Building knowledge-based competitive advantages in China and India: Lessons and consequences for other developing countries

Tilman Altenburg / Hubert Schmitz / Andreas Stamm

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1 Successful technological upgrading in China and India: challenges for the academic debate

In the last three decades, developing countries have made considerable progress with regard to industrialization. In 1975, when UNIDO held the Lima Conference on industrial development, the developing country’s share in global manufacturing production was as low as 7%. The “Lima target” of reaching 25% by 2000 set at the Conference thus appeared to be highly ambitious. With a share of 23.6% in 2002, though, it has been missed only slightly. Much of this industrial output, however, is of relatively low knowledge-intensity: either production for less demanding domestic and regional developing country markets, relatively simple processing of natural resources, or export manufacturing activities with low entry barriers. During the three decades after the Lima Conference only very few developing countries (the first generation NIC’s Korea, Taiwan, formerly independent Hongkong and partly Singapore) have managed to catch up with the technological frontier and to appropriate significant innovation rents.

The success of these countries has triggered an intensive and controversial debate on the role of the state in the development process in general and the effectiveness of industrial policy in particular. This debate is not concluded. Different interpretations persist especially with regard to the role of infant-industry protection, the use of trade-related investment measures (TRIMs), the application of “horizontal” vs. selective policies, and the need for government to target “strategic” sectors vs. market-driven resource allocation.

However, most scholars concerned with technological upgrading agree that entry barriers for newcomers tend to rise for a number of reasons. First, technologies become more complex and increasingly require not only world-class capabilities in different technological fields but also the capacity for systems integration. Countries with well-established and diversified innovation systems thus have a strong advantage over latecomers lacking certain “ingredients” of mature innovation systems as well as the experience of interactive problem-solving. Second, globalization tends to increase scale requirements. Third, product cycles become ever shorter as the speed of innovation accelerates. Forth, new international rules on trade, investment, and property rights protect proprietors of technologies better and strongly confine developing countries’ possibilities to employ trade policy, mandatory technology sharing, local content and equity requirements, subsidies and other “distorting” elements for their own technological development. Strategies of infant industry protection, aggressive product piracy and reverse engineering, which have been pursued in earlier catch up-processes, can largely be ruled out for contemporary development processes. While some industrialists argue that such policies have anyway done more harm than good, others claim that the new global trade, in-

1 UNIDO (2005), p. 130.
2 Ernst/ Mytelka/ Ganiatsos (1998); Lall (1994); Wade (1990); World Bank (1993).
vestment and property rights regimes have “kicked away the ladder” that developing countries needed to climb up from factor-cost to knowledge-based competitive advantages.4

The successful technological latecomer development of the “Asian tigers” thus seemed to be an exceptional case, built on a quite extraordinary combination of good governance, strong external support, and luck (in terms of industrializing at a moment when windows of opportunity were wide open). However, recently new successful latecomers appear on the scene. Especially China and India are making considerable progress towards knowledge-based competition. Their share in the world trade of knowledge-intensive goods has increased enormously while goods of this category continuously increase their participation in the export structure of both countries. Furthermore, transnational corporations (TNCs) increasingly relocate knowledge-intensive, and even R&D, functions to these countries. An UNCTAD survey of the largest R&D investors among TNCs shows the mounting role of developing countries as recipients of corporate R&D. According to the survey, China is now the 3rd global destination for investments in R&D and India the 6th5. What is more, their importance will increase substantially in the near future. In the UNCTAD survey, TNCs mentioned China as the most attractive location for future R&D investment, far ahead of the United States, with India ranking 3rd.6 This increasing interest by TNCs is matched by rapidly growing national R&D expenditure. Having quintupled its budget since the mid 1990s (!), China now invests more in R&D than any European country (84.6 billion US$) while India’s expenditure mounts up to 20.7 billion, exceeding the levels of Canada and Russia.7

This process is interesting for several reasons. First, the success of several Chinese and Indian industries shows that catching up is still possible, despite the systemic and cumulative character of technological development and regardless of global framework conditions that limit the scope for proactive industrial policy. Second, the trajectories of technological upgrading followed in the sectors portrayed in this paper partly deviate from previous experiences and thus hold important lessons for policymakers. While the Chinese and Indian examples confirm some of the lessons learned from the first generation NICs (e.g. the relevance of strategic vision and political leadership, targeted investment in specific advanced skills, and return migration) they challenge other widespread assumptions (e.g. the central role of a business-friendly institutional environment) and point to some other driving forces of technological development which have not played a major role in the first generation NIC’s (e.g. bargaining power vis-à-vis MNCs and systematic buy-in of strategic assets from developing countries). Third, given the sheer size of these two countries and the enormous emerging supply of high-skilled researchers, engineers, technicians and skilled workers, technological progress of

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4 E.g. Chang (2002).
5 UNCTAD (2005), p. 133.
6 Ibid., p. 153.
7 OECD (2005).
China and India poses a much greater challenge for the rest of the world, both for OECD and developing countries.

This raises the following questions:

1. To what extent, at which velocity, and in which sectors can we expect China and India to catch up with global technological leaders and to appropriate innovation rents at the expense of the currently leading countries and corporations?

2. In those sectors where China and India managed to make inroads in leading technological fields, how did they manage to catch up?

3. What are the ramifications for the rest of the world, in particular other developing countries?

This paper seeks to provide some initial answers to these questions and identify the key issues for future research. Its core consists of the analysis of trajectories of technological upgrading in four Hi-Tech sectors, asking how wide the technological gap still is, how fast it is closing, and how both countries managed the process. Having examined the progress made by China and India, the paper then reflects on the implications for other developing countries. Very little is known about these implications and therefore the paper does not seek to provide answers but rather aims at setting out the agenda for future work.

Chapter 2 takes stock of what we know about technological latecomer development. It gives a brief overview of different strands of the academic debate and undertakes to extract the most important determinants of technological upgrading, some of which are generally acknowledged while others remain controversial. The stocktaking exercise shows that there (still) is no theoretical concept capable of explaining the nature of technological latecomer development. Rather, there is list of critical factors which are very much context-specific and therefore tend to be combined in very different ways, giving rise to highly divergent technological trajectories. Chapter 3 presents trajectories of four select industries which have embarked on a successful upgrading strategy – two Chinese and two Indian examples –, discussing the relevance of the determinants identified in the previous chapter. The analysis shows that each of these industries followed a different technological path, emphasizing a specific set of policies and going through different sequences of development, even though all the different trajectories tend to converge towards rather similar patterns of systemic innovation. Chapter 4 then briefly addresses potential consequences of China’s and India’s technological upgrading for other developing countries and identifies issues for future research.

2 What do we know about technological upgrading of latecomers?

Issues of knowledge creation, innovation and technological catching-up have been high on the agenda of development research for at least two decades. Neo-classical economists for a long time did not perceive the technology gap between industrialized and developing countries as a major problem calling for political action. In their view, in the long run, the world growth rate
is driven by discoveries in the technologically leading economies. Followers have good prospects for catching up with the leaders because copying is cheaper than innovation.\(^8\) Technological progress itself is seen as a more or less automatic process and a reaction to shifts in factor costs, drawing on previously existing external stocks of knowledge (“induced innovation”).

Empirical evidence, however, suggests a different view. The technological gap between advanced and poorer economies has by no means diminished, at least not during most decades of the post-war period. Structuralists, and evolutionary economists in particular, pointed to pervasive failure in technology markets and called for political action by nation-states and the international community. Specifically, they have shown that:\(^9\)

- technology is not just a form of *information* that has the properties of being costly to produce but virtually costless to transfer and to apply. Technology as a form of *knowledge* requires interpersonal interaction to be transferred. Related to this, technology absorption requires dedicated investment and special capabilities;\(^10\)

- technological innovation is not the result of a linear process, starting with discoveries in basic science, and passing through applied research to commercial application. Rather it has to be conceptualized as an interactive process with frequent feedback-loops between links in the chain;\(^11\)

- creating and maintaining technological capabilities requires frequent interaction among agents from the private (manufacturing companies, service providers) and public (universities, R&D institutes) sphere. These interactions are especially effective when not based on mere price relations, but on mutual familiarity, loyalty, and trust. Such relationships play an especially important role in local production clusters. Even global value chains are increasingly being coordinated through non-market mechanisms, given that lead firms, such as powerful buyers, increasingly set and enforce the standards that other firms have to comply with.\(^12\)

Given these characteristics of technology markets, learning processes are highly context-specific and cumulative. Initial investment decisions thus determine the available options at later stages of development. In other words, knowledge creation is path dependent, and economic development follows certain trajectories. Furthermore, innovation systems have divergent characteristics, depending on the society they are rooted in. This observation gave rise to the National Innovation System (NIS) concept.\(^13\)

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\(^8\) Barro / Sala-i-Martin (1997).


