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Policies for Industrial Learning in China and Mexico

Kevin P. Gallagher *
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Abstract: Previous work has shown that the results of both China and Mexico's export-led market reforms over the past quarter century have been strikingly different. In contrast to China, Mexico has not managed to increase the value added of its exports of manufactured goods and has subsequently had a difficult time competing with China in world markets. Building on this previous work, in this paper we conduct a comparative analysis of the role of government policies in industrial learning and the development of capabilities of indigenous firms in Mexico and China in order to shed light on why China is outperforming Mexico. We find that Mexico and China have had starkly different approaches to economic reform in this area. Mexico's approach to reform has been followed a "neo-liberal" path, whereas China's approach could be described as "neo-developmental." Mexico's hands-off approach to learning has resulted in a lack of development of endogenous capacity of domestic firms, little transfer of technology, negligible progress in the upgrading of industrial production, and little increase in value added of exports. By contrast, China has deployed a hands-on approach of targeting and nurturing domestic firms through a gradual and trial and error led set of government policies.

1. Introduction

There are striking similarities between China and Mexico's economic development over the last quarter century. There are also significant differences. Like Mexico, China's economic model was not performing

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well and there was a need for economic reform, including export promotion. Like Mexico, China was a one-party state during the period of reform (Mexico democratized in 2000, however). Like Mexico, China has sought to attract foreign direct investment (FDI) into manufacturing and high technology sectors to gain access to technology. Both countries have expanded export of manufactured goods, particularly in high or information technology industries (IT hereinafter).

As we will see, this is where the similarities end. China's annual average per capita growth rate has topped 8 per cent over this period, where Mexico's has been barely over one per cent. China's annual average growth rate in manufacturing value added has been well over ten per cent since 1980, whereas Mexico has been closer to 3 per cent. China is becoming the manufacturing powerhouse of the world economy and an increasing source of innovation, moving up the technology ladder from assembly-based manufacturing activity. In Mexico, manufacturing remains at the low end of the technology ladder and it is losing its competitiveness relative to China (Gallagher and Porzecanski 2008; Gallagher, Moreno-Brid, and Porzecanski 2008; Pizarro and Shafaeddin 2007; Dussel Peters 2005, 2007). We show that Mexico's performance is in part a function of a neo-liberal mindset that sees a very limited role for the state while integrating into the world economy. China on the other hand, followed a pro-active strategy for its globalization pursuits. Mexico's route to international integration has come at the expense of industrialization and learning; China's pro-active approach has made it the manufacturing powerhouse of the world economy.

The purpose of this paper is to examine the extent to which government policies toward industrial learning for enhancing value added in exports and subsequent development have differed in the two countries over the past quarter century. The paper is divided into four parts in addition to the introduction. Following this brief introduction Part I is a short literature review on industrial learning. Part II examines the cases of Mexico, Part III analyzes China. Part IV summarizes our main findings and draws lessons for research and policy.

I. The Role of Learning in Industrialization

Regardless of the theoretical framework deployed, the role of learning in

capacity building is seen as paramount for industrial development. Yet, the literature has two poles. On one end, the proponents of governments playing a strong role in industrialization stress "learning-by-doing". By contrast, those in favor of market-led industrialization believe in the contribution of "learning through trading".

A neo-developmentalist approach argues that it contributes to industrialization through "learning-by-doing" and experience. By contrast, neo-classical or neo-liberal approaches argue that industrialization comes from "learning through trading". The basic difference between the two is that while the first group favors government intervention, the second one argues for the operation of market forces without government interference.

In the neo-classical theory of international trade, technological knowledge and information is freely available, diffusion of knowledge is costless, instantaneous and automatic; there is no significant learning process and its development of technology is riskless. All markets are competitive and comparative advantage is determined by factor cost. As the existence of increasing return and barriers to entry are assumed away, there is no need for the late-comers to invest in human capital and to intervene in the market to promote knowledge intensive products which are produced by established firms. Further, there are no static or dynamic externalities. Production costs in different products are not interdependent; there are no spill-over effects. Similarly, there are no inter-temporal relations between present income/costs and future income/costs as experience has no place in cost/income determination. In nutshell, as there is no market and institutional failure, there is no need for any policy intervention.

