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Korea and the BICs (Brazil, India and China)

Catching Up Experiences

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Abstract

This paper tests a neo-Schumpeterian model with industry-level data to analyze how Brazil, India, and China are catching up with South Korea's technological frontier in a globalized world. The paper validates Aghion et al.'s inverted-U hypothesis that industries that are closer to the technological frontier innovate to escape competition while longer distances discourage innovating. It suggests that for effective catching up, distance-shortening (or innovation-enhancing) policies may be a necessary complement to liberalization. South Korea and China combined a variety of distance-shortening policies with financial subsidies to promote high tech industries and an export-led growth strategy. Post-liberalization, they leveraged swift competition to spur catch-up. In comparison, Brazil, which was as rich as South Korea, and India, which was as rich as China in 1980, are catching up more slowly. Import-substitution industrialization strategies saddled Brazil and India with a large anti-export bias, and unfocused attention to innovation-enhancing policies dampened global competitiveness. Post liberalization, many of their industries were too far behind the technological frontier to effectively benefit from competition. The catch-up experiences of Brazil, India, and China with South Korea illustrate that distance from the technological frontier matters and that the design of country-specific distance-shortening policies can be an important complement to trade liberalization in promoting catching up with richer countries.

This paper—a product of the Economic Policy and Debt Department, Poverty Reduction and Economic Management Network—is part of a larger effort in the department to study the role of innovation policies in catch-up in emerging market economies with the OECD countries. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The authors may be contacted at vchandra@worldbank.org, iosoriorodarte@worldbank.org or cbraga@worldbank.org.

Korea and the BICs (Brazil, India and China): Catching Up Experiences

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1. Introduction

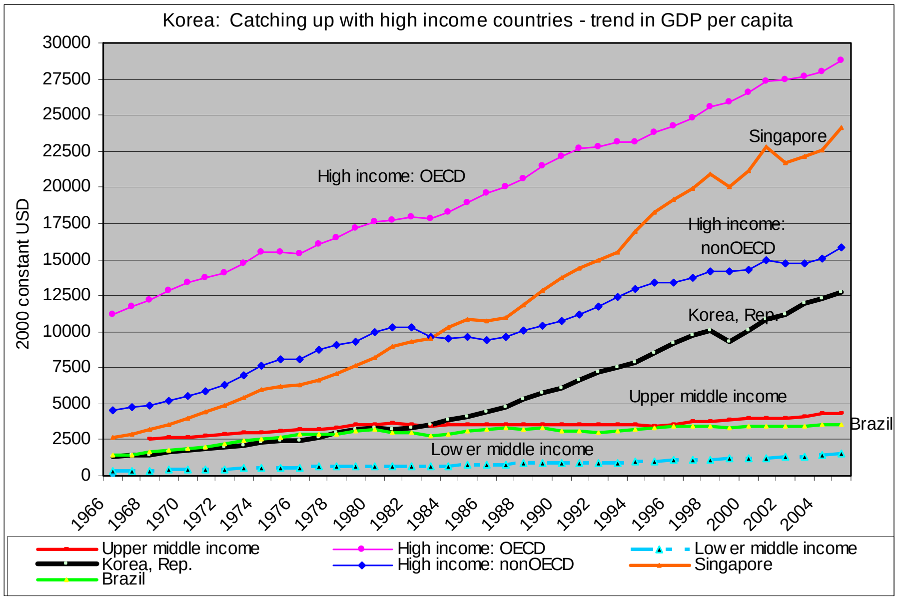
The story of how the Republic of Korea leveraged its growth strategy to begin closing the income gap with OECD countries and in less than three decades transformed itself into an innovation-grade leader is well known.[2] The catching-up game is also being pursued by many other emerging market economies such as Brazil, India, and China (the BICs), South Africa, Chile, and Russia. Interested readers are invariably drawn to two headlines with important implications for public policy. Are trade liberalization and global integration a hindrance or a help in the process of catching up with high-income economies? And why is it that after implementing trade reforms, only a handful of countries is indeed catching up?

Developing countries have good reasons to study the South Korean growth experience. It is true that even though income levels doubled (in 2000 constant US dollars) in South Korea, Brazil, and other middle-income countries between 1965 and 1980, a distinct divide persisted between this group and the OECD countries (figure 1). Around 1981, however, in a break from its steady growth trajectory, the South Korean economy experienced a growth-acceleration and began catching up with the high-income non-OECD countries. By 2007, its income per capita was $19,690 in nominal terms. In comparison, Brazil's income per capita was $5,910.

China's tale of catch up is equally impressive. Around the mid-1980s, when its per capita income was still below $200 (2000 constant US dollars), China began closing the gap with India (figure 2). By 2007, its per capita income had risen to $2,360 while India's income per capita was only $950 in nominal terms. In sum, starting at levels of income per capita typical of a low-income country in the 1950s, Korea was already a middle-income country by the early 1980s, joined OECD in 1996, and has been catching up with the OECD average income per capita – in spite of the temporary setback associated with the Asian financial crisis (1997-98). At the same time, the income gap between Korea and the BICs has widened.

[2] The denominations South Korea and Republic of Korea are used interchangeably in this text. For details about the Korean growth strategy, see, for example, Commission on Growth and Development (2008), Suh and Chen (2007) and World Bank (1998).

Figure 1: Korea and Brazil – catching up with the OECD



Source: WDI

Since the 1980s, many developing countries, both low and middle-income, have liberalized their economies and pursued greater integration with global markets with the expectation of becoming more prosperous, but only a handful are catching up with OECD economies. What can they learn from the experience of the BICs and of Korea? Moreover, among the BICs, what is China doing differently to overtake Brazil and India?

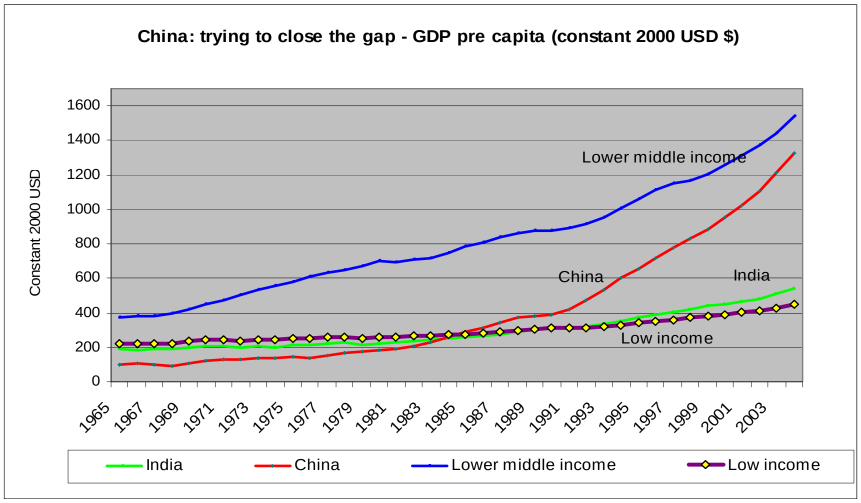
Standard neoclassical economic theory does not offer conclusive answers to these questions. It asserts that increasing the level of competition through trade liberalization, for example, improves efficiency, spurs innovation, and increases productivity growth. Empirical evidence confirms that productivity growth can contribute as much as fifty percent of overall economic growth (N. Loayza, P.Fajnzylber and C.Calderon (2005), D.M. De Ferranti et al. (2003)); it also suggests that productivity growth is powered by innovation. However, it does not indicate that liberalization automatically breeds innovation. In fact, in many developing countries, trade liberalization has not been followed by sustained innovation-powered productivity gains that have led to higher per capita incomes in the long term.

Economists have proposed two alternative paradigms to explain why trade liberalization or increased competition may not lead to a sustained increase in productivity. Schumpeter, for example, contended that economic rents were essential for innovation to occur. From this perspective, by dissipating rents, competition can adversely affect innovation. Recently, in advancing the new growth theory which is grounded in a Schumpeterian framework, Aghion et al. (2003, 2004, 2005, 2006 and 2008)[3] hypothesized that competition can have variable effects on productivity. It need not benefit all firms in an industry uniformly. Firms that are relatively technologically sophisticated and hence close to the most technologically sophisticated firm

[3] P. Aghion, R. Blundell, R. Griffith, P. Howitt, and S. Prantl (2004), P. Aghion, N. Bloom, R. Blundell, R. Griffith and P. Howitt (2005), P. Aghion, R. Blundell, R. Griffith, P. Howitt and S. Prantl (2006), and D.P. Acemoglu, P. Aghion and F. Zilibotti. (2006).

(i.e., the proxy for the innovation frontier) are able to "escape" competition from new entrants when faced with the threat of entry. They innovate to become more competitive and reap productivity gains. Firms that are farther from the technological frontier, in turn, may be hurt by competition. In recent studies of firm behavior, some researchers have found evidence that supports this argument.

Figure 2: China and India in the catch up game



Source: WDI

In this paper, we analyze how much the BICs are catching up with Korea and why. Our analysis is cast in the setting of a globalizing world market in which countries compete at the level of the industry to grow their per capita incomes and catch up. This makes sense. As tariffs, other trade barriers to imports and government policies for industrial development are usually applied at the level of an industry; hence, an industry-level analysis has policy relevance. In particular, we are interested in understanding the role of export orientation in a country's catch up. We are also interested in evaluating whether domestic market-oriented production (i.e., import-substitution) has penalized productivity growth. We find three measures of competitiveness useful in analyzing the catch-up "game": labor productivity, revealed comparative advantage (RCA) and the capability to export more high tech industrial products similar to those in the OECD export basket.

Aghion et al.'s new Schumpeterian paradigm provides the theoretical setting for our analysis. Its attention to the dynamic between competition and "distance" lends itself to our study of how trade liberalization and innovation affected the catch up of the BICs with Korea. Specifically, we apply industry level data (ISIC2 – 3 digit) to analyze why some industries in some BICs are catching up with Korea while others are not. Catch up is measured by growth in labor productivity as well as the level of labor productivity which serve as a proxy for total factor productivity.[4] Conventionally, the latter is considered a proxy for innovation. As Korea is the benchmark, its labor productivity is treated as the technological frontier. The distance from

[4] In the absence of data on the stock of capital at the industry-level, we use labor productivity as a proxy for total factor productivity. This is a reasonable assumption and can be verified from the Investment Climate Assessment surveys of enterprises for Brazil (2002; 1485 firms), China (2002; 1153 firms) and India (2004; 1420 firms). An analysis of the survey data by industry as well as for the whole manufacturing sector using various definitions of TFP indicates that there is a strong correlation between value added per worker and TFP in the BICs.

the frontier for any given industry is defined as the ratio of Korea and the BIC's labor productivity levels in that specific industry. The lower the labor productivity of a BIC, the larger will be its distance from the Korean technological frontier. Catch up is faster if a BIC is able to shorten a particular industry's distance to the frontier. We use trade liberalization, relying on reduction in weighted tariffs, as a proxy for industry level competition.

Our analysis indicates several interesting characteristics of the global catch up phenomenon as well as a new result with policy implications that complement those of the Aghion et al.'s model:

> First, on the eve of trade liberalization, whose timing and pace varied significantly among the BICs, most of the BICs' leading industries (that account for the bulk of their GDP) were a "very long" distance from the Korean technological frontier. In a set of about 30 industries, there were 8 exceptions[5] in which Brazil was within 80-100 percent of the technological frontier.
>
> Second, distance to the frontier is not fixed. In most industries, the frontier or the Korean industry's labor productivity is growing very fast. This makes it more challenging for the BICs to catch up unless their industries are growing even more rapidly. With distinctly higher rates of productivity growth, we find that select Chinese industries have acquired and maintained superior performance and had more success in shortening the distance to the technological frontier. The fact that this result holds even after we control for the efficiency-improving effects of competition in all industries supports the hypothesis that some other factor such as innovation spurred these productivity gains. Which innovation strategies are enabling China's success cannot be determined at the industry level because of data limitations, but the remarkable variation in their performance suggests that they could not be industry neutral.
>
> Third, a test of Aghion et al.'s (2006) hypothesis in our model (conducted at the industry level) finds empirical support for their findings.
>
> Fourth, we also find that regardless of competition, if an industry is too far from the frontier, it has no incentive to innovate and become competitive. As a result it is unlikely to improve its productivity and catch up. Our result has interesting policy implications. If policies that can shorten the distance to the technological frontier are implemented, it is possible to boost productivity which in turn should boost competitiveness. This result directly puts the onus of distance shortening or innovation enhancing (used interchangeably in this paper) policies on a BIC that desires to catch up in the global market. In contrast to the Aghion model that emphasizes competition policy as the source of catch up, our result suggests that in industries which are relatively far from the technological frontier, there may be a need to implement innovation-enhancing policies in addition to trade liberalization.

The outline of our paper is as follows. In section 2, we briefly discuss Aghion et al.'s theoretical framework. Section 3 discusses data limitations. Section 4 sets the stage for benchmarking Korea's technological frontier and briefly discusses Korea's catch up. In section 5, we examine China's catch up with Korea. Sections 6 and 7 do the same for Brazil and India.

[5] These were transport equipment, industrial chemicals, non-electrical machinery, paper and its products, printing and publishing products, professional and scientific equipment, non ferrous metals, and petroleum refineries.

Section 8 brings together the discussion of sections 5-7 in a comparative context to reflect on the balance between competition and innovation. It also presents our empirical results. Section 9 concludes the paper.

2. Theory and some evidence

The framework developed in Acemoglu, Aghion and Zilibotti (2006), Aghion, Bloom, Blundell, Griffith and Howitt (2005) Aghion, Blundell, Griffith, Howitt, and Prantl (2006), and Aghion, Blundell, Griffith, Howitt, and Prantl (2004) introduces potential entry and the effects of entry threat on the incumbent's investment in innovation to boost productivity growth. Foreign firms are assumed to represent the technological frontier. If the foreign firm enters and competes with a local firm which has lower productivity, it takes over the market and becomes the new dominant firm in that industry. If it competes with the local firm that has the same productivity, competition drives the profits of both firms to zero. If the potential entrant knows *ex ante* the post-innovation productivity level of the incumbent, it will enter only if the latter's post-innovation productivity level is lower than the technological frontier. Of course, assuming perfect foresight, the foreign firm will never enter if the local firm has achieved frontier innovation levels.

An increased threat of a new product has effects that are similar to those of a liberalization reform. Increasing the threat of entry encourages innovation in advanced firms, and discourages it in backward firms. The intuition for this comparative statics is as follows: the higher the threat of entry, the more instrumental innovations will be in helping incumbent firms that are already close to the technological frontier from retaining the local market. However, if they are too far away from the frontier, they have no choice of winning against a potential entrant. In that case, a higher threat of entry will only lower the expected net gain from innovation. This translates into an inverted U relationship between competition and innovation.