\(^10\) Narula (2003).

\(^11\) Kline/Rosenberg (1986).

\(^12\) Gereffi (1996); Humphrey / Schmitz (2002).

\(^13\) Lundvall (1985).
Quite often, the technological specialisations of NIS reflect not so much the supply-side of innovation systems, but the preferences of the strongest and most demanding customers. Strong user-producer interaction triggers learning-by-doing and thus reinforces technological capabilities. This observation was later reinforced by Porter who placed much emphasis on “demand conditions” as a driver of technological specialization.\footnote{Porter (1990).}

The concept of National Innovation Systems is today the most widely used framework for analyzing the technological capabilities of nations. However, it faces two main challenges:

1. The concept has been developed in the context of mature industrialized societies and is less applicable to developing countries. Although the interactive and cumulative character of technological learning is ubiquitous, many institutional linkages characteristics of mature innovation system, such as university-enterprise linkages, are weak.

2. There is an obvious tension between a concept that takes the nation-state as the starting point and its application in an era of rapid globalization. Although many determinants of innovation systems are still largely being shaped by nation-states (such as the legal framework), others may be local or global in nature.

Thus, depending on the object of investigation, different concepts focusing on sub-national clusters, on sectors, or value chains rather than on the level of nation-states may be equally appropriate. Hence large bodies of literature focus on “clusters”,\footnote{E.g. Schmitz (1999).} “value chains”,\footnote{E.g. Gereffi (1996).} “technological systems”,\footnote{E.g. Carlsson / Jacobsson (1997).} or “sectoral systems of innovations.”\footnote{E.g. Breschi / Malerba (1997).}

For large “anchor countries”, like China and India, where national policies are highly relevant in shaping framework conditions for technological development and where institutional and inter-firm linkages exist, the NIS approach seems to be appropriate. At the same time, a value chain perspective may be important to better understand how national firms and institutions are linked to global actors, how cross-border value-creating processes are organized and how rents are being appropriated at different stages of the value chain, within or outside national boundaries.

To understand how NIS are linked internationally, three transfer channels for technological learning mechanisms are of particular importance:

1. technology transfer through trade;
2. technological learning through foreign direct investment (FDI);
3. transfer of knowledge through return migration.
Increasing *trade relations* between industrialized and developing countries can induce technology transfer in different ways. Trade augments the set of accessible technologies, hence increasing the scope for national learning. Import of capital goods has a direct impact on the productivity in the sector where it is employed. Moreover, trade enhances competition which again is a driver of technological innovation. Trade openness is therefore one of the most powerful determinants of technological learning. However, openness may at times overstrain weak national actors. Trade liberalisation should therefore be pursued in accordance with the ability and velocity of national actors to acquire and adapt to new technologies.

The value chain literature stresses that international production and trade are increasingly taking place in tightly coordinated forms (rather than market-based transactions), where lead firms become more important as innovators, coordinators and “governors” of production networks. Lead firms hold control of key technologies and patents, they sometimes introduce brand names, they have the capability of integrating product and service inputs efficiently, they often determine the logistics parameters in the supply chain and set and enforce different kinds of product and process standards. The quality of relationships with global lead firms is thus particularly important for latecomer development.

*Foreign Direct Investment* in developing countries potentially constitutes an important channel for the transfer of knowledge and technology as foreign investors usually have access to leading markets and new technologies developed in their own R&D labs or through various forms of partnering in different regions of the world. Empirical evidence, however, shows that benefits from FDI do not accrue to all recipients automatically. There is broad consensus on the fact that a host country’s policy environment strongly determines to what extent national firms and institutions benefit from foreign investment; there is no consensus, however, on the appropriate mix of encouraging and regulatory policies. In practice, prescriptive policies have largely been out ruled by the WTO, limiting the available policy options to “softer” policy instruments.

*Return migration* of qualified experts is increasingly recognized as an effective way of transferring technology, as it allows the translocation of both explicit and tacit knowledge. People from developing countries studying or working in technologically more advanced countries may acquire world class technological and/or scientific knowledge. At the same time they are exposed to different cultural settings which can lead to an increased open-mindedness. Some migrants establish relationships with actors from other local, regional and national innovation systems. Returning to their host country, they may capitalise on these assets, establishing cross-border networks, inducing innovations within existing home country organizations, or forming new companies.19

To cope with the pervasive failure in technology markets developing country governments have adopted different policies. While our concern in this article is with technological upgrad-

ing, it should be noted that governments sometimes shape technological policies with other, non-economic objectives in mind, such as image-building through highly visible state-run technology projects, or the perceived needs of national sovereignty in strategic matters and – closely related – of national security. The above structuralist arguments are therefore often taken up by highly self-confident governments and state bureaucracies that perceive themselves as indispensable agents of development.

Some countries engaged in national large-scale technology projects which are driven by national pride and military reasons as much as by the desire to “leapfrog” into high-tech sectors and to appropriate innovation rents. Investments in nuclear energy, aircrafts, space technology or ambitious “national car projects” are common examples. They often imply large-scale investment in R&D and specific technological skills, massive recruitment of leading researchers and special versions of infant industry policies, such as market reservation for technology-based products. A comprehensive cross-country evaluation of these policies is still lacking. In many cases state-induced technology sectors broke down once governments were unable to continue subsidizing or when markets were opened to international competition. However, some of the most remarkable examples of high-tech production in developing countries, such as the Brazilian aircraft producer Embraer and the Indian space industry, emerged from this kind of interventionist strategy.

### 3 Sector case studies and trajectories of technological upgrading

This chapter portrays four sectoral case studies of technological upgrading, two from India and another two from China, namely:

- the software industry in India;
- the automotive industry (automobiles and parts) in China;
- the personal computer industry in China;
- the space industry in India.

In all four cases it has been possible to catch up with, or at least to come close to, the technological frontier and to position the emerging Chinese and/or Indian industry as serious competitors to established OECD players. The four selected industries are among the most important industries in terms of R&D spending worldwide\(^\text{20}\) and may therefore be regarded a good sample of the world’s cutting-edge technology sectors. From the policy perspective, it is particularly interesting to note that all of them developed along different trajectories and thus offer a range of lessons for the policymaker. In order to bring out the similarities and differences, some key features of the different sectoral experiences will be presented here. The

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\(^{20}\) UNCTAD (2005).
presentation of each sector will adopt a common three-fold structure: first, achievements of the sector in question, second, genesis of the process, and third, a summary of key explanatory factors.

3.1 Human capital formation and return migration: Technological development in India’s software industry

3.1.1 Major achievements

After 1984 and especially from the mid-nineties onwards India’s software industry has grown in a spectacular way, achieving annual growth rates of 37.5 % per annum (1995-2000) and 14.5 % in the first years of the new Millennium. This dynamic is based on a highly successful penetration of global software markets. Exports accounted for nearly 80 % of industry sales in 2001-2002.\(^{21}\) The value of exports of software and other services reached US$ 12 billion in 2003-2004.\(^{22}\) This growth in exports was accompanied by a similar expansion of the sector specific labor market: In 2004 the Indian software industry employed around 345,000 persons.\(^{23}\) A secondary effect of this impressive development is that the visible increase of the rewards for being educated has boosted demand for educational services.\(^{24}\)

While for a long time, Indian IT-software production was basically associated with low-cost programming, following strict design guidelines established by contracting companies, in recent years there are signs of a gradual upgrading, however still far from proving a narrowing of the technological gap between Indian firms and the leading global players. While at the end of the 1990s, around 90 % of the overall export work was done onsite, subsequently these shares declined considerably, to 66 % in 1995 and 45 % in 2001-02, reflecting a rapid growth of offshore development. This implies that the countries’ capabilities in acquiring and managing software programming projects for foreign customer have considerably increased.

