services such as R&D managers, administrators and clerical staff. The *Frascati Manual* defines researchers as "professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems and in the management of the projects concerned".

On both the total number and on density as well, the numbers are far less than what one finds for other developed countries including that of Korea an erstwhile developing country now having joined the club of developed countries.

Two issues have an impact on the potential supply of scientists and engineers for especially domestic business enterprises. The first is an issue that has been in existence for a long time, namely the migration of high skilled personnel from China and India to the west. There is every indication that this flow has increased in recent times. The second one is the growing FDI in R&D in both the countries. Foreign R&D centres are able to offer better incentives, both pecuniary and otherwise to domestic researchers and R&D personnel than domestic business enterprises. As a result the small stock of scientists and engineers may get attracted to the foreign R&D centers and a 'crowding out' of sorts may take place. Lan and Liang (2006) has already noted this for China and my own discussions (although not based on a statistically random sample) with domestic research-oriented firms have indicated this possibility.

Apart from this supply, doubts also have been expressed about the quality of science and engineering workforce in both the countries although the quality is often difficult to measure in an objective manner.

Fortunately the governments in both China and India are very much aware of this constraint and over the last few years have instituted a large number of programmes to increase both the supply of science and technology personnel in the two countries and to improve its quality as well. China, especially has put in place many schemes to even reverse the "brain drain" from the country although India is depending much more on market means to reverse high skilled migration from the country.

Financing of innovation: Studies done across the world and especially the innovation surveys have time and again brought to the fore the importance for financing innovations as this is an area which is characterised by severe market failures. I discuss this constraint in the context of the two countries.

According to OCED (2007) some important constraints on China's financial system affect innovative activity in the business enterprise sector:

- China's financial system does not meet the funding needs of private firms, notably SMEs. The capital market is underdeveloped and SMEs find it difficult to secure loans since banks favour large companies, particularly SOEs. Smaller, privately owned firms thus largely depend on self-funding. Recent initiatives to address this issue propose funding mechanisms to support science and technology and innovation activities; and

- There is a severe lack of capital for financing new ventures, which are one important source of innovation. China lacks both the expertise and the necessary legal and regulatory conditions for an adequately functioning venture capital system. Domestic venture capital firms have been set up by the government, at national or provincial level, and are run by government officials who do not always have adequate technical, commercial or managerial skills.

India has two types of financial schemes for financing innovations: first, research grants and loans at concessional rates of interest and second, tax incentives for committing resources to R&D. First, recent analysis by Mani (2010 a) showed that much if not all of the small number of research grants and loans available for financing innovations (such as those by the Technology Development Board etc) are directed largely at the public sector although, as we have just demonstrated that, much of the innovations actually emanate from private sector enterprises. In short, there is a mismatch in the financing of innovations in the sense that research grants and concessional loans are not directed towards those sectors which are active in innovations. Second, the country has a tax incentive scheme for encouraging more investments in R&D. These incentives have been correctly fine tuned to encourage innovations in ten high and medium technology-based industries which are at the same time active in innovative activity. Mani (2010 a) endeavoured to estimate the coefficient of elasticity of R&D with respect to tax foregone as result of this incentive scheme The elasticity of R&D expenditure with respect to tax foregone as a result of the operation of the R&D tax incentive is less than unity for all the relevant industries, although it is significant only in the case of the chemicals industry. In two of the industries, namely in automotive and electronic industries the elasticity is even negative, although not significant. From this, the reasonable interpretation that is possible is that tax incentive does not have any influence on R&D, excepting possibly in the chemicals industry where it has some influence although even in this case the change in R&D as a result of tax incentive is less than the amount of tax foregone. This lack of significant relationship between R&D and tax foregone can be rationalized by the fact that the tax subsidy covers only a very small percentage share (on an average 6 per cent) of R&D undertaken by the enterprises in the four broad industry groups. So our conclusion is that for tax incentive to be effective in raising R&D expenditures it must form a significant portion of R&D investments by an enterprise. It is not thus a determinant of R&D investments by enterprises for the present.

IV. Conclusions

China and India are definitely on a higher economic growth path, although the contribution of technology to economic growth is still not very clearly estimated. There is evidence to show that innovative activities in the industrial sector in both the countries have shown some significant increases during the post reform process. Knowledge content of both domestic output and exports are increasing in both the countries.

The Chinese NSI is dominated by the SSI of the electronics and telecommunications industries and in the case of India it is led by the SSI of the pharmaceutical industry. In both the countries, increasingly much of the innovative activities are contributed by MNCs. In other words, both China and India have become important locations for innovative activities. There is even some macro evidence to show that the productivity of R&D investments in India is higher than in China, although this proposition requires careful empirical scrutiny before firm conclusions can be reached. However, continued rise in innovative activity is limited by the availability finance and of good quality scientists and engineers. Although the available supply appears to be very productive, its important that to sustain this on a long term basis and also to spread the innovation culture to other areas of the industrial establishment concerted efforts will have to be made to increase both the quantity and quality of scientific manpower. Fortunately the governments in both the countries are aware of this problem and have started initiating a number of steps towards easing the supply of technically trained personnel. But the governments still have to rethink its financial support schemes by reducing as much as possible the distortions that are currently in this area.

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