Aghion and Griffith (2008) note that according to the Schumpeterian model, growth results from entrepreneurial innovation. Each new innovation destroys monopoly rents generated by previous innovators. Those in favor of competition – which is fostered by trade liberalization, free entry by foreign investors, and monetary integration -- underscore that competition is necessary for innovation because it encourages new entry and provides an incentive for incumbent firms to innovate to survive competition. In contrast, the proponents of the endogenous growth paradigm argue that more intense competition may dissipate the monopoly rents that are necessary for a firm to innovate by investing in R&D and other factors that propel innovation. This can discourage entry and the emergence of new industries and have a negative effect on productivity growth (Dixit and Stiglitz (1977), Romer (1990), Aghion and Howitt (1992), Grossman and Helpman (1991)). As emphasized in Aghion and Griffith (2008, p16) "These models predict that property rights protection is growth enhancing; however, for exactly the same reason they also predict that competition policy is unambiguously detrimental to growth. Patent protection protects monopoly rents from innovation, whereas increased product market competition destroys these rents. Thus if we were to take these models at face value, when making policy prescriptions, we would never advocate that patent policy and antitrust be pursued at the same time, at least not from the point of view of promoting dynamic efficiency." [6]

In the theoretical framework of Aghion et al., when firms innovate to compete and retain or even expand their market share because of threat of entry, they engage in "escape-competition" tactics; when firms fail to innovate and compete, the authors argue that they are falling prey to the Schumpeterian effects. In their early models, price costs margins are used as the competition indicator and citation-weighted patents as a measure of innovation. In their more recent papers, the authors find that technologically advanced entry by foreign firms has a positive effect on innovation if the domestic firms are close to the frontier. The effect of entry on total factor productivity growth interacts negatively with respect to the distance to frontier. Aghion, Burgess, Redding and Zilibotti (2008) find support for the inverted U hypothesis by testing it with firm level data from Indian states for 1980-97, and Aghion, Blundell, Griffith, Howitt and Prantl (2004)) for the U.K. between 1970 and 1994. They also examine the effect of de-licensing and its effect on within industry inequality in productivity.

Carlin, Schaeffer and Seabright (2004) test the inverted U hypothesis using BEEPS data from transition economies. They conclude that innovation is higher in monopolistic industries, when there is low competition. Gorodnichenko, Svejnar and Terrel (2008) also conclude the same with additional data from BEEPS 2002 and 2005. Sabirianova, Svejnar and K. Terrel (2005, 2004) find support for the heterogeneous effect of firm entry on firm performance using data from Russian and Czech firms. In their most recent paper, Gorodnichenko, Svejnar and Terrel (2008) use data from 11,500 firms from over 27 countries and find that product market competition has a negative effect on innovation. However, their findings do not validate the inverted U shaped relationship between competition and innovation as proposed in Aghion and Griffith (2008). They support, however, the basic Schumpeterian view that monopolist market structures boost innovation.

In the remainder of this paper, using Aghion et al.'s framework, we will discuss how much the BICs have succeeded in catching up with Korea at the industry level.

3. Data limitations

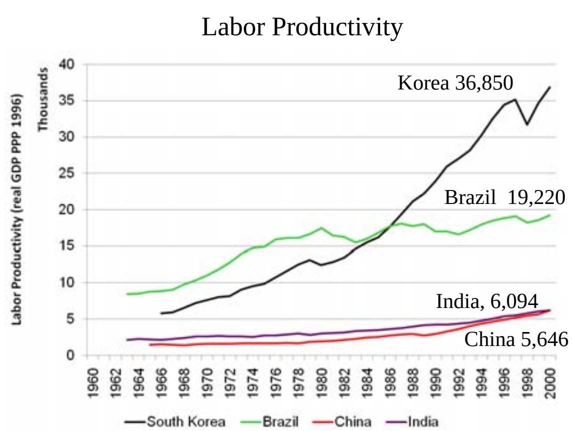
We use UNIDO's ISIC2 - 3 digit industry level data for about 30 industries for Brazil, India, China and Korea to test the predictions of the Schumpeterian model at the level of a country. A finer level of disaggregation, i.e., ISIC2-4 digit is available for Brazil and India but not for China. Moreover, Brazilian data in the UNIDO dataset is available only for 1996-2005. Trade data is available for all countries and all industries for the 1976-2005 period. Data for weighted tariffs is available for industries and most countries from the 1980s onward. Unfortunately, a full time series for non-tariff barriers is not available. Data from the Penn World tables is used to calculate TFP growth at the national level for all 4 countries for the period 1964-2000.

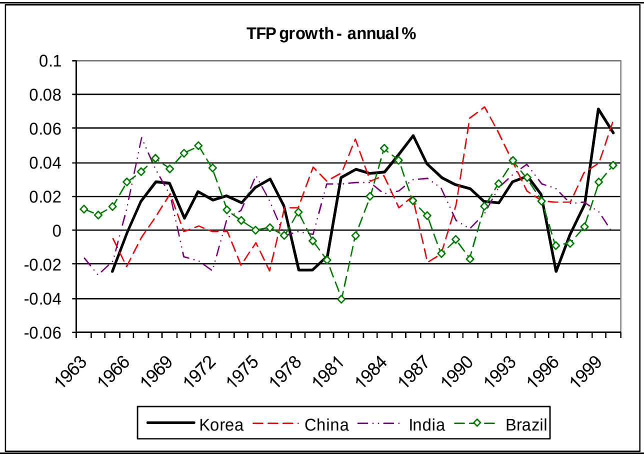
[6] For a more detailed discussion on the role of intellectual property rights in the process of economic development see Primo Braga, Fink and Sepulveda (2000).

Catch up is defined as the increase in the competitiveness of an industry in the global market especially with respect to the Korean technological frontier. Labor productivity, revealed comparative advantage from world trade data and the technological content of exports are used as proxies for the concept in question. Competition is marked by industry level tariff reduction. Ideally, innovation is measured by changes in innovation indicators, but as the latter are unavailable at the level of an industry, we only refer to innovation without explicitly measuring it. There is ample national level data on innovation indicators in OECD's Science and Technology Outlook (2008) and Science, Technology and Industry Scoreboard (2008). We do not repeat them here.

Figure 3: Benchmark – trends in catch up with the Korean technological frontier

Korea's economic performance was powered by uninterrupted and rapid growth in labor productivity since the 1960s



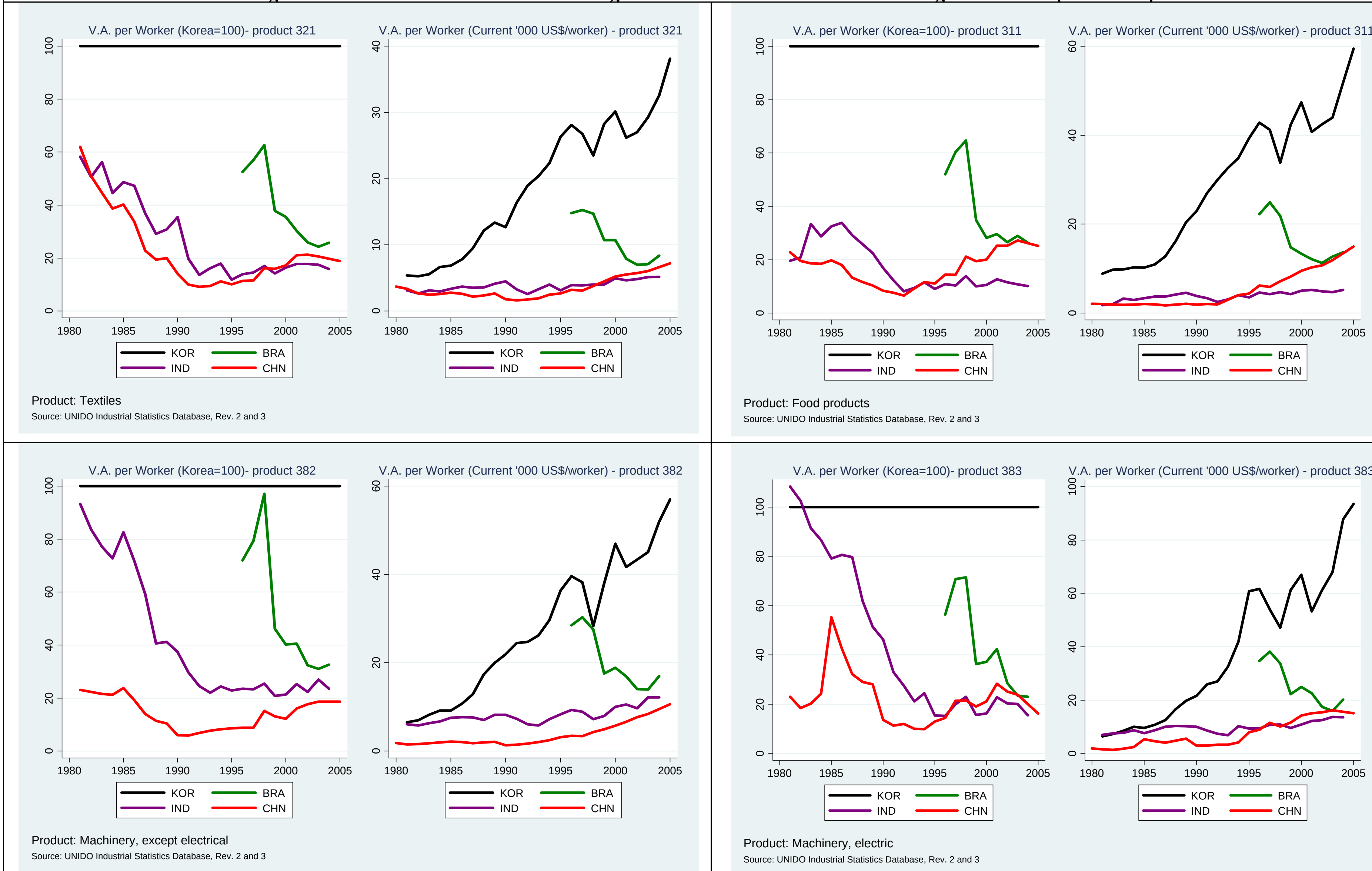


Korea's ability to outstrip middle income countries like Brazil after 1980 and catch up with the OECD was fuelled by a sustained increase in technological innovation as illustrated by trends in labor productivity in figure 3 (see footnote 4). This record was unbroken until the mid-1980s when similar trends in the growth rate of Chinese labor productivity emerged. They explain most of the miracle associated with China's catch up with Korea (figure 3). While the trend in labor productivity in the Indian economy since the early 1990s pales in comparison to the Chinese experience, it is impressive by the standards of many other developing economies.

A collapse in productivity marked Brazil's 'lost decade' and influenced the country's ability to start catching up in the 1990s. A recent upturn in the trend in Brazil's labor productivity (since 2004), however, suggests that Brazil may be beginning to benefit (in terms of its innovation performance) from its market-oriented reforms in the 1990s.

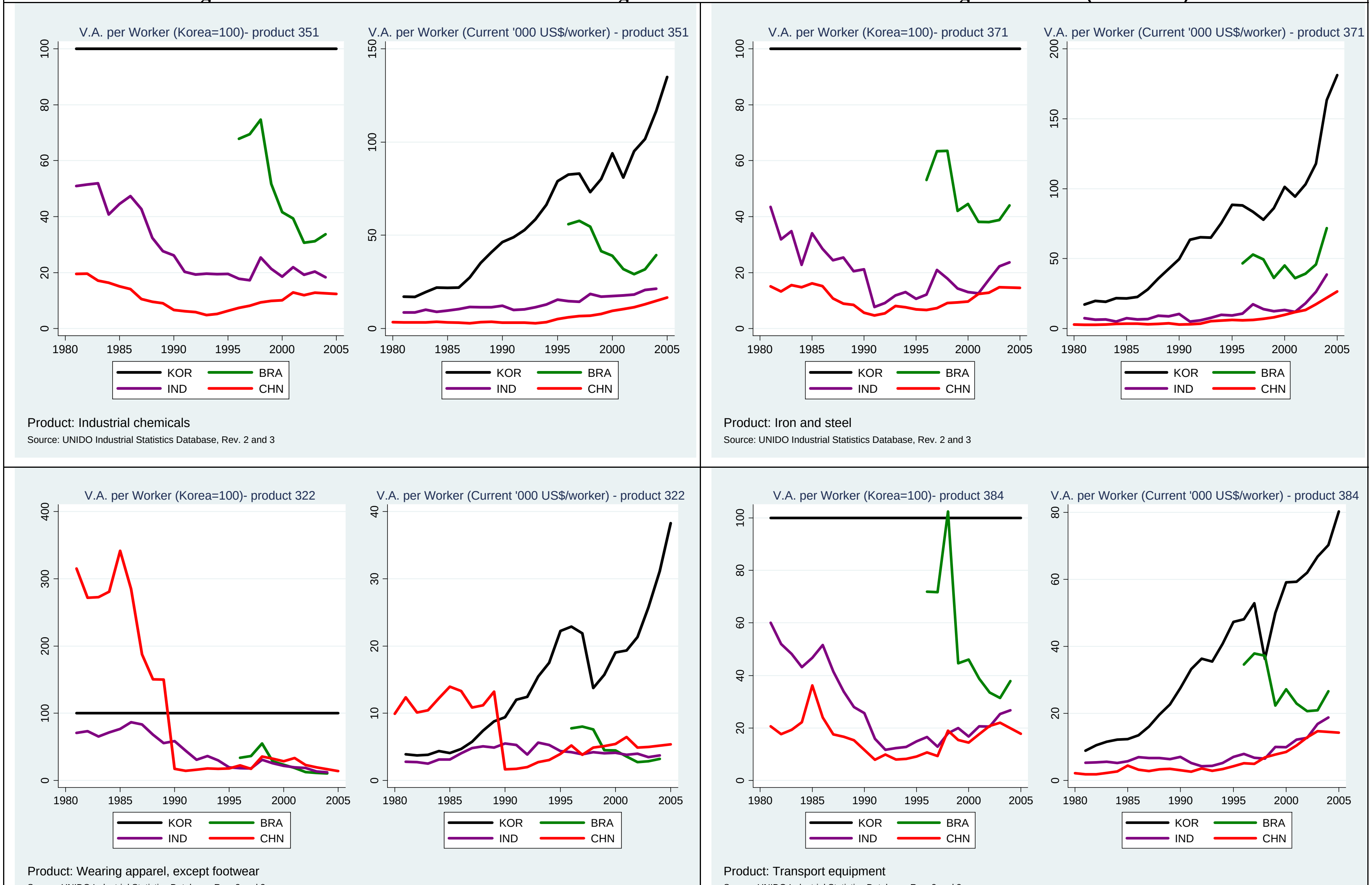
Source: Penn World Tables

Figure 4: BICs and Korea – distance of largest industries to the Korean Technological Frontier (1980-2005)



Source: Authors' calculations

Figure 4 contd.: BICs and Korea – distance of largest industries to the Korean Technological Frontier (1980-2005)



Source: Authors' calculations

4. How did Korea catch up with the OECD?

Figure 1 in the introduction of this paper illustrates the rapid pace of Korean catch up with the OECD and contrasts it with the Brazilian experience even though Brazil had a similar level of per capita income around 1980. Figure 4 displays a set of 2 charts each for 8 industries that grew to be Korea's leading industries with the highest share of manufacturing value added (MVA). The first chart presents the levels of labor productivity in the BICs relative to the Korean frontier, i.e. Korean labor productivity is set equal to 100 displayed by the flat black line. The adjacent chart for the Textiles industry for example displays the trend in labor productivity in Korea and the BICs. The first point to note is that the Korean frontier is far from the relative productivity levels in the BICs in most industries. The exceptions are a few industries in Brazil. The second point to note is that the technological frontier is a moving target as Korean labor productivity was growing much faster than that in the BICs.