Of a global market in IT services of US$ 349 billion in 2001 India accounted for 2.2 %, three times India’s share in world merchandise trade. This market share is basically due to very strong participation in the global market for custom application and application management (14.6 % and 15.6 % respectively). The participation in very demanding professional services, e.g. system integration is still very low (0.2 % of the world market). The development of own products is still largely incipient.

\(^{21}\) Athreye (2005), p. 4.
\(^{22}\) UNCTAD (2004), p. 169, based on NASSCOM data.
\(^{23}\) Dossani (2005).
\(^{24}\) Rodrik / Subramanian (2004), pp. 9 f.
The specialization pattern of India in the global software market can be traced back to a combination of a good level of technological expertise, well developed management capabilities and still low labor costs. However, India still has not managed to compete directly with the best global players on the basis of technological know-how. Desai puts it in the following way:

“When big clients install new computers and want new software systems, they call IBM, Cisco, Oracle, or such large, established firms; so also when they want to connect up offices across the globe. But when those systems need to be repaired, maintained or expanded, they are more likely to call an Indian firm; it requires painstaking examination of existing software and stick-and-paste reconstruction, but does not call for overall architecture. Indian firms are just beginning to enter embedded software and product design, but that market is largely unpene- trated”.”

3.1.2 Genesis

Indian development planning after independence (1947) aimed at an accelerated modernization trough industrialization and narrowing of the technology gap between the country and the industrialized economies. A closely linked objective was to gain higher independence from the latter (“self reliance”). The most important instrument implemented by the government was the establishment of universities, technical colleges and other training- and research centers with quite high capabilities by international standards.

This early employed instrument continues to play a prominent role until today, in spite of more or less paradigmatic changes in the overall macroeconomic setting and the policies applied (see below). India graduates around 350,000 engineers each year – five times as many as the US.26 There are about 1675 technical training institutes,27 releasing annually about 53,400 graduates and 41,100 diplomats in IT, electronics and telecommunication.28 Due to the high priority given to broad and qualitatively high technical training, India itself estimates to have the largest pool of personnel, qualified in natural sciences and technology.

Beyond this, for a long time there was no sector specific promotion policy targeting the IT-industry or more specifically the software sector. Quite the contrary the state remained rather hostile to the industry throughout the 1970s and early 1980s. Up to 1984 industrial policy clearly prioritized the aim of achieving self-reliance in hardware capabilities and creating national champions. Import tariffs were high (135 % on hardware and 100 % on software) and

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the sector was not recognized as an “industry”, impeding software developers and exporters access to bank loans. FDI was heavily regulated, limiting equity holding to minority shares.

Investing heavily in technical training on the one hand and impeding a dynamic development of a local industry on the other led to a considerable oversupply of IT-skilled people. This had two mayor consequences, the first and most important being emigration. In 1986, for instance, about 59% of IIT (Indian Institute of Technology) graduates in computer science and engineering migrated. Second, large service providers (such as Tata Consultancy Services) started to offer onsite programming services (“body shopping”), sending teams of programmer to clients in the US, Great Britain and other industrialized countries.

The development path changed significantly with political changes induced by the Rajiv Gandhi administration taking office in 1984. Import tariffs on hardware and software were reduced to 60%, software exporters became eligible for bank finance and in 1985 all export revenue was exempted from income-tax. Foreign Investment was greatly deregulated, at least with regard to export-dedicated units. Finally the establishment of a chain of software parks in the early 1990s was started that offer infrastructure at below-market costs.

This paradigmatic shift in the macroeconomic framework conditions came hand in hand with an important change within the industry itself: In the mid-1980s the global implementation of the so-called “U-W-standard” (Unix-workstation-standard) made programming of software independent from the platform and from the hardware component. This was an important step towards an international division of labour in the software industry.

“Programming became a stand-alone activity that required no domain skills: once the system was fully specified by the overseas designer, the programmer did not need to know either the hardware platform or the industry for which he was writing the program”.

These changes led to a considerable new dynamics in India’s software industry. The number of software firms rose from 35 in 1984 to 700 in 1990, with a considerable increase in the share of small firms. Many new companies were formed in the technological parks, partly by return migrants, who saw new business opportunities in their home country. However, the largest contract takers for the increasing software offshoring projects continued to be the already established large companies, such as Wipro Technologies or Tata Consultancy. New FDI entered the country, among them some of the most important global players in the computer industry (Hewlett-Packard, Texas Instruments).

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29 Dossani (2005), p. 15.
31 Dossani (2005), p. 17 f.
Industry started a geographical relocation from Mumbai and Delhi to Bangalore, where the first software technology park had been created and labor was cheaper and in greater supply. As early as 1909, the Indian Institute of Science (IIS) had been established in Bangalore. One of the most important player in the Indian Software and IT-enabled services (ITES-) industry, Wipro Technologies, is an IIS spin-off. Some of the global players in the electronic industry and related services (IBM, Accenture, Oracle, General Electric, Dell) located their Indian headquarter in Bangalore, contributing to the formation of an important technology region.34

The future development path of India’s software industry is not yet completely clear. There are only few indications that companies are specializing on technologically more demanding developments, such as embedded software of standard and packaged software. The last years were rather characterized by an increase in Business Process Outsourcing (BPO). In many cases, the contracted companies are the same large firms that have established trust-based relations to foreign customers in onsite and offshoring projects in software development. Many of the BPO-projects cannot be conceptualized as upgrading in the technological dimension, but comprise even rather simple services, such as call centers and transcription services. However, management capabilities of the large agents in India’s IT industry have undoubtedly risen. Many of them are themselves transforming into active international players, opening subsidiaries in developing as well as industrialized countries in order to acquire even larger shares of the outsourcing business.

3.1.3 Key characteristics of the trajectory and lessons for latecomer industrialization

The dynamic development of India’s software industry can clearly be traced back to IT sector reforms including the implementation of new technical norms in the industry in 1984-85. However, the most important driving force of this process can be seen in the early and continuous investment in human capital. For many years, this investment seemed to yield a negative return, as the money invested in education and training was lost due to very high rates of emigration. However, in the long run, this very migration proved to be one of the catalysts for development.

— First, a very strong Indian diaspora came into being, mainly in North America. Indian IT-specialists working in the US computer and software industry were important intercultural mediators, establishing contacts to the emerging IT-sector in India and facilitating contracts for onsite and offshore projects.

— Second, many of the emigrated professionals returned to India once the overall conditions for the IT-industry improved and new opportunities were created. They re-entered their country with an important stock of acquired technological expertise, intercultural

34 Fromhold-Eisebith (1999).
knowledge and contacts. In this context the establishment of new IT-firms by return mi-
grants had an especially catalytic effect.

However, for two reasons the Indian case cannot be considered an appropriate blueprint for
the development of IT-sectors in other developing countries.

- First, the country’s IT-training capacities have been very large in absolute terms, since
the very beginning of the process. Thus, even with an important share of experts leaving
the country, the number of remaining skilled professionals was sufficient to allow for
the development of a dynamic local industry, once appropriate framework conditions
had been established. Only the interplay between diaspora and local industry and the
subsequent return of migrants can explain the overall growth of India’s software sector.

- Second, India, mainly by chance, took advantage of an important window of opportu-
nity. In the mid 1980’s, political reforms that provided good framework conditions oc-
curred simultaneously to the implementation of technical standards that allowed for an
international division of labor in software programming. The concomitant “take-off” of
the PC and workstations market, substituting mainframe computers and leading to many
completely new applications, induced a rapid expansion and diversification of the
global demand for computer software.