The importance of learning and knowledge accumulation has been emphasized in the post-war and modern theoretical and empirical literature since the publication of the pioneering article on learning-by-doing by Arrow (1962). To him, the acquisition of knowledge is a product of experience which grows in time. The need for government intervention in learning by doing is articulated in "capability building theory". The theory of capability building (TCB) is built on the infant industry argument of Frederick List according to which "mental capital", or the accumulation of knowledge and experience, is regarded as the main element of "productive power" [development] and industrialization. Industrialization in newcomer countries would not take place according "to the natural course of things" (through the operation of market forces alone) and government policies should aim, *inter alia*, at facilitating learning at both the industry and country levels (see Shafaeddin 2005: 50 for details).[1] The importance of learning and experience in industrialization has also been emphasized by many other scholars (Linder 1961; Krugman 1984; Nelson and Winter 1982).

The theoretical and empirical literature on TCB theory is vast.[2] One strand, the evolutionary theory of TCB, is most relevant for developing countries. The evolutionary version of TCB draws not only on the infant industry argument but also on the evolutionary theory of change (Nelson and Winter 1982) and new growth theory (see: Lucas 1988; Romer 1986, 1987). Scholars[3] of this version of TCB regard technological capabilities (learning) and technology absorption and diffusion, as the backbone of industrialization and international competitiveness (e.g. Teubal 1987). They define technological capabilities (TCs) in a very broad sense at all levels of activities of firms (i.e. beyond the technique of production) "as *the information and skills - technical, organizational and institutional - that allow productive enterprises to utilize equipment and information efficiently"* [italics added] throughout the value chain (Lall 1993: 7). Evolutionary theory also considers the interaction of a firm with other firms and the external environment in obtaining inputs, in the sale and marketing of its products, and particularly in the innovation of new products and processes.

In contrast to neoclassical theory, under TCB technology is not freely available; the market fails to develop technological capabilities automatically due to reasons of dynamic externalities and linkages, lack of information, uncertainties, risks and missing and malfunctioning markets. Technological learning involves costs and takes time. It does not take place instantaneously because the required learning is a long, costly and evolutionary process. It requires purposeful efforts by enterprises as well as government to pursue policies for capability building through R&D, development of knowledge and organizational change, particularly at early stages of industrialization (Schmitz and Hewitt 1991: 190; Teubal 1996: 449; Moore 1997: 516). Government policies should be both functional and selective. Selective and targeted intervention is, in particular, necessary because learning is technology specific, firm specific and activity specific, and technologies differ in their tacit features and externalities (Lall 2005). Further, all activities

and industries cannot be developed at the same time because of the scarcity of skills and other resources (Shafaeddin 2005).

R&D for development of domestic technological capabilities and upgrading is the backbone of TCB. R&D is seen as being so important that even some neoclassical economists advocate direct subsidization of knowledge acquisition and R&D (Baldwin 1969). The experience of many developing countries with traditional import substitution indicate that learning from experience alone is not sufficient for building-up necessary technological capabilities; appropriate policies are required to overcome market failures constraining development of technological capabilities[4] (Bell, Ross-Larson, and Westphal 1984). In fact, in the case of Asian NICs, government policies and close cooperation between the government and the private sector were crucial in promoting technological capabilities for industrialization and upgrading and for remedying the related obstacles (see e.g. Lall 2005).