Korean competitiveness is also captured by its evolving RCA in an industry. This measure is relevant in the global market place in which countries must compete if they rely on exports as a driver of growth. The set of 8 charts in figure 6 display the trends in RCA of Korea's leading industries. Most notable are the trends in relatively high tech exports such as electrical machinery, non-electrical machinery, transport equipment and iron and steel. The declining trend in Korean RCA in the textiles and wearing apparel industry exports is consistent with the diminishing importance of these industries in its growth strategy (Table 1).

Another measure of Korean competitiveness is the technological content of its exports illustrated in figure 7. Between the 1980s when Korean exports were heavily concentrated in low tech textiles and wearing apparel, and 2005-06 when its export basket was heavily concentrated in machinery for instance, there was a consistent shift in the technological content of exports from low tech towards high and medium tech products. This trend is consistent with that of OECD (Lall, 2005).

As each of figures 4, 6 and 7 illustrates, Korean productivity took off at a phenomenal pace after 1985. So how did Korea do it? Table 1 provides statistical evidence that shows certain key characteristics of the Korean catch up with OECD.

Structural transformation: Columns 5 and 6 in table 1 indicate the dramatic transformation in the industrial structure of the Korean economy between 1980 and 2004. The rank of textiles, that was Korea's number 1 industry in 1980, fell to 10 by 2004, underscoring the shift away from low tech industries. Similarly, non-electrical machinery that was number 8 occupied the 3rd rank in 2004. Overall the 10 industries listed in table 1 accounted for 84 percent of Korean MVA in 2004, up from 71 percent in 1980. The share of machinery and transport equipment had risen from 18 to 48 percent (columns 2 – 4). The growth rates in the MVA of these industries (column 7) also support this argument.

Table 1. Transformation of the manufacturing sector - change in manufacturing value added in leading industries

Korea	Share in total Manufacturing Value Added (%) 1980-84	1995-99	2000-04	Rank in 1980-01	Rank in 2004-05	Growth 1980-04(%)	Share of Share of output exported (%) 1980-81	2000-04
Machinery, electric	9.8	18.3	24.2	2	1	3008	38.5	63.8
Transport equipment	8.0	12.3	13.7	4	2	2004	5.0	32.9
Machinery, except electrical	3.9	9.6	9.7	8	3	3085	19.7	45.8
Industrial chemicals	9.2	9.9	8.8	3	4	937	9.5	36.0
Iron and steel	7.2	5.2	6.5	5	5	906	27.9	22.8
Fabricated metal products	3.9	4.7	4.8	9	6	1292	39.1	14.1
Food products	7.1	5.6	4.8	6	7	647	15.7	4.6
Plastic products	1.9	2.8	3.3	11	8	1681	4.9	6.3
Petroleum	5.2	3.8	2.9	7	9	326	1.8	1.1
Textiles	11.5	5.3	2.9	1	10	147	30.3	43.4
Other non-metallic mineral products	3.5	3.3	2.4	10	11	657	13.2	3.9
% of total	**71.2**	**80.8**	**84.1**					
China								
Machinery, electric	3.6	11.6	16.2	9	1	3047	3.2	33.7
Industrial chemicals	11.6	11.6	11.2	3	2	592	2.6	9.5
Iron and steel	7.3	7.0	10.1	4	3	694	1.6	7.2
Machinery, except electrical	14.6	8.3	8.1	1	4	256	0.7	67.5
Food products	4.6	6.6	6.8	8	5	942	7.9	10.3
Transport equipment	3.4	6.7	6.7	10	6	1667	1.7	15.0
Textiles	13.6	7.0	5.7	2	7	161	8.6	37.2
Other non-metallic mineral products	5.1	5.8	3.8	7	8	462	1.3	5.8
Tobacco	5.2	5.3	3.6	6	9	716	0.1	1.5
Petroleum	5.4	3.8	3.5	5	10	441	12.2	3.1
Non-ferrous metals	2.0	2.2	3.4	11	11	788	2.9	12.1
% of total	**76.2**	**76.0**	**79.1**					
Brazil								
Food products		14.7	14.0	1	1	-14		28.9
Industrial chemicals		13.2	12.2	2	2	-16		8.9
Transport equipment		9.1	10.4	3	3	2		32.8
Petroleum		4.8	10.3	7	4	108		0.1
Iron and steel		4.1	7.6	8	5	64		29.4
Machinery, except electrical		7.4	6.7	4	6	-24		22.4
Machinery, electric		6.1	4.4	5	7	-38		18.6
Paper and products		3.8	4.1	10	8	-6		23.1
Fabricated metal products		3.9	3.5	9	9	-23		9.5
Printing and publishing		5.1	3.1	6	10	-46		1.7
Other non-metallic mineral products		3.2	2.9	11	11	-11		12.4
% of total		**75.6**	**79.3**					
India								
Industrial chemicals	14.8	20.6	16.6	2	1	301	0.8	13.9
Iron and steel	11.6	9.6	15.1	3	2	283	0.7	12.3
Petroleum	2.8	4.2	11.4	9	3	1326	0.4	0.1
Transport equipment	8.9	8.9	9.7	4	4	268	6.0	7.4
Textiles	15.2	9.0	6.5	1	5	35	12.2	34.8
Food products	8.9	9.0	6.4	5	6	188	13.1	11.4
Machinery, except electrical	8.7	7.2	5.6	6	7	124	3.8	13.7
Machinery, electric	8.4	6.8	4.6	7	8	112	3.3	11.9
Other non-metallic mineral products	4.2	4.0	4.4	8	9	408	1.5	6.8
Non-ferrous metals	1.0	3.3	3.8	11	10	1477	1.1	10.0
Fabricated metal products	2.8	2.5	2.3	10	11	163	12.4	26.9
% of total	**87.3**	**85.0**	**86.5**					

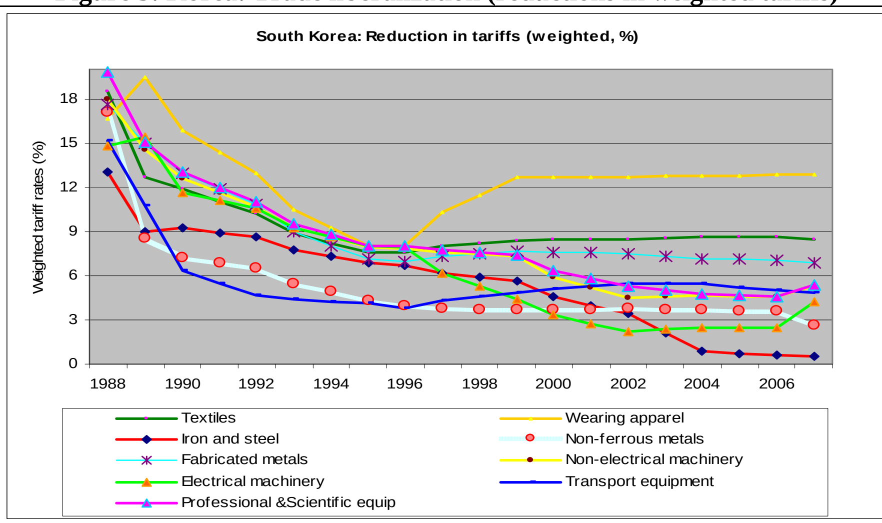
Source: UNIDO, Authors' calculations

In the remainder of this section, we argue that Korea's catch-up strategy involved a combination of interventions to promote export-led growth (even though import substitution efforts were initially pursued) and support for innovation-grade industries. In short, the anti-export bias created by import-substitution was offset by pro-export measures and the government maintained close monitoring of performance in the international market in prioritizing areas for intervention.

Export-led. Growth in select industries was powered by Korean exports. Between the early 1980s and 2004, the share of output exported increased from 38 to 64 percent in electrical machinery which was Korea's leading industry, and from 5 to 33 percent in transport, its second largest industry (table 1, columns 8-9). The overall share of exports in GDP increased from 23 to 43 percent between the 1970s and 2006. Export-led catch up could not have been possible without the competitiveness of its leading industries; the trends in the RCA of these industries validate this description of Korea's growth and catch up strategy (figure 6).

Trade liberalization. After sharpening its technological capabilities, around 1984, Korea liberalized its trade to level the playing field. Its tariffs dropped from about 18-20 percent in 1988 to less than 10 percent in the 1990s and are presently around 3-5 percent (see figure 5). A good example is the electronics industry which was nurtured with the aid of import substitution and domestically financed innovation, but evolved into a world class industry through strong export orientation. By 1993, Korea had already become a global power in the international market for electronics.

Figure 5: Korea: Trade liberalization (reductions in weighted tariffs)



Source: TRAINS database

Industrial policy. The Korean state was committed to creating a strong economy based on domestic ownership, quite reminiscent of 'big push' type industrialization. Underpinning its innovation strategy were Korea's national champions or chaebols. Selective industrial policies targeted high-tech industries centered on chaebols that were protected from global competition and given open access to subsidized finance. The two key factors in this stage were government commitment and state-owned banks that bore the risk of technological innovation (Amsden 1989).

In the first stage of development, the state adroitly used an industrial policy that was a blend of import substituting trade policies and a dedicated technological adaptation strategy. Initially, the chaebols sought to master the use of imported technologies in selected low tech export-oriented industries such as textiles, garments and footwear which became the leading industries (Kim and Nelson, 2000). Then they pursued a more sophisticated import substitution strategy aimed at replacing imported inputs with domestically produced ones. But there was always a careful balance between import substitution on the one hand, and support to technological mastery to compensate for the implicit anti-export bias of the trade regime on the other hand.

The chaebols were the pillars of Korea's industrial development policy and the list of handpicked industries which covered them was regularly revised. For example, during the 1970s, the focus was on heavy chemical industries; in the 1980s on labor intensive export industries and from the 1990 and onwards, on high tech IT products and components (e.g., dynamic random memory chips, thin-film-transistor liquid crystal displays). In each case, there was a clear market test in terms of judging the success of the targeted industries by their performance in the global market.

The seeding and expansion of the chaebols created an oligopolistic market structure in major industries. For example, in the early 1980s, the top ten chaebols including Hyundai, Samsung, Daewoo, and LG produced 20 percent of Korea's manufacturing output.[7] The chaebols operated as a highly-leveraged Schumpeterian agent for change in which a centralized industrial structure favored big firms seeking to pursue innovation based on scale economies (Wang, 2007). The targeted industries received long term fiscal incentives and financial subsidies which included tariff exemption for importing intermediary goods, tax incentives, preferential access to capital, accelerated depreciation of imported equipment and subsidized prices of energy and transportation. The government also intervened in the banking system, directing subsidized lines of credit to certain sectors, projects and firms.

The Ministry of Trade and Industry used a two-phase policy towards FDI. In the first phase, there was a restrictive policy towards FDI and a lenient one toward contractual licensing. Government reserved the right to reject "undesired investment." Local content requirement and export quotas were imposed (Kim and Nelson, 2000). In the second stage, the Foreign Capital Inducement Act was revised to encourage FDI. There was special treatment for high tech industries.

Innovation policy (distance shortening strategies). The Korean government set up public R&D facilities, but the chaebols were the major source of assimilation and innovation of technology in the initial stages of the process. The technological content of production and exports was emphasized. The Korean chaebols transformed themselves from technological followers into technological leaders by taking advantage of scale economies and receiving strong support from the state for their own R&D.

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[7] The chaebols were also conceived as a mechanism to partly offset the disadvantage of limited entrepreneurial talent. Conglomerates like the Samsung Group and Hyundai Group pioneered new industries (shipbuilding, automobiles and semiconductors ahead of their time). They sometimes cooperated with the government in the areas of economic planning and innovation but the government also encouraged competition among the chaebols in strategic areas to avoid excessive market power.

The Republic of Korea invested roughly 0.5 percent of GDP in R&D in the mid-1960s with the government responsible for 80 percent of the investments. By 1995, gross R&D expenditures (GERD) already represented 2.3 percent of GDP with the private sector responsible for 80 percent of these expenditures. Korea's GERD was significantly larger than the OECD average (2.07 percent) but still behind the GERD for the U.S. (2.51 percent). By 2006, Korea's GERD of 3.2 percent positioned it among the OECD leaders. The corresponding figures in 2005 were 2.6 percent for the U.S. and 2.25 percent for the OECD.[8] In parallel with a greater role of the private sector in R&D, the government has continued to foster university-industry linkages through fiscal incentives and government procurement of advanced technologies. On almost all indicators of human resources for S&T, Korean scores exceed those for China by a large margin.

By the early 1990s, the technological capability of Korean firms had transformed into innovation grade. According to the metric of the number of patents granted by the US Patenting Office, Taiwan, China became the eighth and Korea the ninth largest recipient of patents surpassed only by the US, Japan, Germany, the UK, France, Canada, and Italy in 2003 (OECD, 2008).

There are also other dimensions of the Korean model that contributed to an innovation-friendly environment: a high savings rate, broad macroeconomic stability (since the 1980s), and a high level of investments in education. Our focus here, however, is on the distance-shortening policies pursued by South Korea and discussed further in section 8.

5. How much has China caught up?

In the early 1980s, China's distance to the Korean technological frontier[9] was extremely 'long' in most industries (figure 4). It was 80 percent in the Food industry, Industrial chemicals and Iron and steel industries, and about 60 percent in Electrical machinery and Transport. Textiles were China and Korea's largest industry and China's distance to the Korean technological frontier in this industry was about 60 percent but in the Wearing Apparel industry, Chinese productivity was about 300 percent greater than Korea's.