Literature does not provide for clear indications whether the rapid growth of the Indian soft-
ware market might give rise to new opportunities for other developing countries. This could
be the case if the impressive growth of the industry leads to substantial rises in the overall
wage level in the Indian IT-sector. Rising wages would probably induce outsourcing of lower
qualified work to “second tier” followers. However, this will only happen if (a) the global
IT market’s upswing continues and if (b) India is not able to expand its IT-training capacities
sufficiently. Moreover, cross-border outsourcing is not so easy taking into account that the
success of international software projects is highly dependent on mutual learning between
contracting and contracted companies. This mutual familiarity needs to be rebuilt once new
agents enter the game. Thus only further research and observation will tell whether a “flying
geese-phenomenon” might occur in the software industry.

3.2 Carrots and sticks for foreign investors: Technological development in China’s
automotive industry

3.2.1 Major achievements

China is making strong efforts to build national technological expertise in the automotive in-
dustry. Since the formulation of the automotive policy in 1987 no other economic sector has
received a comparably strong backing by industrial policy.\(^{35}\) Given the soaring development of auto consumption, the government’s interest in the auto industry as a key sector for technological capability building remains unchanged, even though policies are less interventionist since WTO accession. Especially the growth of passenger car consumption is enormous, growing at 15% per annum during the last two decades. According to projections by Goldman Sachs, the number of cars sold in China is likely to triple during this decade, and within 20 years China will have overtaken the US as the world’s largest auto market.\(^{36}\)

At the end of China’s Cultural Revolution, the country practically had no technological base and no market for automobiles. Although much progress has been made since then, domestic technological capabilities still lag far behind. According to the China Automotive Technology & Research Centre,

“before the reform and opening up to the outside world, the Chinese auto industry was 30 to 40 years behind that of the developed countries, whereas nowadays the level as a whole is 10 to 15 years behind.”\(^{37}\)

Auto production is almost fully carried out under licence from foreign manufacturers. The industry still needs to overcome typical weaknesses of import substitution industries in small developing markets, e.g. less than optimal scale of production, lack of competition and, as a result of this, low productivity and low quality. In the late 1990s labour productivity in state-owned firms and collectively-owned Chinese firms was less than 20% of the levels in joint ventures with foreign partners.\(^{38}\) Chinese auto exports are almost nil.

Despite this obvious backlog many analysts assume that China’s domestic automotive industry will quickly catch-up with global industry leaders. According to Kroeber,

“foreign automakers should be afraid of domestic competition – very afraid. In industry after industry, Chinese firms have picked up technology much faster and kicked foreign competitors out of the market faster than anyone predicted. Think of TVs, air-conditioners, microwave ovens, washing machines, refrigerators, personal computers, telecoms switching equipment – all areas once dominated by foreign manufacturers, now dominated by Chinese producers ... In sector after sector, foreign manufacturers have piled into China only to see their technology copied and their prices undercut with alarming speed by domestic competitors operating with government support.”\(^{39}\)

\(^{35}\) Wang (2001), p. 3.
\(^{37}\) Quoted in Gallagher (2004).
This scenario is supported by the facts that China will soon be the world’s major auto market (thus providing for the necessary economies of scale), and the Chinese government and private sector are expanding their R&D expenditure while exerting pressure on foreign car manufacturers to share their technologies. Several leading car manufacturers, above all General Motors and Volkswagen, have set up major R&D centres in China – in part because they were encouraged, or even obliged, to do so, but in part also because they want to make use of a growing pool of skilled engineers and technicians. Furthermore, some national manufacturers of parts and components, and increasingly also car makers, aim to become global players in their own right. Most notably, China’s largest auto parts manufacturer Wanxiang acquired, merged with, or established 30 companies in eight countries, including the US, England and Germany.\(^40\) Shanghai Automotive Industries Corporation (SAIC) intends to develop its own car based on Chinese technologies. For this purpose SAIC acquired a majority stake in Korean Ssangyong for 500 million USD and is said to have interest in taking over Fiat.\(^41\) Chinese car manufacturer Brilliance just started exporting to Europe.

All in all, most observers concede that China is catching up quickly, although from a quite backward starting position. It is not yet clear, however, how successful the country will be, especially as the country’s WTO accession induced a marked shift in policy, and opinions diverge as to whether the old prescriptive FDI policy or the current more liberal framework is more conducive to technological learning. Different scenarios still seem to be possible.\(^42\) In the more optimistic scenario Chinese producers would rise to the challenges of a liberalised market and learn to make cost-competitive world-class vehicles, starting to export and achieving the governments target that by 2010, 50 % of the units sold in China must consist of automobiles whose technology is fully Chinese-owned.\(^43\) Alternatively, it is also possible that the industry will largely remain dependent on foreign technology licensing and go through an adjustment process that leaves a number of weaker manufacturers in bankruptcy.

### 3.2.2 Genesis

China’s automotive policy has passed through four phases:\(^44\)

1. The first auto assembly plant, FAW, started production in 1956. In the following years, several state-owned enterprises were established, each one producing for a different market segment. During the Cultural Revolution (1966-76) the Chinese gov-

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\(^40\) Gao (2004).
\(^41\) Frankfurter Allgemeine Zeitung, 22 June 2005
\(^43\) This goal was expressed in earlier drafts of the 2004 Automotive Industry Development Policy. However, it was later dropped as a binding target that might restrict sales of foreign manufacturers.
ernment started to build one car factory in each province aimed at supplying the respective local markets. This decision gave rise to a highly decentralised structure of small-scale production plants that persists until today. As private consumption was restricted the focus of production was on commercial vehicles. China’s auto policy at that time strove for self-reliance.

2. In 1978, China adopted the so-called “open policy”, starting to accept the use of foreign technology. High import tariffs were maintained while foreign investors were encouraged to take up automobile production in China. To encourage local linkages and spillovers China imposed a series of conditions on foreign investors with regard to foreign equity, local content, minimum exports, foreign exchange balancing, and technology transfer. In principle, China thus pursued an import substitution policies like most other developing countries at that time. To overcome the fragmented industry structure, China encouraged national producers to form groups of companies and to engage in specialised production. Self-interests of the provinces however limited the effectiveness of this policy. Still in 1996, 118 auto plants produced for a market of just 1.5 million cars annually! Despite this high number, competition was weak due to the fact that all these enterprises were controlled by local authorities which protected their provincial markets. Lack of competition, little demand and a fragmented small-scale industry structure went hand in hand with outdated equipment, poorly trained and motivated workers. As a result the Chinese auto industry performed very badly in terms of productivity and quality.

3. In 1994 China promulgated a new automotive policy. Its main objectives were to draw more foreign capital into passenger car production but at the same time being much more selective and conditional. During the 1990s, China’s long-term economic boom raised the expectations of global car makers and strongly enhanced China’s bargaining power. China was thus able to impose additional conditions on foreign investors, above all to establish R&D divisions in their Chinese affiliates, to bring in up-to-date technologies, to increase exports and to accept minority stakes in joint ventures. The new automotive policy thus increased central government influence on the auto industry, in contrast to the liberalising trend in the overall economy at that time.

4. WTO accession in 2001 led to strong liberalisation. In several steps China removed or phased out local content requirements, mandatory export targets and import licenses, and significantly reduced import tariffs. Since 2004, a new Automotive Industry Development Policy codifies post-WTO changes. Despite increased liberalisation, foreign ownership of joint ventures in the industry remains limited to a maximum if 50%. Earlier drafts of the official 2004 auto policy document set the goal of achieving that “50% of the vehicles sold in China must consist of vehicles whose technology is fully Chinese-owned”.\(^{45}\) Even though this provision was finally dropped, it shows that the

\(^{45}\) Freshfields Bruckhaus Deringer (2004).
government still pursues the objective to increase indigenisation. As Long has put it: “Although some performance requirements were called off after China’s accession to the World Trade Organization (WTO), certain voluntary performance requirements remain”. Industry analysts agree that the Chinese government will continue to influence foreign investors using such “voluntary performance requirements.” This may include both encouragement and legally doubtful forms of pressure. Among the first are tax incentives for firms which contribute to indigenous technology development. Moreover, foreign manufacturers of cars, motorcycles, engines, parts and components will more easily get permissions and be considered in public tenders if they set up R&D centres in China. Volkswagen experienced an example of the latter when its local joint venture partner copied its design and produced replica cars using original VW parts obviously with the tacit consent of the Chinese government.46

3.2.3 Key characteristics of the trajectory and lessons for latecomer industrialisation

Moving from the self-reliance policy of the Maoist era to import substitution policy and later to WTO conformity, China’s auto policy has made a remarkable shift towards liberalisation. Until quite recently, China’s import substitution policy displayed the typical weaknesses of small protected markets. Today, economic boom and massive FDI inflows in a more liberal setting help China to catch up fast with technological leaders. Despite all the inefficiencies involved in protectionist policies, it is unlikely that China would have fared better without previous infant industry protection. Incipient successes like those of Wanxiang and Brilliance would hardly have been possible if China had embarked on a liberal open-door policy from the beginning.

The most salient characteristic of Chinese auto policy is the country’s strong bargaining power vis-à-vis foreign car makers. To get approbation, foreign investors need to undergo a screening process and have to make concessions, e.g. committing themselves to invest in R&D and to share technologies. Chinese authorities quasi “swap market for technology.”47 Especially during the 1990s, i.e. before WTO accession, the Chinese government succeeded in playing off one foreign investors against the other,48 taking advantage of the fact that almost no global car manufacturer resisted the market pull from China. When Volkswagen refused to pass certain core technologies over to its local partner SAIC, General Motor was brought in as a second partner,49 based on the commitment to establish a R&D centre. Conversely, rents were granted to compliant investors. For example, Shanghai Volkswagen earlier “succeeded in making the Shanghai municipality forbid other cars from entering the Shanghai

49 Goldman Sachs Global Equity Research (2003), p. 27.
taxi market and government purchase plan.”\textsuperscript{50} Later on, GM benefited from municipal support.

Even though China committed itself to a more liberal trade regime and more transparent policies, there is evidence that China will continue to use “carrots and sticks” to protect Chinese companies and accelerate technological learning. Goldman Sachs expect “continued government influence on industrial policy and capital flows.”\textsuperscript{51} According to Harwit, there is evidence that various trade barriers outside WTO rules could remain, e.g. in public procurement, or encouraging citizens to “buy Chinese.”\textsuperscript{52} Long states that “in practice, the Chinese partners of some joint ventures or cooperatives privately require technology sharing or transfer from FIE foreign investors.”\textsuperscript{53} The Automotive Industry Development Policy still requires foreign automakers to set up research and development centres and limits foreign ownership in automotive joint ventures to a maximum of 50%.

Another remarkable trait of China’s industrial development is the acquisition of foreign companies. Enormous growth prospects and liquidity in China’s financial market enable local firms to buy major foreign technology companies. Acquisitions help to gain access to technologies, markets, and established brands. Major acquisitions of US and European firms by Chinese companies have just started and are likely to continue.\textsuperscript{54} In addition to “encouraging voluntary technology transfer” by foreign investors, acquisitions are another relevant option for bridging the remaining technological divide.

### 3.3 Spillovers from Taiwan: Technological development in China’s personal computer industry

#### 3.3.1 Major achievements

China is today the world’s main producer of personal computers, both desktops and laptops. Its share in global markets varies considerably with the product and vintage, but the overall dominance of China in producing personal computers is not in doubt.

\begin{itemize}
\item \textsuperscript{50} Wang (2001), p. 9.
\item \textsuperscript{51} Goldman Sachs Global Equity Research (2003), p. 26. China’s Guiding Directory on Industries Open to Foreign Investment distinguishes four types of activities where FDI is accordingly encouraged, allowed, restricted, or prohibited.
\item \textsuperscript{52} Harwit (2001), p. 668.
\item \textsuperscript{53} Long (2005), p. 7.
\item \textsuperscript{54} Besides the already mentioned acquisitions by SAIC and Wanxiang, car manufacturer Geely is just bidding for the remainders of Rover. Large takeovers by Chinese firms recently took place in a number of industries including household appliances, TVs, aircrafts and personal computers.
\end{itemize}
Becoming the No. 1 producer in one of the most rapidly changing and fastest growing sectors is an enormous achievement. However, history tells us that producing and innovating do not necessarily go together. Indeed, most the computers exported by China are produced to the specifications of their foreign customers. However, recently China has begun to make its own products and brands, for both the home and export market. The remainder of this section summarises the history of how this was achieved and then seeks to pull together the key explanatory factors.

3.3.2 Genesis

China’s computer producing history begins in Taiwan. Much of the Chinese production capacity results from the relocation of, or is an extension of, Taiwanese enterprises. In the early 1980s, Taiwanese firms gained a foothold in the computer industry by producing monitors or assembling fake Apple II computers and IBM compatible machines. Previous experience in producing TVs and other consumer electronics helped them to gain contracts from outsourcing US computer firms. Tracing the subsequent development is important in order to identify how Taiwan and then China managed to build up its capabilities.

The OEM system was critical for the build up of the computer industry in Taiwan, particularly in the early phase. Under OEM, the foreign customers purchased large quantities of goods manufactured by the latecomers. The customers defined the product, took care of the branding and provided the marketing channel; the local producers thus avoided the need for heavy investment in marketing and distribution. They concentrated instead entirely on acquiring production capabilities, investing in specialised skills and equipment. Challenge and support from the main customers was critical, as stressed by Hobday:

"Under the early OEM deals, the foreign corporations frequently supplied training, technical specifications and advice on engineering and capital goods. The OEM system proved an enduring technological training school for latecomers in the NIE [newly industrialising economies], enabling hundreds of small firms to overcome barriers to entry."\(^{55}\)

The rapid build of production capabilities resulting from this insertion in global value chains is agreed in the literature. The question is whether local firms were able to move up the value chain, in other words, progress from OEM to ODM (own design manufacture) and then OBM (own brand manufacture). Hobday’s research suggests that Taiwanese firms succeeded in acquiring the design capabilities but were not so successful in establishing own brands or own marketing channels. Acer was the main exception.

“... by the late 1980s foreign buyers and TNCs had begun purchasing goods under so-called ODM, allowing local companies to exploit their design talents and thereby gain more of the value added. Sometimes the latecomers designed goods independently, using their own knowledge of the international market. In other cases, they worked closely with foreign buyers and TNCs. The emergence of ODM signified a new phase of latecomer technological progress, indicating that local firms had internalized much of the ability to understand market needs, then to design, develop and make electronic products for overseas markets. As with OEM, the ODM system allows the foreign buyer or TNC to brand and distribute the goods ... enabling the latecomer to circumvent the need for heavy marketing investments.”

Kishimoto comes to similar conclusions, showing more evidence of firms reaching the ODM stage than attaining the OBM stage. He emphasises however that those firms which progressed to ODM or OBM did not withdraw from OEM. Typically a large part of their production capacity continued to be ‘reserved’ for their OEM clients and only some of their production lines were given over to production using their own design and brands. This strategy of operating in different types of chains simultaneously and leveraging competences across them has also been emphasised by Lee and Chen and was critical for understanding the build up capabilities in the Taiwanese computer industry.

Kishimoto emphasises that the computer industry’s dynamism came from the interaction of global and local linkages. The former are stressed by the global value chain approach and the latter by the cluster approach. One could go a step further and suggest that by 2000 the Taiwanese computer industry had developed into a modular production network in the sense described by Sturgeon. Firms have the entire range of required production skills; all the specialists are available locally; they can produce infinite product variety, any combination of attributes stipulated by customer can be dealt with; and where required they provide incremental R&D for adjustments.

Saxenian and Hsu add an important qualification to this analysis. They stress that major R&D continues to be carried out in Japan or the US.