Throughout the 1980s and the early 1990s, China's distance to the frontier grew even *longer* for two reasons. First, the Korean technological frontier was not static – in nearly every industry, the frontier was a rapidly moving target -- a reminder that catch up is not about closing a fixed gap, but requires a country to grow at a rate that outpaces productivity growth in the frontier country (for each industry, see the adjacent chart in millions of US $). In 1980-96, China's leading industries had productivity growth rates that were significantly below those of Korea. As an example, Chinese productivity growth in Industrial chemicals was only 4.6 percent compared to 11.4 percent for Korea; only 5.4 percent in Iron and steel compared to 12 percent for Korea and so on (table 2). Since 1997 however, Chinese productivity growth has been in the double digits relative to the drop to single digits in most Korean industries. The second reason why China's distance to the frontier widened throughout the 1980s is that the productivity dividend from its liberalization reforms did not begin to accrue in large measure until almost the mid1990s.

[8] See Dahlman (2008) and OECD (2008) for further details.
[9] Distance to the frontier is measured by manufacturing value added per worker.

In comparison to the other countries analyzed, however, Chinese productivity growth was phenomenal during 1995 and 2000 (see set of 8 charts in figure 4). Even though Indian productivity levels were higher than China's in almost every industry prior to 1995, China's productivity growth outpaced India's and led to a narrowing of the productivity gap between China and India. The shrinking of the productivity gap between China and Brazil is even more remarkable. In 1995, the gap was significant in most industries but in the following 10 years, China's productivity exceeded Brazil's in a consistent manner. In short, while China's distance to the Korean technological frontier is still "long," its rate of catch up has far outpaced that of other BICs.

China's catch up with Korea in terms of global competitiveness can be also tracked by its revealed comparative advantage (RCA) in key industries (figure 6). In the 1980s, China had the highest RCA levels among the BICs and Korea in exporting Textiles. Even as it and Korea diversified away from textiles towards other industries, China maintained its global edge over the Korean Textiles industry. By 2002, Korea was no longer competitive in the industry (its RCA dropped under 1). In Wearing Apparel too, China's RCA was below Korea's in 1980, but had exceeded it by the mid-1990s by which time Korea became uncompetitive in that industry.

Another remarkable aspect of the extent of China's catch up with Korea is the transformation in the technological content of its exports. Lall (2000) observed that in the post World War II period, countries whose export baskets transformed from relatively low-tech products towards high-tech ones grew the fastest. In fact, Korea's catch up with the OECD countries is strongly correlated with its success in bolstering the technological content of its exports in the direction of OECD exports. China's success in rapidly transforming its weak technological capabilities and developing a RCA in more sophisticated and dynamic industries is reflected in Figure 7. By the 2000s, it exported a large proportion of relatively higher tech products that displayed a structure of exports that resembled Korea's far more than that of either Brazil or India.

Table 2. Industrial Value Added Per Worker, Average Growth Rates

		Brazil			China		
ISIC Code	*Industry Description*	*1980-96*	*1997-00*	*2001-05*	*1980-96*	*1997-00*	*2001-05*
311	Food products	n.a.	-10.6	1.1	8.5	11.8	9.5
313	Beverages	n.a.	1.9	-9.2	6.4	13.2	7.5
314	Tobacco	n.a.	-4.0	-4.4	6.6	12.6	14.1
321	Textiles	n.a.	-6.9	-4.5	0.4	13.4	6.7
322	Wearing apparel, except footwear	n.a.	-10.8	-6.8	5.1	3.0	0.9
323	Leather products	n.a.	-8.7	4.4	7.9	0.6	-0.9
324	Footwear, except rubber or plastic	n.a.	-12.9	-4.2	n.a.	n.a.	n.a.
331	Wood products, except furniture	n.a.	-7.9	6.6	7.5	13.4	5.7
332	Furniture, except metal	n.a.	-8.1	-0.9	4.3	13.0	0.6
341	Paper and products	n.a.	1.7	-1.3	4.6	11.0	10.0
342	Printing and publishing	n.a.	-6.7	-3.5	5.8	21.2	5.2
351	Industrial chemicals	n.a.	-8.0	1.5	4.6	11.8	11.9
353	Petroleum refineries	n.a.	24.9	-1.2	1.6	15.5	7.6
355	Rubber products	n.a.	-6.0	2.7	0.4	7.8	8.8
356	Plastic products	n.a.	-10.6	-0.5	3.9	11.1	2.1
362	Glass and products	n.a.	-5.8	0.9	3.3	19.9	5.3
369	Other non-metallic mineral products	n.a.	-4.3	-0.1	3.7	14.6	12.1
371	Iron and steel	n.a.	1.1	15.6	5.4	14.2	22.1
372	Non-ferrous metals	n.a.	2.0	5.1	4.7	13.7	15.4
381	Fabricated metal products	n.a.	-9.8	0.6	1.3	12.0	6.1
382	Machinery, except electrical	n.a.	-7.8	-1.6	5.5	13.7	13.2
383	Machinery, electric	n.a.	-5.9	-3.6	16.5	13.6	1.4
384	Transport equipment	n.a.	-2.6	0.6	7.9	14.6	11.4
385	Professional & scientific equipment	n.a.	-3.0	-1.8	5.6	24.1	7.7
390	Other manufactured products	n.a.	-9.3	-6.0	7.9	5.7	1.0

		India			Korea		
ISIC Code	*Industry Description*	*1980-96*	*1997-00*	*2001-05*	*1980-96*	*1997-00*	*2001-05*
311	Food products	9.0	2.6	1.3	11.4	3.9	5.3
313	Beverages	5.3	5.0	1.0	13.6	8.7	9.6
314	Tobacco	7.3	11.9	3.4	14.9	1.6	1.3
321	Textiles	3.1	6.5	1.2	12.1	2.5	5.3
322	Wearing apparel, except footwear	4.3	-0.1	-2.2	13.1	-1.5	15.3
323	Leather products	4.4	-5.8	5.8	11.7	2.2	6.8
324	Footwear, except rubber or plastic	3.6	8.0	-2.5	14.6	-2.6	9.9
331	Wood products, except furniture	6.3	-3.2	3.9	16.0	2.8	5.2
332	Furniture, except metal	1.8	36.4	4.3	14.1	3.1	7.4
341	Paper and products	4.2	19.3	-2.9	13.3	4.2	1.5
342	Printing and publishing	4.2	10.3	2.7	12.6	1.7	4.6
351	Industrial chemicals	4.1	5.2	5.4	11.4	3.9	8.2
353	Petroleum refineries	10.4	16.5	34.1	14.7	3.6	22.4
355	Rubber products	5.3	6.2	1.3	19.5	-0.5	9.4
356	Plastic products	2.9	11.6	5.5	13.8	0.5	6.7
362	Glass and products	3.5	16.4	12.5	16.6	11.8	4.3
369	Other non-metallic mineral products	5.7	11.3	7.1	11.4	5.3	6.2
371	Iron and steel	6.0	9.5	33.6	12.0	4.1	13.3
372	Non-ferrous metals	10.8	3.2	18.8	12.1	4.6	9.8
381	Fabricated metal products	1.8	4.5	5.1	12.8	-3.1	7.3
382	Machinery, except electrical	3.5	3.2	5.8	13.1	7.1	4.3
383	Machinery, electric	3.0	4.4	5.8	16.9	3.5	8.2
384	Transport equipment	3.8	8.4	17.9	12.2	8.6	6.4
385	Professional & scientific equipment	4.0	5.8	14.5	13.3	4.5	6.3
390	Other manufactured products	8.4	6.1	5.5	13.7	0.3	6.6

Source: Author's estimates using UNIDO Database / Data adapted to ISIC Rev. 2 – 3 digit

Figure 6: China maintained its edge in Textiles and rapidly closed the gap with South Korea in Wearing Apparel

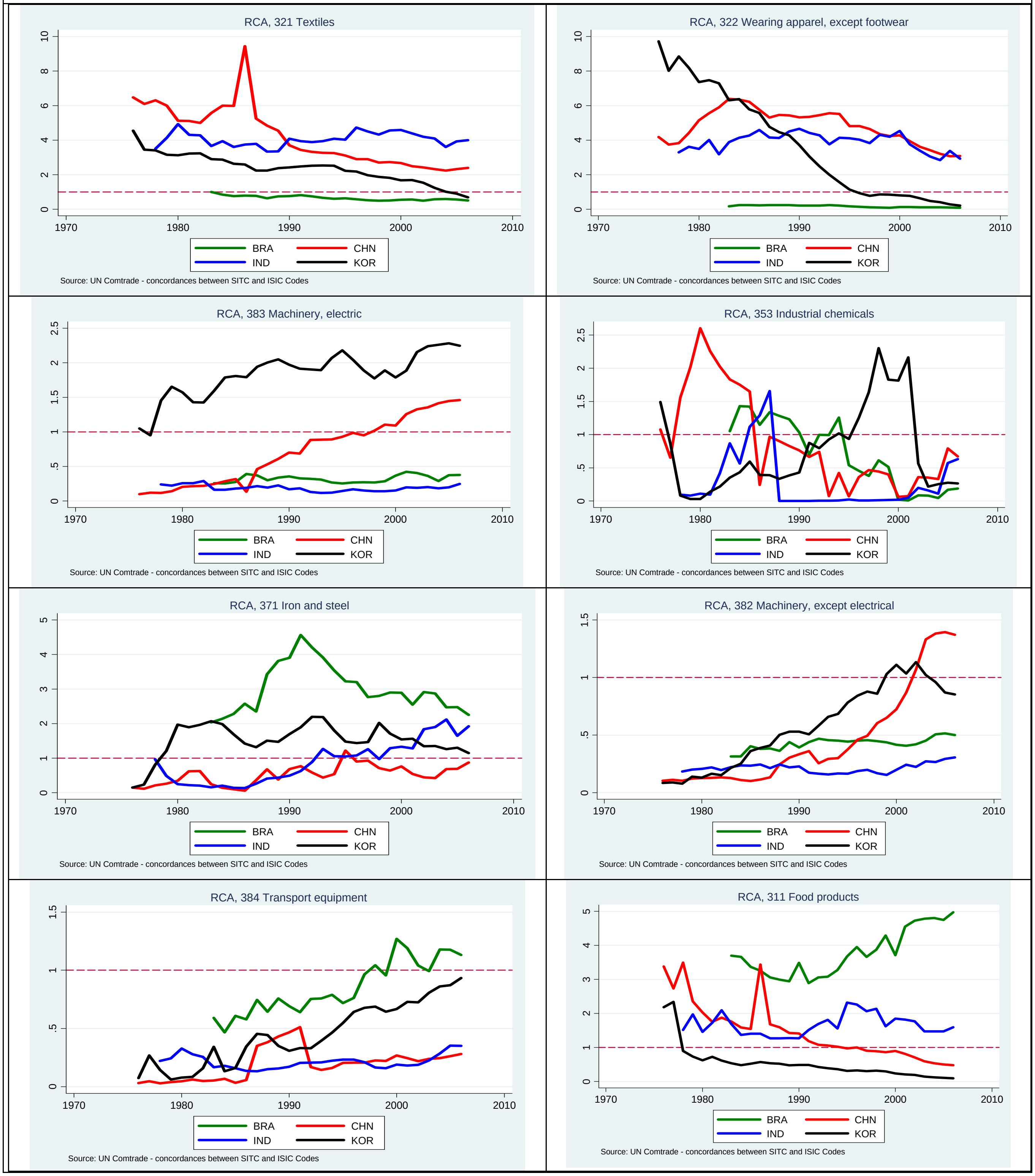
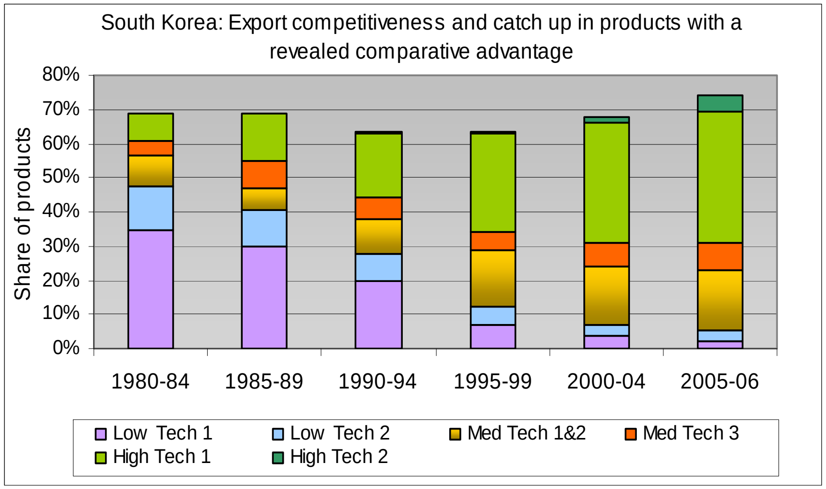
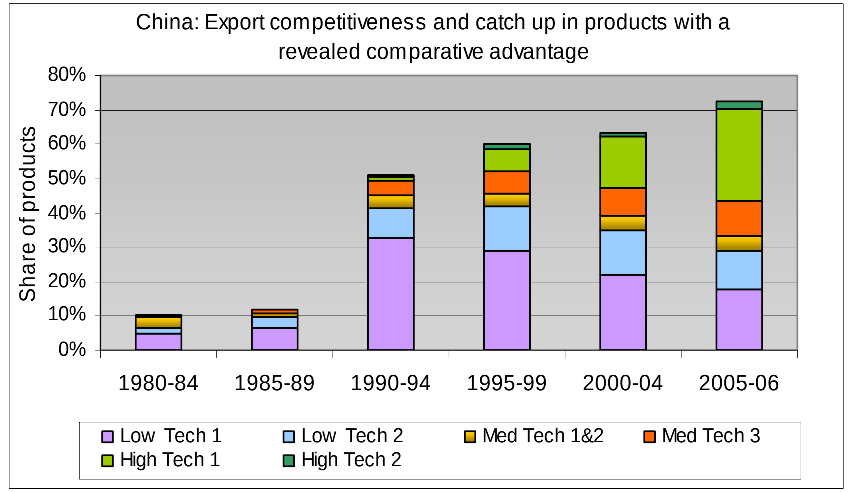


Figure 7: Export transformation and technological catch up

Relative to Korea, China's competitiveness has increased in two ways: the share of exports in which it has a RCA (greater than 1) is the same as Korea's, and the medium and high tech content of its exports has increased significantly more than Brazil or India.