“New product definition and leading edge-innovation will remain in Silicon Valley. However, Taiwanese companies continue to enhance their ability to design, modify and adapt as well as rapidly commercialize technologies developed elsewhere. As local design and product development capabilities improve, Taiwanese

58 Lee / Chen (2000).
59 Sturgeon (2002).
companies are increasingly well positioned to take new product ideas and technologies from Silicon Valley and quickly integrate and produce them in high volume at a relatively low cost.\textsuperscript{60}

It is important to recall that these advances were made under extreme competitive pressure to lower costs. As a result of these pressures and rising wages in Taiwan, the industry began in the 1990s to relocate production to Mainland China. This relocation was initially limited to mature products such as monitors. Since 2000, this relocation and extension into Mainland China has accelerated, covering most products and including the production of notebooks. There does not seem to be an up-to-date overview of how this geographical relocation affected the build of capabilities. However, a picture can be pieced together on the basis of various sources and informed guesses.

It seems that the relocation concentrated on two areas, the Greater Pearl River Delta region, in particular Dongguan, and the Yangtze River Delta region, in particular Shanghai. This is important because it seems that the industrial clustering which benefited the industry in Taiwan is being recreated in Mainland China. Within 40 square kilometres of Dongguan, it is possible to source 95\% of the components required for computer assembly.\textsuperscript{61} Kishimoto\textsuperscript{62} showed the importance of co-location for specialisation, speed of response and innovation in the Taiwanese computer cluster. The same effect can be expected – though with a time lag – also in China.

Even though the location of production has moved from Taiwan to the Mainland, insertion in global value chains continues to be critical for acquiring new capabilities. The transmitters of knowledge, however, are only rarely the US or Japanese customers but more often the Taiwanese intermediaries. Former Taiwanese producers have become increasingly involved in organising the chains and connecting the Chinese producers with the buyers in main foreign markets. Previously, chain coordination was in the hands of the brand name computer vendors but, as noted by Dedrick and Kraemer,\textsuperscript{63} the Taiwanese ODMs are vying to take over this role.

There is a danger, given the fascination with recent Chinese achievements, that the role of the Taiwanese firms and networks is overlooked. More research is needed on their contribution and its change over time. Casual observation suggests that the Taiwanese firms played a major role in establishing the computer industry in China and continue to play a role in management, co-ordination and certain design activities.

\textsuperscript{60} Saxenian / Hsu (2001), p. 915.
\textsuperscript{61} Enright et al. (2005), p. 112.
\textsuperscript{62} Kishimoto (2002).
\textsuperscript{63} Dedrick and Kraemer (2003).
China has also benefited from the foreign direct investment of US and Japanese component manufacturers. For example, the world’s leading producers of micro-processors and electronic storage devices (Intel, AMD and Seagate) have invested in China. As stressed earlier in this paper, China has benefited not just from foreign direct investment in production but also in R&D. It is not clear however, whether this R&D remains limited to secondary innovation, merely supporting or complementing R&D carried out in the US or Japan, or concerned with the core technologies. In the computer industry, the big question is whether – using the words of Saxenian and Hsu (see above) – new product definition and leading-edge innovation will remain in Silicon Valley or gradually move to China.

What seems clear is that the production of computers (not advanced components) is carried out increasingly by Chinese firms. Future research will need to show whether these firms remain limited to production or move further up the value chain, into design, branding, marketing. Most firms will probably continue to concentrate on production but some firms are likely to become innovators. This advance is likely to take place for five reasons:

— **The size and peculiarity of the home market**: Close knowledge of and brand presence in the lead market has been critical for concept design. The US remains the main lead market, followed by Japan. China is developing its own distinct lead market, due to its size and peculiarity (greater emphasis on low price, different marketing channels). A local brand (Legend/Lenovo) is market leader in the PC market, with a market share of 30%. Other local brands followed. “Chinese PC brands now take roughly two thirds of the market share in China.”64 Future research will need to establish how innovative their products are, in which respects they differ from products for the world market and to what extent Lenovo and other Chinese OBM*s* have achieved mastery in core technology areas.

— **Return migration**: Large numbers of Chinese students have studied in the US, in particular electronics and computer science. They are now returning to China in order to take advantage of the new economic opportunities. Saxenian and Hsu65 have stressed the importance of return migration from the US for the development of the Taiwanese computer industry. Müller and Sternberg66 have underlined the importance of return migration for the semiconductor and software industry in Shanghai. Future research will need to show whether the same applies more generally to the Chinese computer industry. This seems important because, as stressed by Müller/Sternberg and Saxenian/Hsu, the returning migrants have professional and personal networks critical for building a new knowledge-based industry.

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65 Saxenian and Hsu (2001).
— **Massive investment in human resources:** There is an “explosion of enrolments of science and engineering students in Chinese universities. Currently they graduate over half a million a year, three times as many as Japan.” Future research will need to establish whether this explosion includes enrolments in electronic engineering and computer science and whether the graduates contribute to technological innovation in the Chinese computer industry.

— **New institutional experiments:** As shown by Yu Zhou, China has been able to transform its most significant Science Park (Zhongguancun in Beijing) into an innovative region by experimenting with new forms of collaboration between academic institutions and the private sector and between Chinese enterprises and multinational companies. It has specialised in particular in computer hardware and software. Future research will need to establish whether this experiment has indeed resulted in an international centre of high-tech research and development.

— **Buying power:** In December 2004, the Chinese computer company Lenovo (which originated in Zhongguancun) purchased IBM’s global PC business, making it the third largest PC maker in the world. IBM’s teams of desktop and laptop designers now belong to Lenovo. It is likely that this design capacity will be moved from the US to China even though the extent and speed of this migration remain unclear. Most critically, future research will need to show whether outright purchase of foreign research capacity can help China to make a leap in developing its own technological capability and perhaps even catch up with the main innovators in the computer business.

### 3.3.3 Key characteristics of the trajectory and lessons for latecomer industrialisation

The build up of competence in China cannot be understood without considering the key role of Taiwan, both historically and currently. There is no mono-causal explanation for the rapid rise of first Taiwan and then China in the computer industry. Given the short product cycles in the computer industry, one might have expected that the fast rise was due to leapfrogging. This was not the case. In Hobday’s words “firms engaged in a painstaking and cumulative process of technological learning: a hard slog rather than a leap frog.”

This hard work bore fruit because it occurred under the following conditions:

— Insertion in global value chains;
— Co-location (clustering) of local firms;
— Return migration of engineers;

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— State investment in higher education;
— Institutional experiments at critical stages.

While these factors are well researched for the 1980s and 1990s when most of the industry was located in Taiwan, each of them needs thorough examination for the post-2000 period when much of the industry moved across to the Mainland.

Perhaps the main difference between the Taiwan and the Mainland experience lies in the reliance on foreign direct investment. The Chinese have been welcoming the foreign direct investors as purveyors of technical, managerial and marketing expertise. The question is whether this position will continue once the Chinese have learnt all there is to learn.

“As China’s stock of technological expertise accumulates and it no longer needs to acquire technology and management expertise from joint venture partners, it is not at all clear that its present welcome to foreign investment will remain as warm. Japan also welcomed Ford and General Motors in the 1930s, and subsequently froze them out when they had learned enough.”70

3.4 Driven by public research: Technological development in India’s space industry

3.4.1 Major achievements

Starting to develop capabilities immediately after independence, India has built one of the world’s leading national space programmes covering three major complementary areas: satellites, missiles, and ground systems. The country has the ability to design, produce, and launch its own satellites, to control and track them from the ground, and to receive and process complex remote sensing data gathered by the satellites.