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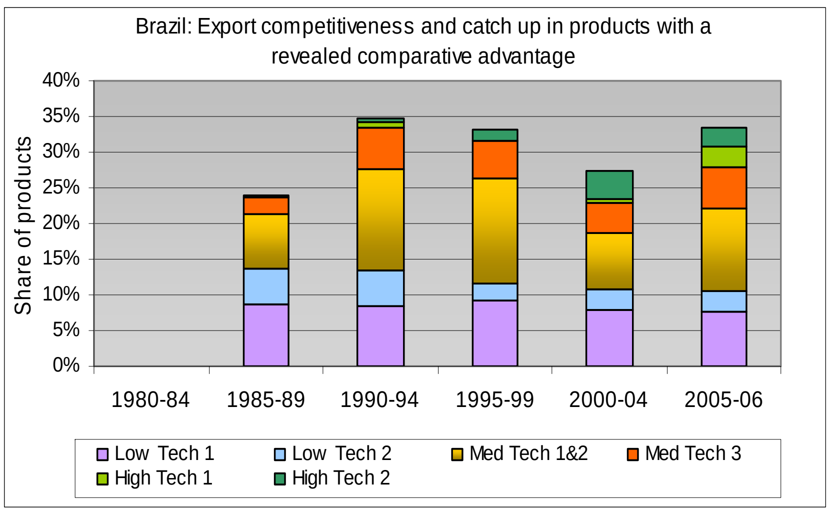
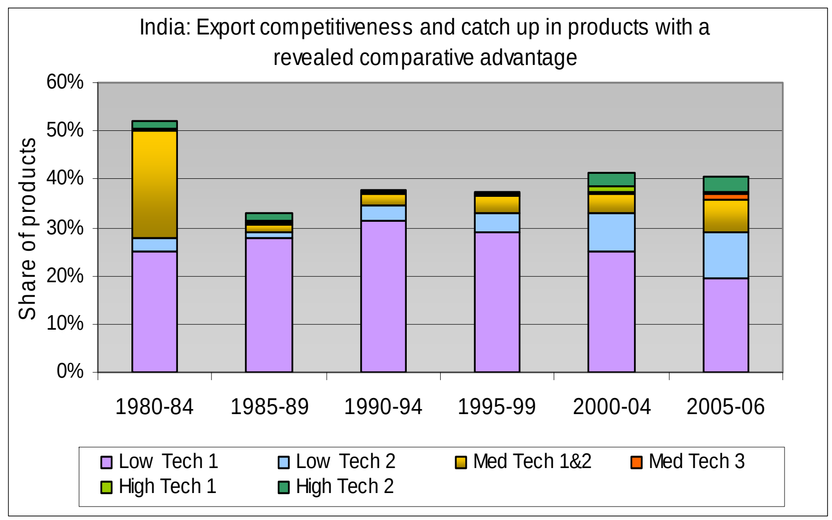


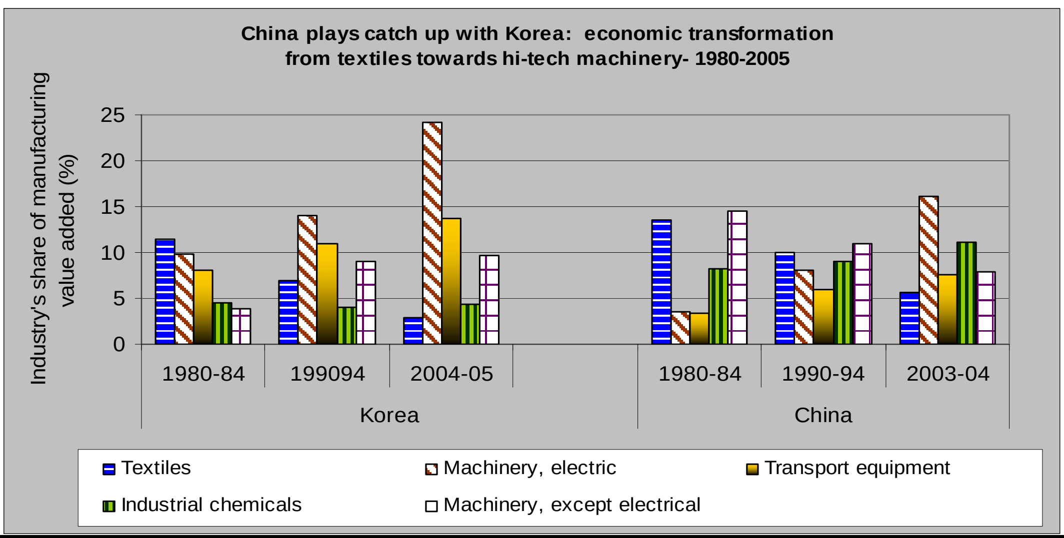


Source: COMTRADE and authors' calculations

How did China catch up?

The industrial transformation of China lagged that of Korea's by a decade but its catch up with Korea was no accident. It reflected the outcome of an industrial strategy designed to emulate the successful catch up of Korea and other newly-industrializing countries with OECD countries about two decades earlier. At least three distinct characteristics indicate how China shortened its distance to the technological frontier and grew faster than the other BICs. The first is selectivity. The sources of productivity growth were concentrated in a select group of about 5 or 6 industries whose individual shares were at least 5 percent. As their collective share in total manufacturing value added (MVA) increased from about 58 percent in 1980-81 to nearly 70 percent in 2004 this set of industries became the drivers of China's catch up (refer back to table 1) .

Figure 8: China mimics Korea's economic transformation

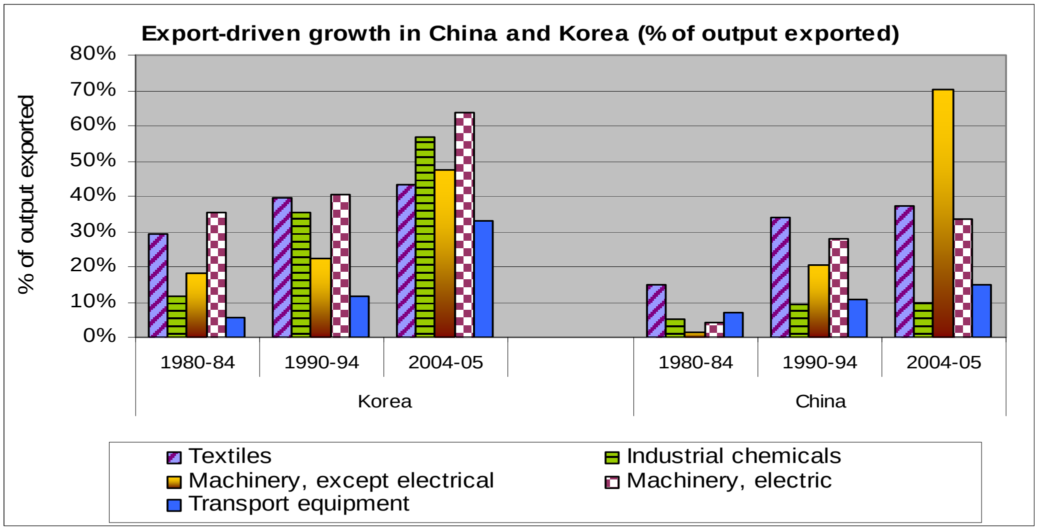


Source: COMTRADE, UNIDO, Author's calculations

The second distinct feature of China's catch up was a discrete shift from industries with a lower technological content towards those with a higher one (table 1). For example, between 1980-2005, the changing ranks of high tech Electrical machinery from ninth to first place and of low tech Textiles from second to seventh place was the outcome of technological innovation similar to that in Korea where these two industries traded first and tenth places (figure 8 and table 1). Another example is the Chinese transport equipment industry which moved up from tenth to sixth place in step with the shift of the same industry from fourth to second place in Korea (figure 8). These structural shifts reflected acceleration in labor productivity that narrowed the distance with the frontier and could not have occurred without significant and swift technological innovation in China.

The third characteristic of China's catch up model indicates that similar to the Korean export model, productivity growth is export driven as evident from the sharp increase in the export content of its leading industries (table 1 and figure 9). As an example, as much as 70 percent of the total production of non-electrical machinery was exported in 2004-05 compared to only 20 percent in 1990-94.

Figure 9: Export led catch-up in Korea and China – the share of output exported was rising

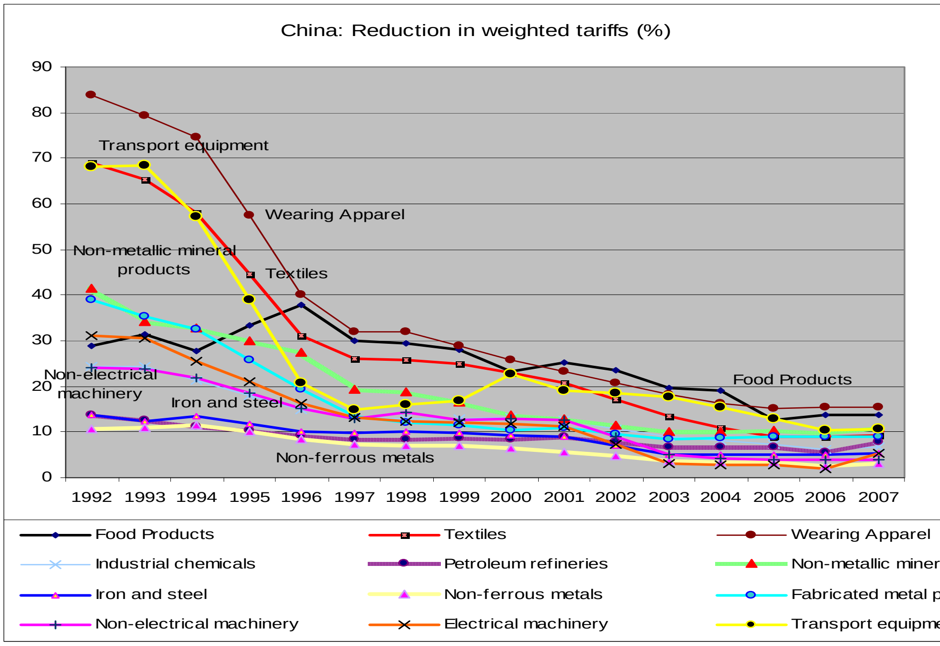


Source: Author's calculations, COMTRADE data.

The Chinese catch-up model was founded on a strategy that gradually distanced the Chinese economy from its original inward-looking (socialist) model of self-reliance. As in South Korea, China's export-led catch up strategy relied on competition in the global market to serve as a screening mechanism to identify globally competitive industries. This was reinforced with policies that maintained a stable macroeconomic environment while attracting foreign investors.

The timing and pace of foreign competition measured by tariff cuts sheds *some* light on the differences among the BICs in their pursuit of economic integration with the world economy. China cut its tariff rates drastically from about 32 percent in 1993 to 16 by 1996 and 2 percent by 2006 (figure 10). In contrast, in the late 1980s, the tariffs on imports of Electrical machinery were 81 percent in India and 46 in Brazil. The Chinese Electrical machinery industry continues to grow post liberalization but its relative position signals that the lowest rates of protection does not guarantee a competitive edge forever. Even though its absolute size was larger than the same industry in Brazil, India or Korea, in 2005, China's distance from the Korean productivity frontier was widening. The latter had begun in 2000 and suggests that the pace of technological innovation in Korea is speeding ahead of the BICs. A new wave of technological innovation is required if China wants to continue to catch up with Korea in this high tech industry.

Figure 10: China - trade liberalization



Source: TRAINS database

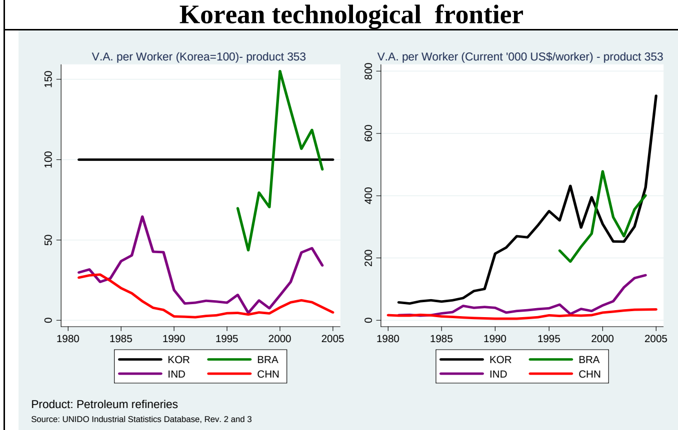
The Chinese brand of "distance shortening" cum industrial policy interventions seem to explain its success in moving closer to the frontier, significantly ahead of Brazil and India (figure 4). China transformed from high tech original equipment manufacturing (OEM) contractor to a global competitor in high tech exports by leveraging foreign technology through FDI which became the means to access capital and introduce competition in the domestic economy. FDI was also used as a distance-shortening mechanism. Instead of waiting for its technological capabilities to mature, China used its 'open door' policy to let the 'market for technology' model coordinate FDI, foreign trade and technology transfer to modernize its economy (OECD, 2008). Until the 1990s, China relied heavily on imported technology especially from Japan and help with the training of engineers in Toshiba, Changhong and Sanyo (Mathews, 2009). In recent years, its own technological capabilities have improved and "indigenous innovation" is being given priority (OECD, 2008). This is distinct from Korea's experience in which the country put the main onus of developing a pool of technological capabilities on itself.

In the past few years, the Chinese government has initiated a variety of measures to speed up convergence with OECD policies. These include enhanced public R&D and tax incentives, government facilitated absorption of imported technology, active use of IPRs and other international standards. Its GERD is 50 percent larger than Brazil's and its business enterprise expenditure on R&D (BERD) almost 100 percent larger. China is almost at par with Korea in terms of the strength of the industry-university linkages proxied by the share of R&D financed by industry. National Guidelines for Science and Technology Development offer tax incentives for business R&D, public procurement, industrial research alliances, and human resource development in S&T to ensure that its industry is not constrained by the paucity of skilled and technical workers (OECD S&T Outlook, 2008). In 2005, as a percent of all new degrees, China had a larger proportion of science and engineering degrees than Korea and nearly four times as many as Brazil. The government is also offering special incentives to attract the Diaspora, rewarding scientific talent, financing for basic research and support for technology innovation and commercialization (OECD, 2008). For this purpose, it has established 18 leading universities and 9 key research organizations. Its national innovation system has shown that China excelled in mobilizing financial and human resources for S&T development on a large scale and has made major progress in R&D indicators (OECD, 2008).

6. Brazil: Decline and recovery

From its position close to or on the Korean technological frontier in many industries in the 1980s, Brazil's productivity levels slid throughout most of the 1980s and 1990s largely in response to an unstable macroeconomic environment and the absence of healthy competition. Around 2000, labor productivity growth started to pick up (table 2). Even though recovery has been sustained, Brazil still has significant catching up to do.

Figure 11: Brazil's petroleum industry was close to the Korean technological frontier



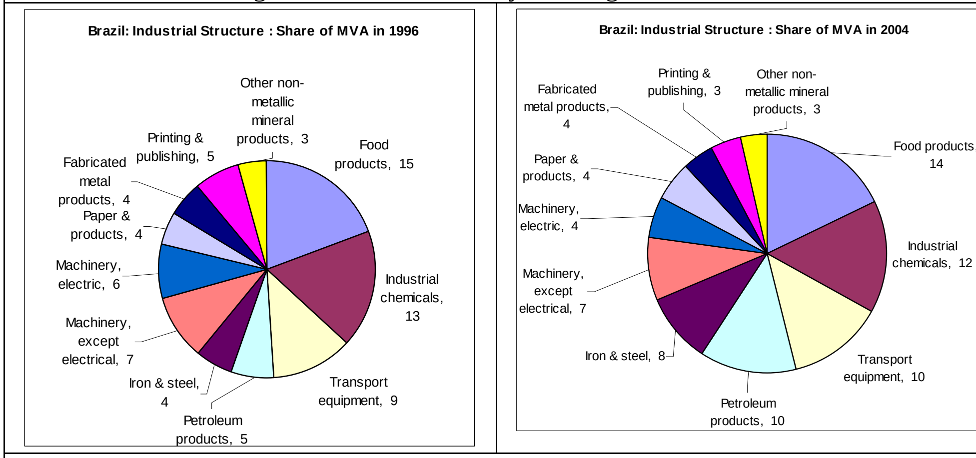
Source: COMTRADE, authors' calculations

Statistical evidence suggests that the distance of Brazil's leading industries from Korea's productivity frontier depends upon the timing of competition and the industry's distance from the frontier *prior* to reform.[10] Consider examples from its largest industries (figure 4). In 2000, the Brazilian Food industry's distance from the frontier was about 25 percent, the same as China's (figure 4). Even after recovering during 2000-05, this distance has not narrowed mostly because the frontier has moved forward faster. Similarly, the distance has widened in Electrical Machinery. Interestingly, in Industrial chemicals, Transport equipment and Iron and steel, productivity levels are converging albeit only gradually. Most notable is the relative productivity trend in the Iron and steel industry in which Brazil was significantly close to the frontier in 2000. Even better, in the Petroleum refining industry, Brazil's technological performance exceeded Korean levels in 2000 (figure 11).

[10] In 1996 and 2004, they were Food products, Industrial chemicals, Transport equipment, Iron and Steel, Petroleum, Electrical machinery and Non-electrical machinery – each had a share of 4 or more percent.

Figure 12: Brazil – limited structural transformation

Except for a doubling in the share of petroleum products, the relative importance of Brazil's leading industries was virtually unchanged between 1996 and 2004.



Source: UNIDO, authors' calculations

The Korean experience of catching up with the OECD and Chinese experience of catching up with Korea were positively correlated with a rapid transformation of the industrial structure. This did not occur in Brazil. A widening of the distance from Korea's technological frontier in some of its largest industries and narrowing in others on average preserved Brazil's industrial structure - in 2005 it was not too different from that in the 1990s. This is discernible in the relatively unchanged shares of Brazil's medium and high tech industries during this period (figure 7). Interestingly, the share of medium tech industries in Brazil was significantly higher than in Korea in 1985, but had not changed by 2005-06. And Brazil's high-tech industries remained relative laggards in comparison to the Korean technological leaders.[11]

Unlike Korea or China, Brazil's catch up strategy was neither selective not focused on leveraging innovation to catch up. It did not invest heavily in distance shortening policies that would have pushed it closer to the frontier when it initiated trade liberalization in the 1990s. Consequently, an inward-oriented economic orientation and a slower pace of reforms have limited industrial transformation even after Brazil opened up (figure 12).

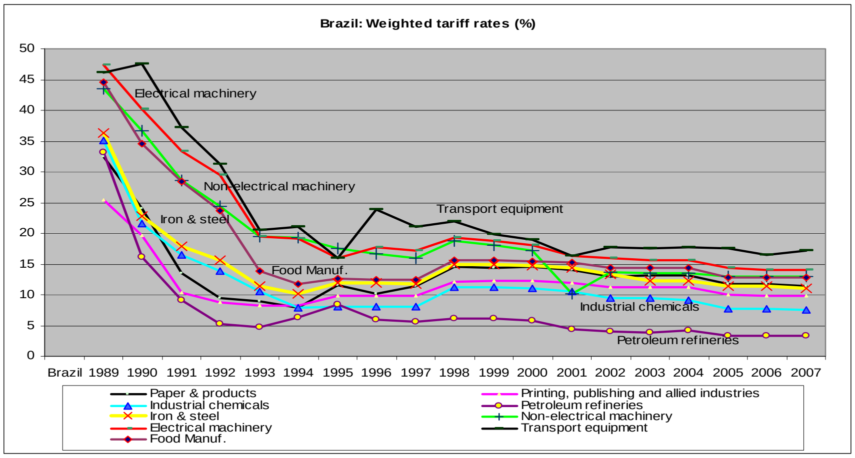
Reforms – competition and innovation[12]

In the late 1980s, protection rates in Brazilian industries were clustered into two main sets. The Food, Transport and Machinery industries were farther from the frontier and had nominal rates of 45-50 percent. The Petroleum products, Iron and steel, and Industrial chemicals industries were closer to the frontier and had tariffs in the range of 25-35 percent. Tariff rates in the other industries were also in the lower range. Tariffs declined with liberalization in the 1990s (figure 13), but with the exception of Food, the assignment of industries in the low or high tariff brackets did not change. In 2007, tariffs on most industries were between 8 – 17 percent in comparison with Korean tariffs that were already below 5 percent.

[11] See I.Costa and S.R.Reis de Queiroz (2002), and C.H.B.Cruz and L.de Mello (2006).

[12] For a recent account of the evolution of Brazil's trade policies see Lattimore and Kowalski (2008).

Figure 13: Brazil – trade liberalization



Source: TRAINS database

Brazils' catch up has suffered in part because of a lack of sustained effort to build its technological strength which underlies competitiveness. Undoubtedly, macro disturbances in the 1980s and 1990s also conspired against innovation. With one notable exception, the declining RCA in Brazilian industries illustrates the declining competitiveness of the manufacturing sector. A review of Brazil's innovation policy suggests that post reform, the only industry that evolved into a world class industry is Food products (including ethanol-related industries). The latter benefited disproportionately from S&T-oriented public investments in EMBRAPA which is a government agricultural research organization created in 1974. Similarly, public innovation funds channeled into Petrobras nurtured world-class petroleum-related activities.

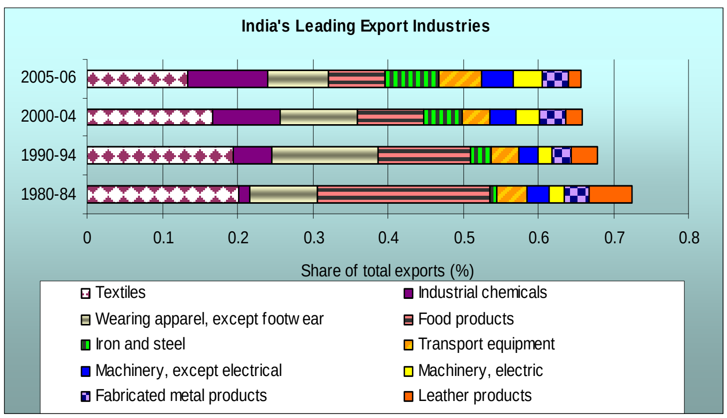
While the Brazilian government has been spending more public funds in financing R&D (close to 1 percent of GDP), synergies between public-sector funded research institutes and private firms in the manufacturing sector remain limited. Compared with about 30 percent in the United States, about 55 percent of the total investment in technological innovation in Brazil is publicly funded (World Bank, 2007) but it has been less successful at energizing technological innovation or patents that can be commercialized. Its import substitution policies shielded its private sector, undermined incentives for private R&D and led to underperformance in innovation. Recent initiatives such as the Innovation Law and the Sector Funds that are aimed at encouraging firms to invest in innovation are attempts to correct these distortions (Katz, 2000).[13]

[13] It has also been noted that overly "theoretical" research in publicly funded universities partially explains why the latter are of little use to entrepreneurial scientists and engineers who do not interact with universities. As an example, Brazil accounts for nearly 2 percent of articles published in internationally recognized research journals, but only 0.18 percent of the patents (OECD S&T Outlook, 2008). Its average educational attainment is the next-to-lowest gross enrollment rate among the larger Latin American countries. Only 8 percent of the labor force has tertiary-level educational qualifications.

7. India: Another latecomer

In the catch-up game of the BICs, India is the indisputable laggard. In the early 1980s, India and China were neck and neck on the economic development plane. By the late 1980s, impressed by China's rapid growth, the Indian government implemented a gradual reduction in tariffs. The proponents of liberalization believed that opening up the economy to global competition would usher in increased efficiency and boost productivity. It opponents contended that competition would wipe out many Indian industries that only served the large domestic market behind tariff walls. As in the case of Brazil and China, both possibilities panned out just as Aghion et al.'s model predicts.

Figure 14: India's leading export industries were the same in 1980 and 2006. They signaled the slow pace of export sophistication and catch up



Source: COMTRADE

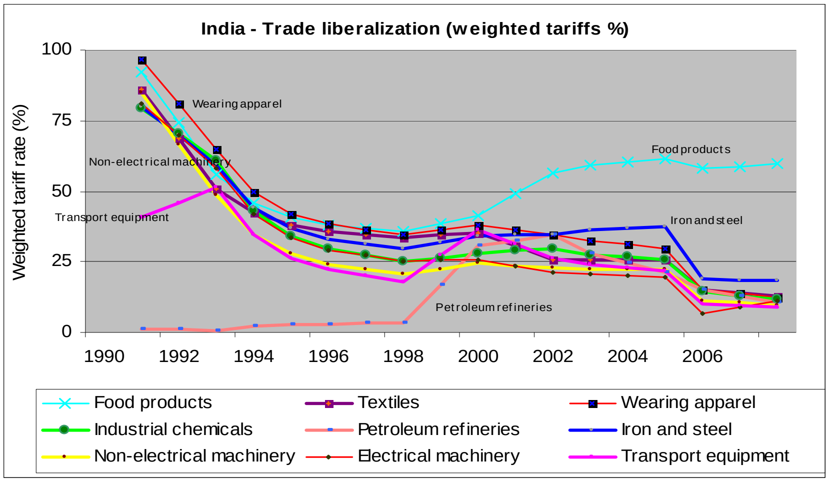
In the post-Independence period, the Indian government followed a national self-sufficiency policy that relied heavily on a complex web of government regulations and policies were protectionist, highly interventionist, marked by a plethora of industrial licensing requirements and strong government ownership in industry. India's trade regime was among the most restrictive in Asia. The 1951 Industries Act adversely affected the technological sophistication of its industries for nearly four decades through industrial licensing that controlled the entry of new firms, expansion of existing ones and closure of inefficient firms. The policy regime was popularly known as the "license raj."[14] In 1991, a balance of payments crisis triggered several key structural reforms that disciplined and prepared the Indian economy to join the club of emerging market countries.

In the early 1980s, in spite of the legacy of the "raj," several Indian industries were relatively close to the Korean technological frontier. Indian productivity levels were within 60 percent in Textiles, 90 percent in Wearing apparel, and 100 percent in the Electrical and Non-electrical machinery industries, i.e. the latter were on the frontier (see figure 4). However, from the mid 1980s until the mid-1990s, productivity levels plummeted to about 20 percent and

[14] See K.Kochhar, U.Kumar, R.Rajan and A. Subramanian (2006) and P.Topalova (2004).

widened the distance of most Indian industries from the frontier. Progress in catch up was mixed. Relative to China, in the Textiles and Food industries, India's distance to the frontier has barely shortened. In Electrical machinery, Iron and steel and Transport equipment, India is neck and neck with China, and in Non-electrical machinery and Industrial chemicals, Indian industries are closer to the Korean frontier than China.

Figure 15: India – Trade Liberalization



Source: TRAINS database

Two characteristics of India's catch-up strategy are as disappointing as Brazil's. One, the structure of its industry is virtually unchanged over 25 years and the transformation of resource-based low tech exports into dynamic medium and high tech exports has been slow (figures 7 and 14). As an example, in 2007, the share of high tech exports in India's total exports was only 5 percent compared to 35 percent each in Korea and China. Since 2005-06, the emergence of sophisticated Electrical and Non-Electrical machinery exports seems to signal some progress. Two, export-driven growth has been weak. In 2000-04, the proportion of output exported by the top two industries in India was only 12-13 percent relative to 64 percent in Korea and 33 percent in China (table 1).

Trade liberalization was very gradual. In the 1990s, when the government opened up the economy to foreign competition, India was a decade too late in the catch up game. From prohibitive rates of 75-100 percent in 1990, tariffs were cut slowly to 20-40 percent by 1996-97, and were between 10-20 percent in 2006, the highest among the BICs (figure 15). Liberalization also entailed other reforms. Between 1987and 1995, the share of products subject to quantitative restrictions fell from 87 to 45 percent, import licensing was eliminated and export controls were relaxed. Only 33 percent of the regulated industries were exempt from licensing in 1985; the remainder was de-licensed in 1991. Delayed and limited foreign competition was not costless. It eroded Indian competitiveness especially in high tech industries at a time when China's competitiveness in them increased.

The Indian government implemented a blend of distance shortening and industrial policies during the closed economy era of the license raj. However, the absence of competition, especially foreign, and lack of export-orientation led India's industrial policies to have many unintended consequences. Specialization in large skill-intensive industries seemed natural but government's commitment to a socialist pattern of development motivated policies that favored small-scale enterprises (SMEs) and discouraged the emergence of large private industries. Government's bias against FDI led to the nationalization of foreign firms in the late 1960s and 1970s. Consequently, Indian industry could not benefit from the financing, technology transfer and learning that come embodied in FDI. Large, private domestic firms were capital constrained while large state-owned manufacturing firms that catered to India's large domestic market benefited from state finance. In contrast, in Korea and China, the government provided cheap financing for its "handpicked" industries to enable scaling and catching up.

India's distance shortening policy was one of technological self-reliance and was implemented through high caliber specialized public institutions such as the Council for Scientific and Industrial Research (CSIR) which developed extensive public R&D infrastructure for large SOEs and SMEs. Technological capabilities were sharpened through reverse engineering products and process technologies.

The Indian government invested heavily in human resources through dedicated world class institutions such as the Indian Institutes of Technology (IITs) and Management (IIMs) that sought excellence in high tech engineering, science, and management skills (Dutz, 2007). In comparison to 11 and 12 percent in China, in 2000 the Indian government spent 86 percent of per capita GDP on each student in tertiary education compared to 14 percent in primary education (Kochar et al, 2006). Unfortunately, India's large private sector could not benefit from the vast pool of high tech skills due to government's preference for SMEs.

When India opened up to foreign competition, its private sector was globally uncompetitive in most industries (Dutz, 2007), but past investments in technical skills were not fully wasted. The benefits of human capital created by Indian public institutions since the 1960s, have accrued in large measure to India's booming software exports and budding medical tourism industries. Both industries are close to the global technological frontier. India's services exports are roughly 8 percent of GDP relative to only 5 percent in Korea. A further expansion of the Indian innovation system could potentially stoke a services exports-oriented catch up strategy.