In the area of satellites, India’s space programme comprises communications satellites (for telecommunication, television broadcasting and meteorological services) and remote sensing satellites (for resource survey and management, environmental monitoring and meteorological services). Its technological capabilities evolved from TV-camera-based systems in the late 1970s to state-of-the art high resolution imaging systems.71 India is the only developing country to develop its own remote sensing satellite. During the 1980s the country developed and successfully launched intermediate-range ballistic missiles for both military purposes and as carriers for the national satellite programme. Since then, new variants of more powerful rockets have been developed. In 1994 India’s Polar Satellite Launch Vehicle (PSLV) succeeded in placing an 800 kg remote sensing satellite in the intended orbit – something which only six

countries have the required capabilities for. More recently the country developed a Geosynchronous Satellite Launch Vehicle (GSLV) capable of putting 2,000 kilograms satellites into space. ISRO is currently trying to develop an indigenous cryogenic engine for the GSLV to become independent from Russian technology. *Ground system technologies* comprise rocket launching facilities, spacecraft control and tracking facilities as well as facilities for receiving, processing and utilizing satellite data (TV stations, weather forecasting, disaster warning etc.). India has made significant advances in all these technologies. The country is now planning a robotic mission to the moon that is tentatively scheduled to launch around 2008 and an astronomical satellite that will enhance the capability to pursue basic science and provide a platform for observing our planetary system and beyond.72

India is now one of the main providers of satellites in the civilian domain, and revenues from commercial applications help to recover some of the costs of the annual space budget. The global satellite manufacturing industry however is plagued by significant over-capacity, and it may well be that market consolidation will leave only one or two satellite manufacturers – probably from the US and Europe – unless minor providers like India continue to subsidize its national industry. Commercial success of India’s space industry is thus not secured.

Space programmes require an extraordinarily broad array of technologies including optics design, electronics and telecommunications systems, software development, new materials, advanced combustion technologies, testing and evaluation, etc. The development of all the related capabilities has probably generated relevant spillovers into different manufacturing industries. In addition, the great number of technologies required for the space programme calls for enhanced capacities to manage very complex systems of closely intertwined technologies. National-level projects which involved a great number of research institutions as well as public and private enterprises helped to develop these capabilities which are crucial for systems integration in other industries.

### 3.4.2 Genesis

Already immediately before and after independence in 1947, India set up a number of scientific organizations which can be seen as precursors of India’s space programme. The space programme as such had its genesis in the Indian National Committee of Space Research, which was established in 1962 and later transformed into the Indian Space Research Organisation (ISRO). In the same year the Thumba Equatorial Rocket Launching Station in Kerala was established. Indian scientists launched US-made rockets carrying French satellites from Thumba to study the upper atmospheric winds over the magnetic equator. The first Indian experimental satellite was developed in the early 1970s and launched in 1975 by the Soviet

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72 ISRO chairman Gopalan Madhavan Nair, Space News, 3 February 2004
Union. Early satellites were dedicated to telecommunication experiments and meteorology. Much later, in 1988, technologically more complex remote sensing satellites followed.\footnote{Baskaran (2001a).}

In the early 1990s INSAT, an interagency project operated by the Department of Space, succeeded in putting its first indigenously-built satellites into geostationary orbit over the Indian Ocean using French rockets. Three fully Indian satellites operated by INSAT for domestic radio relay, computer network, television, rural telegraph network, and weather, emergency, and other radio communications were in use in the mid-1990s.

In 1980 India began using domestically produced launch vehicles for its experimental satellites. In May 1994, after several failed launches, India succeeded in deploying a satellite and placing it in a low earth orbit. A number of successful launches of increasingly powerful rockets followed in the subsequent years. With every new generation of rockets Indian scientists and industry learned to master more sophisticated technologies.\footnote{See “ISRO’s milestones” at the institution’s website.}

1992 was the beginning of the “commercial phase”. ISRO set up Antrix Corporation Limited as its commercial arm for the promotion and commercial exploration of products and services from the Indian Space Programme. Commercial success was achieved in different fields:\footnote{Baskaran (2005), p. 168 f.}

- selling remote sensing data,
- exporting satellite sub-systems and components,
- providing consultancy and training in ground systems,
- providing telemetry, tracking and command services to foreign satellites,
- launching satellites for European countries.

Although revenues continue to be quite low in comparison to the cost of the space programme, the ability to sell services and components to many OECD countries is proof of the technological maturity of India’s space programme.

### 3.4.3 Key characteristics of the trajectory and lessons for latecomer industrialization

The development of India’s space industry was almost fully government driven in a strategically planned top-down approach. From its very beginning the project was conceived as a political pet project that was driven by scientific ambition and nurtured by a good deal of national pride. The programme required hierarchical coordination and a top-down decreed division of labour among many national space centres with the aim of developing complementary key elements of a national space programme. ISRO was instrumental in leading this centralized technological development effect. All its chairmen were closely connected with Indian
governments while all political leaders were strongly supportive and secured continuously high funding from the very beginning of the space programme.\textsuperscript{76} India’s current President Dr. Abdul Kalam for example had formerly been the head of India’s missile programme.

Market forces played much less of a role than in any of the previously discussed technological trajectories in India and China. However, the space programme can be assumed to have generated substantial technological spillovers both into the technological development of local industries and into institutional research capabilities. The private sector was hardly involved in the early years of the space programme. With increasing requirements, however, ISRO started to farm out many parts and technological solutions to the Indian industry. ISRO created a group of coordinators who helped to raise technological capabilities in cooperating enterprises and to enhance the transfer of technology from various space research centres. During the second half of the 1970s already 230 enterprises worked with the space programme, and this number increased to 500 firms by 1992, absorbing more than half the Department of Space’s budget in contracts.\textsuperscript{77} “The firms were involved in prototype development, engineering, research and development related to fabrication problems and final production. ISRO also encouraged major suppliers to use subcontractors to cut costs and development time.”\textsuperscript{78} Several industries, e.g. software development, TV and broadcasting, received strong impulses from the space programme. Science-enterprise relations thus played a major role since the 1970s, but unlike in mature innovation systems, technology flowed largely unidirectional from R&D institutions to the private sector.

Likewise, academic research capabilities strongly benefited from the space programme. ISRO alone employ around 11,000 scientist and engineers. In addition, already by 1993 ISRO had supported about 300 research projects involving over 100 academic and public R&D institutions.\textsuperscript{79}

International linkages were fundamental in all phases of development. Unlike in most other industrial sectors, the main sources of foreign technology were institutional partners rather than private foreign investment. In early phases, NASA, as well as ITU, UNDP and other international organisations, supported the programme through donations, training, and increasingly joint research programmes. Later on, French, Russian and German space research organisations as well as ESA were important partners. Furthermore India sent a great number of scientists and engineers to be trained in industrialized countries and ISRO generously sponsors participation of Indian scientists in collaborative space research programmes with foreign space agencies.

\textsuperscript{76} India intends to spend $722 million on space activities during its 2005-2006 fiscal year, an increase of 24\% over the previous year.

\textsuperscript{77} Baskaran (2005), p. 166.

\textsuperscript{78} Baskaran (2001b), p. 212.

Spatial clustering and local academic milieus do not seem to have played a major role. Although much of the top executive authority of the science and technology infrastructure in India resides in New Delhi, some premier science and technology institutions are located elsewhere. ISRO is headquartered in Bangalore and has operating units at twenty-two sites throughout the country that deal with space systems, propulsion, communications, telemetry and tracking, research, launches, and other facets of the space program. Bangalore is a centre for high-technology industry and a major research and development site. Much of the activity in Bangalore is carried out through collaborative arrangements with multinational corporations in fields such as aeronautics, communications, electronics, and machine tools. The Tata Institute of Fundamental Research in Mumbai conducts fundamental research in astronomy, mathematics, molecular biology, and physics; and applied research in computer science, ion accelerators, material science, and solid state electronics. Earlier, Ahmedabad served as a local hub for the first project to develop satellite television broadcasting.\(^80\)

### 4 Impact on other developing countries: some observations and research questions

The previous sections suggest that there remain many questions concerning the depth and mode of building innovation capabilities in China and India. Nevertheless, it is clear that the advances in China and India indicate a significant shift in the global distribution of innovation activities. It is therefore not too early to ask how other countries will be affected by this shift. It seems likely that the main losers will be the developed countries, i.e. North America, Western Europe and Japan. For three decades they have been willing to let go of industrial production activities, assuming that they would retain innovation activities. This assumption is now very questionable, even though the impact of the shift in innovation activities to China and India is likely to vary between countries, sectors and type of innovation.

In line with the theme of the St Petersburg workshop, this paper aims at identifying some research questions regarding the impact on other developing countries. How are they affected by the technological advances of China and India? This is uncharted territory. The main questions to be considered are as follows:

1. Can China or India be role models for other developing countries? What can the latter learn from these two newcomers on the innovation stage?
2. What other impacts on the economic and technological development of developing countries can be expected?