8. The role of policy – balance between competition and innovation

An important insight from the experiences of the four countries is not whether competition and innovation are necessary for sustained economic growth. Rather, it is about what kind of sequencing is best to maximize the gains from competition and innovation to spur catch up. It is also about the balance between competition and innovation that policy makers can strike to accelerate growth. These issues are further explored by examining some statistics about competition and distance shortening, and modeling the data using the Aghion et al. approach.

Table 3. Tariff and Non Tariff Measures in BICs - Total Trade

Weighted Averaged Tariffs in Total Trade

	1990	*1995*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*
Brazil	19.0	12.7	12.7	10.4	10.0	9.4	9.0	8.5	8.5	8.7
China	32.2	23.8	14.7	14.1	10.3	6.5	6.0	4.9	4.4	4.7
India	49.6	23.2	27.5	26.5	25.3	24.1	22.8	13.4	11.9	10.4
Korea	9.5	6.8	7.2	8.6	10.0	9.6	9.2	8.3	7.4	7.4

OTRI[1] (MFN applied tariffs plus Non Tariff Measures)

	2001	*2005*	*2006*
Brazil	27.2	22.3	21.9
China	21.1	11.2	10.1
India	32.2	19.7	21.9
Korea	10.0	-	10.0

Source: World Integrated Trade Solution and World Trade Indicators

[1]OTRI (MFN applied tariff+NTMs)- The OTRI is expressed as a tariff rate and applies to all goods. This index summarizes the impact of each country's non-discriminatory trade policies on its aggregate imports. It is the uniform equivalent tariff that would maintain the country’s aggregate import volume at its current level (given heterogeneous tariffs) including non-tariff measures. It captures the trade distortions that each country’s MFN tariffs impose on its import bundle using estimated elasticities to calculate the impact of a tariff schedule on a country’s imports. These measures are based on actual or current trade patterns and thus do not capture restrictions facing new or potential trade. They also do not take into account domestic subsidies or export taxes.

Table 3 complements tariff information with a proxy for non-tariff measures (OTRI) and summarizes the trends in trade liberalization that increased competition in the BICs and Korea. Evidently, in the early 1990s, at 10 percent Korean tariff and non-tariff barriers were already quite low; they have stabilized since at those levels. In 2006, the OTRI rates in Brazil and India were twice as high as those of Korea and China. Evidently, the latter liberalized relatively rapidly while Brazil and India did it more slowly. If the industries of the three BICs were significantly and equally far from the Korean technological frontier, then Aghion et al.’s model would predict that liberalization would hurt these industries. Slower and belated competition without export orientation in Brazil and India perpetuated uncompetitive and inefficient industries.

Table 4 summarizes some of the outcome indicators of the main distance-shortening policies of the BICs and Korea. In the absence of a time series, we rely on recent statistics to track progress and identify several noteworthy issues that are highlighted in Table 4.

First, nearly every cell in table 4 is populated with statistics which suggests that government-led innovation interventions were at work in all four countries. Second, the data suggests that governments value the strategic-nature of distance reducing policies and are willing to spend on them. However, the data does not indicate that there is a formula for combining the precise mix of public and private interventions to spur innovation. A few examples are noted below.

Consider the case of R&D financing. Consistently high scores of GERD and BERD in Korea and China point to the importance of R&D expenditures for distance shortening policies. The university-industry linkages scores which suggest a more efficient role of the private sector are also significantly higher in these two countries than in Brazil and India. It should be noted however, that these data points do not indicate whether a higher level of government procurement of advanced technology or fiscal incentives for private R&D or both were necessary for encouraging private investments in R&D in Korea and China. They also do not specify the optimal balance between these policy instruments. Is there a magic formula that Brazil and India have yet to discover?

The role of foreign technology transfer through licensing underscores its importance for catch up in all four countries, but the role of foreign co-inventors does not. Does Korea's low score suggest that foreign co-inventors are relatively unimportant or simply that China and Brazil are better at attracting foreign co-inventors?

Patent-related innovation indicators show that the BICs have graduated beyond the technological adaptation stage and, like Korea, are playing catch up. Consider, for example, the number of triadic patents, i.e., patents submitted to the European Patents Office, the US Patent and Trademark Office and the Japanese Patent Office in 2005. Korean patent records are firm evidence of its achievement in patenting. In 2005, even though it lagged the U.S. by a large margin (U.S. had 15,700 and Korea had 2,800), it had made phenomenal progress relative to 1985 when it had only 7 patents. Similarly in 2005, the figures for the BICs were impressive when compared to 104 for Singapore, 20 for Hong Kong and 4 for Chile.

The main policy insight which can be drawn from Table 4 is that each BIC and Korea had its own brand of distance shortening policies. Evidently, *in addition* to and *prior* to trade liberalization, in varying degrees Korea and the BICs leveraged a package of distance shortening policies to foster domestic innovation capabilities that prepared them better to compete in the global market when they opened up. The crux lay not in a single indicator or two or even three, but in a comprehensive package of support to innovation capabilities that could be measured by indicators such as those in Table 4. Among the policy instruments they used were targeted fiscal incentives for innovation R&D, FDI for technology transfer, and heavy targeted investments in human resources for S&T.

Table 4: A comparison of distance-shortening with other policies in the BICs and Korea				
	Korea	**China**	**Brazil**	**India**
Macro and *Trade liberalization* reforms				
Timing	1970s	1980s	1990s	1990s
Stabilization	Yes	Yes	Yes	Yes
Degree of openness (trade as % of GDP -1980s-2006)	67 to 84	27 to 71	18 to 26	14 to 46
Level of tariff and non-tariff barriers (Text tables)	Very low	Very low	Medium low	Medium high
Industrial Policy				
Preference for export-led growth (Export/GDP (%); 1970s and 2005-06, WDI)	23 to 43	5 to 40	7 to 14	5 to 21
Preference for hi- tech exports (% in total exports, OECD-A15 *)*	35	35	8	5
Preference for natural resource-based exports *(% in total exports, OECD B)*[16]	0.2	2.3	20.6	9.6
Intellectual property indicators				
Patent applications filed under PCT (2005; OECD)	5152	3774	339	978
Triadic patent families[17] (2005, OECD A)	2811	356	58	113
Intellectual property protection 2007 *(Scale 1 – 7, KAM)*	5.4	3.4	3.3	4.0
Total royalty payments and receipts (US$ mil.) 2006 *(KAM, World Bank)*	6497	5478	1506	446
Distance shortening in early stages	Mostly state-led	Mostly state-led	Mostly state-led	Mostly state-led
Financing of R&D				
Gross domestic R&D expenditure/GDP (2006, OECD A)	3.23	1.43	1.02	0.71 [18]
Business enterprise R&D expenditure /GDP (2006, ,OECD A)	2.49	1.02	0.49	
GERD per capita (current US $ (PPP, OECD A)	743	66	92	13
University-industry linkages				
University-industry research collaboration in 2007 (Scale 1 – 7, KAM, World Bank)	5.4	4.1	3.4	3.5
University-industry linkages (indicator -Share financed by industry, OECD Factbook, 2008)	75 %	69%	39%	16%
Incentives for research				
Tax subsidies for USD 1 of R&D (OECD Scoreboard, 2007)19	0.18	0.339	0.254	0.266
Subsidies for firm level research (Scale1–7; 2003, WEF)	3.52	1.86	2.03	2.87
Government procurement of advanced technology products (Scale 1 – 7; 2003, WEF)	4.5	4.7	3.6	3.3
Role of foreign innovators				
Prevalence of foreign technology licensing (Scale 1 – 7; 2003, WEF)	5.32	3.79	4.65	3.27
Role of foreign innovators – (indicator: Patents with foreign co inventors (2002-04, OECD A))	4.60	27.87	28.42	
Human resources for S&T				
Quality of S&T research [Scientific and technical journal articles per million population, 2005 (KAM)]	339.5	31.89	52.9	13.35
Researchers/1000 total employment (2006, OECDA)	8.65	1.60	1.48	0.3 (in 2000)
Science and engineering degrees as a % of all new degrees (2005, OECD A)	37.80	39.18	10.78	

[15] OECD A – OECD S&T Outlook, 2008

[16] OECD B S&T Scoreboard, 2007

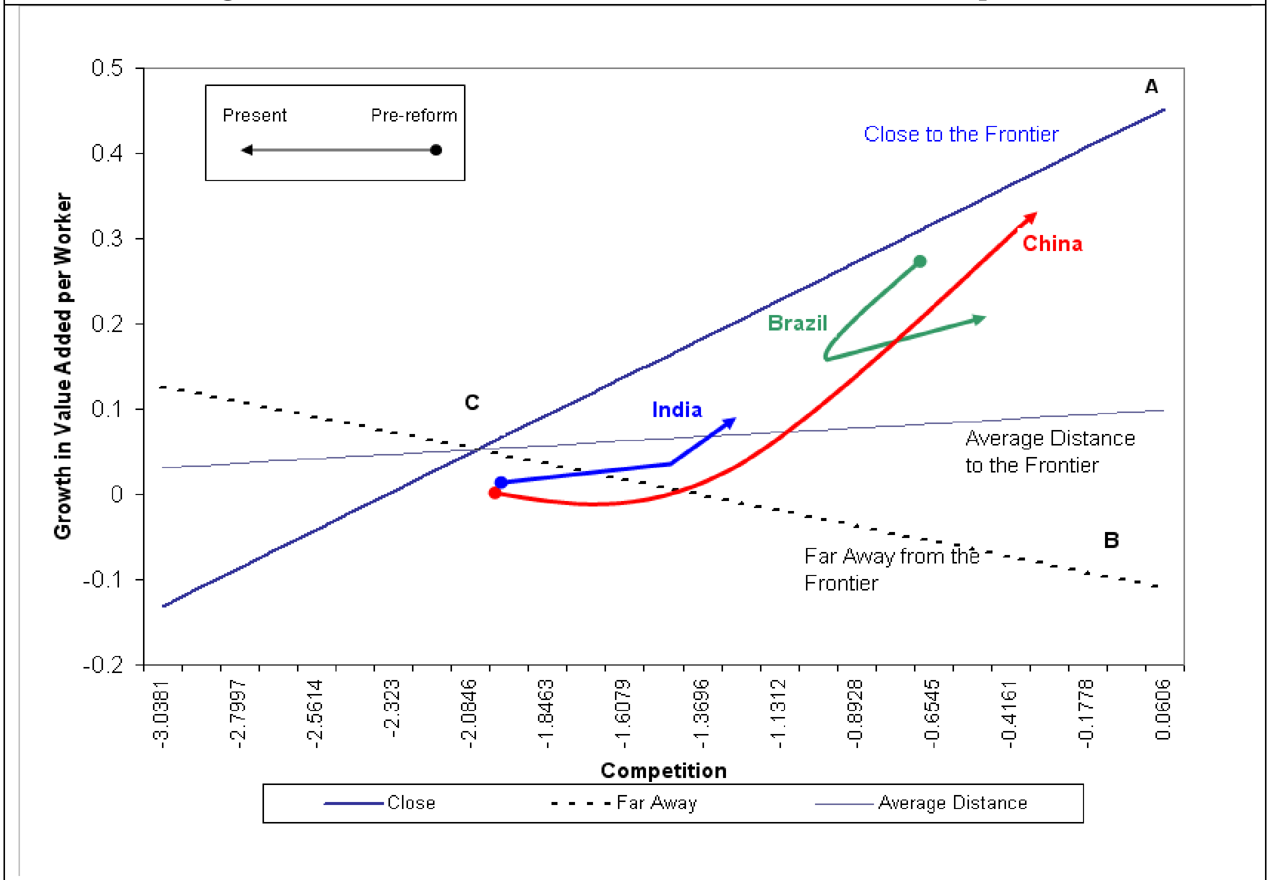
[17] Patents applied for at the US Patent Office, European Patent Office and Japanese Patent Office in 2005.

[18] OECD Factbook 2008.

[19] The corresponding tax subsidy for the U.S. is 0.66.

The tradeoffs between competition and innovation are further illustrated with the help of figure 16 below.

Figure 16: Tradeoffs between distance to the frontier and competition



Source: Figure 16 is a representation of the estimates from the empirical model that is discussed in section 8.
Note: Lines for Brazil, India, and China are provided for exemplification purposes and do not necessarily represent the behavior of all industries in these countries.

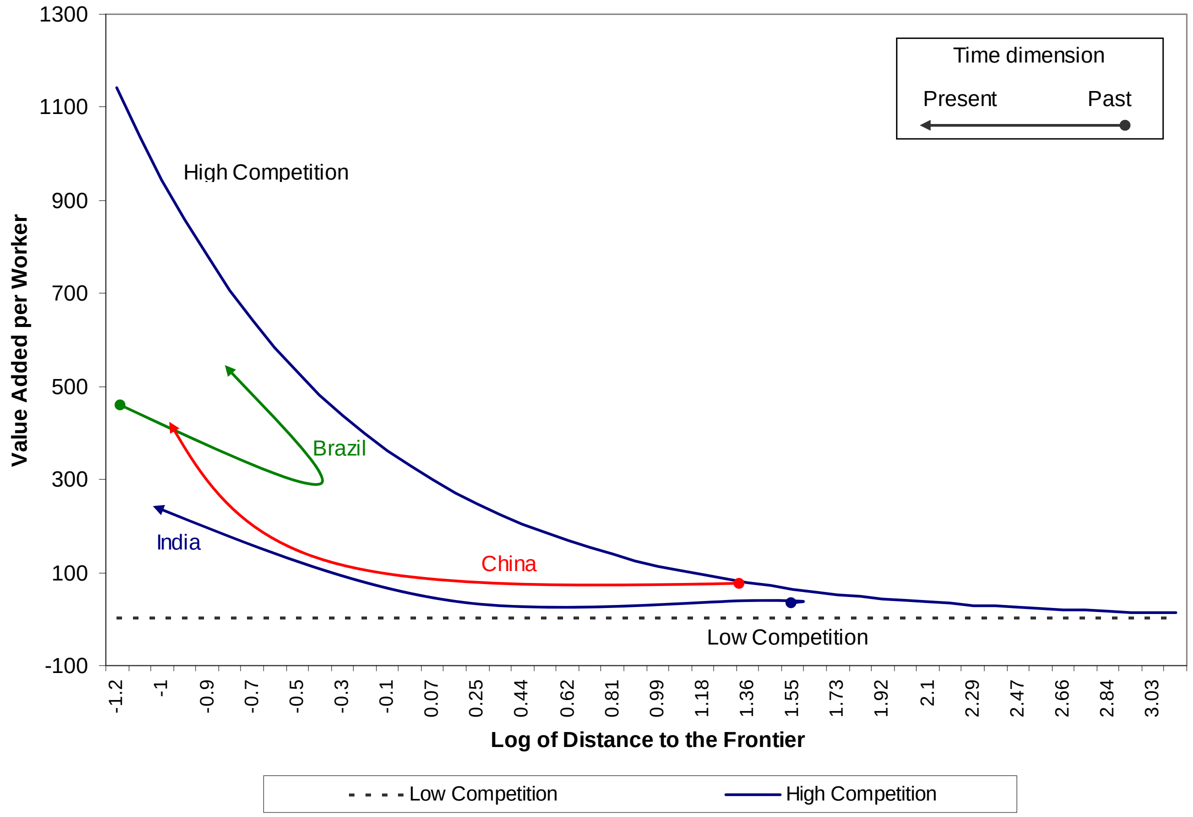
Figure 16 shows a diagram of the tradeoff between competition and innovation. It is a graphical description of simulations using the parameters of the empirical model discussed below. It shows competition on the x-axis and growth in value added per worker which enables catch up on the y-axis. The maximum growth rate of labor productivity is at point A which, in the context of our analysis, represents the Korean technological frontier. Conventional neo-classical analysis assumes that when the rate of growth is low, swift competition can help an industry to move speedily along the solid line towards the frontier to point A. However, as neo-Schumpterian theory argues, if distance matters, competition may induce the industry to move along a path with slower growth in value added. In fact, if the industry is too far from the frontier, opening up to competition can lead to negative growth in value added as shown by trajectory CB on the dotted line. For the same level of competition, industries closer to the frontier innovate and enjoy higher productivity growth. A sequencing of distance shortening policies followed by competition can enable the industry to move closer to the frontier, but along a flatter slope, i.e., with relatively slow growth in value added until competition is introduced.