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\(^{80}\) Ibid., p. 164.
4.1 China and India as role models?

The successful, or at least very promising, upgrading strategies summarised in this paper hold a number of lessons for other developing countries.

1. All four case studies have shown that it still is feasible to catch up technologically with industrialized countries, despite certain adverse framework conditions emanating from the increasingly complex technologies and regardless of regulatory restrictions on industrial policy. In none of these industries, however, China and India have really caught up with leading global innovators. It is not sure in which sectors one or both emerging economies will really be able to pocket innovation rents and how long this would take. However, the technology gap has narrowed considerably and the progress achieved is significant.

2. Very different trajectories may lead to technological upgrading. The four sectors presented in this paper had very different starting points: a science-driven government pet project, network spillovers from Taiwan to Mainland China, early investment in IT skills development, and traditional import substitution in conjunction with a strong bargaining power.

3. Despite different starting points, the different trajectories tend to converge towards rather similar patterns of systemic innovation. The space industry for example originated from a group of scientists and politicians. It was started based on one vertically integrated government research institution but incorporated decentralized Universities and private sector suppliers as it grew. Typical elements of mature NIS, such as University-enterprise linkages, public-private development partnerships and the governance structures necessary to integrate different technologies in coherent systems emerged only gradually. Likewise, such systemic relationships (including the giant Zhongguancun Science Park in Beijing, with a strong enterprise cluster and several Universities and research centres) emerged in China’s PC industry - which had started as a low cost assembly location.

4. In some sectors strategic vision and political leadership were crucial for success. This was most notably the case in Indian space technology. The software industry in contrast was not developed with the aim of building a new competitive industry. Rather, its rapid success seems to have taken India by surprise. Important infrastructure and regulatory bottlenecks thus persisted for quite some time. Indian authorities however have the merit of having recognized the importance of IT skills earlier than most others.

5. Both countries place high emphasis on skills development. This is not only government policy but deeply rooted in the values of Chinese people as well as India’s upper castes. Both countries have a tradition of sending many of their best students to study and work abroad. This has provoked brain drain, but also created diaspora and cross-border networks which have resulted in enhanced flows of knowledge and technology. Perhaps poor countries should now send their most promising cadres (students, young professionals, attachés) for study and work to the centres of learning and innovation in China and India rather than to OECD countries. It may prove to be cheaper and more effective.
6. Neither China nor India offer what liberal economists consider to be a conducive investment climate. China only ranks 112th among 155 countries listed in the Economic Freedom Index, and India ranks even lower (118th). On the World Bank’s “Ease of Doing Business Index” (also 155 countries) China ranks 91st and India 116th. Both countries nevertheless attract considerable FDI (with China being by far the leading destination of global FDI) and successfully induce spillovers. Future research will need to shed light on the links between business climate and investment. In the case of China and India, it is important to understand why the elements captured by the business climate indicators seem less relevant and whether the market size factor compensates for the disadvantages of state bureaucracy.

However, two very unique factors greatly contributed to China’s and India’s progress, which can hardly be replicated in smaller developing countries:

- Both countries have huge and rapidly expanding internal markets. In China, “the number of people with incomes over US$ 3,000 could increase by close to ten times in the next decade and by nearly 14 times in India, though off a much lower base.” Domestic demand for many consumer products like automobiles, motorcycles and mobile phones, TVs, air-conditioners, washing machines, refrigerators, and personal computers is rocketing. As a result, economies of scale are easy to achieve without the need to export. Market size, coupled with long-term growth prospects, makes the two countries very attractive for FDI and gives both countries a good bargaining position vis-à-vis foreign investors.

- Both countries have accumulated foreign exchange reserves at historically unprecedented levels. This enables them to buy knowledge-related assets from industrialized countries at a relevant scale, e.g. acquiring leading technology firms, to boost R&D expenditure, and to offer very attractive salaries and working conditions to high-level experts from leading universities and corporations in the West, especially Indian and Chinese expatriates in order to attract them back. This is something unique in the history of developing countries, with the exception of the Gulf States.

4.2 Other impacts on the economic and technological development of developing countries

China’s and India’s build up of technological capability is likely to generate a number of more direct economic spillover effects for other late comer countries. Five elements, derived from China’s and India’s changing role in the global division of labour, seem to be particularly relevant: They are captured in the following hypotheses which will need to be examined in future empirical research.

**Spillovers from sustainable productivity-driven growth:** Technological advance helps China and India to move from factor-driven to productivity-driven growth which is necessary to ensure the sustainability of the growth process. China’s and India’s rate of economic growth has a very strong impact on other developing countries, especially

- **crowding out effects** via low cost export of basic manufacturing products and
- **stimulating effects** via increased global economic growth and demand for natural resources in particular.

This will be shown by other papers at the St. Petersburg workshop. It can be assumed that growth in China and India will be more sustainable if it is fuelled by TFP growth rather than increased utilization of production factors only. Technological upgrading in these two large economies will thus contribute to improving the growth conditions of the rest of the world. This will drive commodity prices up, favouring natural-resource exporters among developing countries.

**Rising entry barriers in technology markets:** At the same time, the fact that two additional large competitors enter the stage who are able to provide knowledge-based goods and services at much lower cost than most developed countries raises entry barriers for other newcomers. One might assume that as China and India move up the technological ladder and productivity and wage levels rise, certain lower productivity/lower wage activities will be left to poorer countries. China might for example shed low-value added stages of production to Vietnam or Indonesia, whereas India’s progress in the software business might open up new opportunities for Egyptian or Jordanian software producers. Moreover, moving up the technological ladder might increase the price of labour-intensive manufacturing in China and relieve pressure on competing producers elsewhere. This would be in line with the theorem of comparative advantages. In the Asian context, the “flying geese” pattern of regional division of labour seems to confirm this empirically. The argument however is not persuasive. Singapore, Taiwan, Korea and Hongkong all have small labour markets. Economic development in these countries quickly led to the full absorption of the available skilled workforce, driving wage levels up and creating incentives for the relocation abroad of less productive industries. China and India however have nearly infinite reserve armies of labour and strongly invest in skills. Significant labour shortages are unlikely in the foreseeable future.

**Improved terms of trade for many developing countries:** Impressive growth in manufacturing and, to a lesser extent, tradable services, adds to global surplus supply in many sectors. This is obvious in the automotive sector or in the satellite industry which are both plagued by excess capacity and fierce price competition. The same may occur in many other sectors including capital goods. Developing countries, which are mainly importers of knowledge-intensive manufacturing and service products, are thus likely to benefit from falling import prices. At the same time, natural resource exporting developing countries are likely to benefit from sustained demand in China and India. Both the shortage of natural resources and the price fall in capital and consumer goods may result in improved terms of trade for developing countries. Again, technological upgrading will have little effect on the problematic situation of those developing countries which compete in low cost manufacturing exports.
China and India may provide knowledge-intensive products or process innovations more appropriate for developing countries than those originating from OECD countries. China and India are likely to look for suitable solutions for their own lower-income home markets and find solutions which are influenced by their own factor endowments (especially cheaper labour). It will be need to tested whether product or process innovations coming out of China or India are really cheaper and more suited to the needs of other developing countries. Another important question is whether/to what extent China and India provide more favourable access to proprietary technology. Then there is the question of whether ownership matters. Does it matter whether the innovating companies in China or India are domestic or foreign?

New South-south technology alliances are likely to emerge: As several emerging economies move into knowledge-intensive activities, new technology partnerships among these countries can be expected. During a Chinese state visit in India in 2004, both countries agreed to start exploiting synergies between Indian software and Chinese IT hardware capabilities. Likewise, China and Brazil signed an agreement on cooperation in the space industry. India formed an Alliance with Brazil and South Africa (called IBSA) which includes increased cooperation on technology projects. If and to what extent these incipient partnerships among anchor countries will be more than “symbolic policy” and become relevant in terms of jointly furthering technological development is another issue for further research.
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