Consider the three arrows in figure 16 that we use to illustrate the experiences of the BICs with distance shortening and competition policies. In the early 1980s, most industries in China and India faced low levels of competition and were located far from the frontier, say at point C. Brazilian labor productivity levels, however, were much higher and placed Brazil closer to the Korean technological frontier. Rapid opening up to foreign competition should have made industries in China and India uncompetitive and set them on a negative growth trajectory towards point B (or extinction). We know quite well that this did not happen although the outcomes were very different. Distance-shortening policies were a precursor to China's opening up to foreign competition and boosted its labor productivity growth, preparing it for global competition. In the late 1980s, when China liberalized swiftly, it benefited from accelerated growth in labor productivity. The Chinese model, like the Korean, balanced an innovation focus (via adoption of distance-shortening policies) with competition. Unsurprisingly, China's growth rate of labor productivity as reflected in its pace of catch up is the fastest. In comparison, India did not employ distance-shortening policies to boost the competitiveness of its manufacturing sectors in a significant manner. As a consequence, upon opening up, it was unable to compete in almost all manufacturing industries.

In the early 1980s, Brazil was closer to the frontier than China and India (figure 4). This reflected the stronger initial position of the Brazilian economy at the end of its "miracle" years. During the debt crisis, the economy stalled and lost its competitiveness as shown by a lower growth in labor productivity. When the Brazilian economy began to display a renewed productivity spurt in the 2000s, the high returns from China's distance shortening policies and speedier rate of liberalization had already made China the country with the fastest growth in value added per worker among the BICs (and indeed globally).

An analysis of how competition and distance shortening policies have affected the *level* of competitiveness in the BICs is illustrated in figure 17 with different variables on the axes. The x-axis displays distance to the frontier (from right to left) and the y-axis displays the level of value added per worker. Note Brazil's initial position was close to the frontier in the 1980s. In levels, its labor productivity is still higher than China's, as displayed in figure 4. Even though China has achieved faster growth in labor productivity, its distance from the Korean technological frontier remains significant and can be measured on the y-axis. In what follows, we test the Aghion et al. model using data for Korea and the BICs.

Figure 17: Tradeoffs between distance to the frontier and competition



Source: Figure 17 is a representation of the estimates from the empirical model that is discussed in section 8.
Note: lines for Brazil, India, and China are provided for exemplification purposes and do not necessarily represent the behavior of all industries in these countries.

Empirical methodology

According to the Schumpeterian model, there is a positive relationship between larger firms and innovation. Scherer's (1965) empirical research did not substantiate the Schumpeterian paradigm. Empirically, there is no *a priori* evidence to support or reject the view that competition adversely affects innovation. The economic environment, distance of industries from the technological frontier, and other variables play an important role in affecting the impact of competition on innovation. Nickell (1996), for example, found a strong and positive relationship between competition and innovation measured by firm level TFP.

An investigation of the Schumpeterian paradigm needs to incorporate several factors. The first is a correction for the correlation between the industry characteristics such as size and innovation. We deal with this by controlling for industry fixed effects. Second, the analysis must address reverse causality: whether growth in labor productivity which is our dependent variable affects the distance to the Korean technological frontier or a change in distance affects the growth and level of labor productivity. Panel data and an instrumental (exogenous) variable are used to correct for this problem. We use systems GMM that uses lags of all exogenous variables to correct for endogeneity. Industry specific weighted tariff rates represent competition.

We use the Aghion, Blundell, Griffith, Howitt, and Prantl (2006) model to test the effects of competition and innovation on catch up. The model is specified as follows:

$$dLNVAPW_{i,j,t} = \alpha_1 + \beta_1 DFrontier_{i,j,t-1} + \beta_2 Competition_{i,j,t-1} \\ + \beta_3 DFrontier_{i,j,t-1} * Competition_{i,j,t-1} + DIND80s + \varepsilon_{i,j,t}$$

for every industry i (at the ISIC Rev. 2-3 digit classification), and country j (Brazil, India, and China) in our sample. dLnVAPW is the growth rate of value added per worker, DFrontier is our measure of distance to the technological frontier lagged, and tariff reduction lagged is our measure for competition in each industry *i*. DIND80s is a dummy variable that simply captures the fact that the liberalization in the case of India only started in the 1990s.[20] We present our results in both levels and growth rates.

Results

The results of our model are reported in table 4 in two columns. The first column shows regressions where the dependent variable is expressed as a growth rate which is the standard approach in the literature. The second shows the same regressions in levels – these are helpful in analyzing the dynamics of catch up in the context of the relative position of the BICs with respect to Korea as reflected in figure 4.

Growth in value added per worker. The ideal dependent variable is growth in TFP. However, as explained earlier, unavailability of comparable time series firm-level data does not allow us to work with TFP. Instead we have used value added per worker as a proxy for innovation -- not an unreasonable substitution, as we confirmed by analyzing large-firm level investment climate assessments for the BICs. In addition, use of the lagged values of the dependent variable allows us to control for the contribution of capital to output, i.e., the previous period's output levels already incorporate the effect of capital on labor productivity. The change in labor productivity then can be interpreted as the effect of a change in technological innovation.

Competition: The estimates from our model show a positive and robust relationship between the competition and innovation variables. As expected, an increase in competition, indirectly measured by lowering tariffs is positively associated with an increase in the growth of manufacturing value added per worker.

Distance to the frontier: This is measured by the ratio of labor productivity in industry *j* in Korea (benchmark) and labor productivity in industry *j* in a BIC. A negative and significant sign of this variable suggests that industries that are farther away from the technological frontier have fewer incentives to innovate and increase growth in value added per worker.

[20] It should be noted that Brazil also only began a comprehensive trade liberalization effort in the 1990s. Our dataset, however, is limited to post-1990 data in this case.

Interactive term: Suppose that two industries have the same level of competition. The industry that is farther away from the technological frontier will innovate less than the one that is closer to the frontier. The interactive term therefore evaluates the effects of competition on growth in labor productivity in a setting in which all industries are not equally close to the frontier. A negative sign suggests that competition is a necessary, but not a sufficient condition to motivate an increase in an industry's innovative capacity. The impact of changes in the competition regime is stronger if industries are technologically more advanced or closer to the frontier but diminishes for industries located farther away from the technological frontier.

Table 5. GMM Estimation Results[21]

Dependent variable:	Growth in value added per worker	Log of value added per worker
Distance to the frontier (lagged)	- 0.12552*	- 1.026538***
Competition	0.113523***	0.8717822***
Distance to the frontier*Competition	- 0.060857***	- 0.13327***
DIND80s	0.200927***	
Constant	0.286821***	5.717783***
Observations	1045	1855
Groups	73	98
Observations per group		
Minimum	6	8
Average	14.32	18.93
Maximum	20	24
Number of instruments	71	74
Tipping point in distance beyond which competition negatively affects innovative capacity	*1.865411*	*6.541214*

Source: Authors' estimates using ISIC Rev2 – 3 digit industrial data, COMTRADE data and TRAINS tariff data.
*** Significant at the 1% level.
Note: DIND80s is a dummy for India in the 1980s.
GMM: System Generalized Method of Momentums using the Arellano-Bond Methodology and the xtabond2 command in STATA. The option collapse is used to avoid the excessive use of lagged instruments that diminishes the efficiency of the estimates.

Our results indicate that several industries in the BICs remain very far from the Korean frontier. The model can be used to calculate how far they are in the following way. If the number

[21] The first estimates present the results of using a panel data estimation procedure with fixed effects for every combination of industry and country in the sample. To overcome the possibility of endogeneity in the specification of our model and heteroskedasticity, we use the system GMM estimator because it is well suited for dynamic "small-T, large-N" panels that may contain fixed effects and idiosyncratic errors that are heteroskedastic and correlated within but, not across individuals. We use the two step variant of the system GMM estimator because it is asymptotically more efficient, compared with the one step variant. Nevertheless, two-step standard errors tend to be severely downward biased (Arellano and Bond 1991; Blundell and Bond 1998). To compensate for this, we use a finite-sample correction to the two-step estimation efficiency covariance matrix derived by Windmeijer (2005).

for distance is bigger than the tipping point of 1.86 (6.54 for the model in log levels), that industry's distance is *too* far from the frontier, i.e., its innovative capability was too weak relative to Korea's and it was adversely affected by trade liberalization.[22] Each BIC has several such industries. Some have been more successful in narrowing the technological gap in the post-liberalization period but the others are still beyond the tipping point. For example, our simulations show that with increased competition, Brazil has been able to innovate and narrow its distance to the Korean frontier in the Food Products industry but the same industry in China and India was unable to withstand competition and has fallen farther behind the frontier. Distance can change when the frontier industry is moving faster than the incumbent (as in the case of Korea where most industries have grown faster (figure 4)).

The positive sign on the competition variable and negative on the interactive term in our model validate Aghion et al.'s results as well as the inverted U-hypothesis. In short, distance matters. The negative sign on the interactive term has led Aghion et al. to note that competition is desirable and should still occur, but government policies should make it easier for the uncompetitive firms to shut down and let resources flow to the more productive firms.

Our result suggests that to benefit from the efficiency gains generated by competition, distance shortening policies such as those targeted at building domestic capabilities to innovate, become particularly relevant. By helping to shorten the distance to the frontier ex ante, they can dampen the otherwise negative effect of the interaction between competition and distance. We also obtain a negative sign on the distance variable which indicates that by itself an increase in the distance to the frontier, caused for example by an increase in Korea's productivity levels, will not encourage the industry to innovate and grow. Overall, distance would have a negative effect on productivity growth. The farther the distance, the harder it would be for the country to catch up. This outcome could apply to the case of a poor country with an industry that is protected and already too far from the frontier. The results also indicate that investment in distance shortening policies alone may have low payoffs as is true of the Indian experience.

The potential of distance shortening policies for catch up offers policymakers a variety of choices from which they can pick the one most suitable for their economy. It would, however, be a mistake to infer that Korean or Chinese style distance-shortening policies are necessarily the optimal ones that should be replicated by every country aspiring to catch up. After all Korea's programs to forge industry - university linkages benefited from its strong endowment of human capital which reflects a long-term commitment to education. Few developing countries can easily replicate the university-industry linkages that Korea enjoys today although going forward, there may some useful lessons. And China's ability to leverage innovation through conditional contracts with foreign investors was a function of the attractiveness (size) of the Chinese domestic market.

9. Conclusions

In this paper we have analyzed how three emerging economies – Brazil, China and India – are catching up with Korea's technological frontier using Aghion et al.'s model across 30 industries. In general we find support for Aghion et al.'s inverted-U hypothesis. When industries are closer to the technological frontier, they innovate to escape competition while a longer

[22] Simulations are available from the authors upon request.

distance discourages them from innovating. We also found that for countries that are far from the frontier, catch-up is a tougher challenge as the frontier itself is a moving target.

In addition to the primacy of competition policy, our results illustrate the role of distance-shortening policies. For a country which has industries that are technological laggards and are likely to be wiped out by foreign competitors, our model illustrates that distance-shortening polices may be a necessary complement to liberalization for effective catching up.

What can Brazil and India and indeed other middle-income countries learn from the Korean and Chinese models of catching up? South Korea and China adopted a variety of distance-shortening policies (supporting R&D investments) in combination with financial subsidies to promote industries (with an emphasis on fostering high tech industries) in parallel with an export-led growth strategy. They ensured that their targeted industries had mastered technological learning and were ready to innovate and keep competitors at bay (and/or had become natural partners for foreign companies) before pursuing trade liberalization. Once the liberalization effort was unleashed, however, both Korea and China did not hesitate to leverage swift competition to garner additional efficiency gains. Starting in the early 1980s, it took China less than two decades to transform its industrial structure away from resource-based primary industries and labor-intensive sectors towards the more high tech ones that Korea had championed in its own catching-up experience.

The Brazilian and Indian catch-up strategies have been less successful (Dahlman, 2008). The large anti-export bias of their import-substitution industrialization strategies was not effectively counteracted by governmental policies and an unfocused attention to innovation-enhancing policies did not foster competitiveness at the international level. Upon opening up in the 1990s, they found themselves too far from the technological frontier and have been less successful in harvesting the gains from competition. Needless to say, there are world-class industries in both countries. But these often reflect the unintended consequences of inward-oriented policies combined with exogenous shocks rather than the sustained pursuit of innovation-driven policies. As an example, the impact of the ICT revolution on the tradability of services coupled with investments in tertiary education lies at the core of the success enjoyed by India’s software industry. Similarly, the pursuit of energy alternatives in Brazil, such as ethanol, was a response to the oil shocks of the 1970s, driven by the desire to minimize energy-dependency for security reasons.

It is important to recognize that a model of state-led innovation would be hard to replicate these days in view of multilateral disciplines under the WTO that constrain discriminatory treatment in favor of national firms. Yet, both Korea and China have had significant success in their efforts to catch up with the OECD and their experiences, as well as those of Brazil and India, provide useful insights on the interplay between innovation, competition and growth.

In sum, the catch-up experience of the BICs with Korea underscores that there is no blueprint for distance-shortening policies. Certain outcomes of distance-shortening policies seem to be common across the BICs and Korea, and indeed in the context of Korea’s catching up with OECD countries. Striving to achieve the distance-shortening policy outcomes illustrated by the Korean experience is a worthwhile goal. The task of identifying the appropriate distance-shortening policies in the case of the BICs (or other followers) in the current global economic environment remains, however, a formidable challenge.

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