In the age of globalization, government action to enhance firm's capabilities to achieve competitive advantage becomes more important than before because the minimum entry barriers and skill requirements have become higher and risks involved in entry of firms of developing countries into new activities has increased (Archibugi and Michi 1997: 121; Shafaeddin 2005; Lall 2005). FDI may provide certain skill and marketing channels for exports. Further, it is argued that when an economy opens up to trade and FDI, an initial period of imitation will lead to a large catch-up opportunity followed by a shift towards innovation "as the knowledge gap is reduced and the economy's technical maturity rises" (Elkan 1996). However, a test of the impact of FDI on the industrialization of a developing country is its impact on development of local capabilities through spillover channels of demonstration effects, training effects and linkages effects (Paus 2005). Such capabilities can be influenced, *inter alia,* by learning, experience, skill development and the accumulation of knowledge by the labour force of the host country. Generally speaking the findings of literature on the spillover effects of the FDI on the host country is mixed (for a comprehensive review of this literature see: Görg and Greenaway 2004).

While learning and technological development are firm specific, they are also activity specific. For example, "the learning curve differs across quite similar products such as distinct types of memory chips" (Gruber 1992:

885). IT industries, which began in Mexico and China at the assembly operation stage, are both supply dynamic and demand dynamic. They are supply dynamic because they can provide important linkages with other industries and their learning effects in the economy. They are demand dynamic because international trade in these products has been expanding rapidly during recent decades. Therefore, while looking at the general process of processing industries in Mexico and China, we will, in particular, look into development of these industries.

Our aim in this paper is to investigate how policies have contributed to the success of China in knowledge accumulation necessary for enhancing local value added in exports which have been absent in the case of Mexico. Our main focus will be on R&D and its role in the process of industrialization, although some other contributing factors to development of capability of local firms will be discussed as well.

II. From Learning to Hoping: Mexican Industrial Strategy under NAFTA

Mexico's industrial strategy has been radically transformed over the past quarter century. The goal has remained the same: "catch-up" with the industrialized world in industrial technologies and capabilities. However, the means have changed. Up until 1984, the core of meeting the nation's objectives centered around a government-led model of learning. Since that time, however, the core means to industrialization has been market-led. This section of the paper shows that whereas in the first period Mexico actively pursued the development of technological capabilities through government policy (though not very successfully), in recent decades government policy has been restricted to creating an environment for foreign investment in the hopes that FDI would bring technological know-how that would automatically spill over into the broader economy. Mexico has had an advantage over China because it has had privileged market access to the USA through NAFTA since 1995.

Over both periods Mexico has certainly aimed at becoming an industrialized country. Mexico has diversified away from an economy primarily based on primary products, has received unprecedented amounts of FDI, and has significantly boosted exports. However, these inroads have

come at considerable cost. Mexico has become plagued by a lack of linkages between foreign firms and the domestic economy, painfully low levels of technological capacity building, low valued added in exports of maquiladora sector, an overdependence on the United States as a chief export market, and a lack of competitiveness *vis- a- vis* China.

ISI and Industrial Learning

In Mexico and elsewhere, the tools of ISI focused on a number of key policies, including major public investment in infrastructure; import tariffs, licenses, and quotas to buffer domestic firms and enhance their technological capabilities; exchange rate controls, and direct government investment in key sectors (Fernández 2000). Through this process, Mexico attempted to create "national leaders" in the form of key state owned enterprises (SOEs) in the petroleum, steel and other industries. These sectors were linked to chemical, machinery, transport and textiles industries that also received government patronage (Baer 1971; Amsden 2000). Indeed, in the first decades after World War II, these sectors received over 60 per cent of all investment, public and private (Aguayo Ayala 2000).

In addition to SOEs and state patronized private industries, Mexico established export-processing zones called *maquiladoras* in the mid-1960s. Maquiladoras are "in-bond" assembly factories where imports of unfinished goods enter Mexico duty-free provided that the importer posts a bond guaranteeing the export of the finished good. Many maquiladoras are located in the U.S.-Mexico border region and include electronics and non-electrical machinery, much of the automotive industry, and apparel. The SOEs, state patronized private enterprises, and maquiladoras supplied growing internal and external markets for their production.

From the beginning of World War II until the early 1980s, this strategy had mixed results well in Mexico. In terms of income growth, this period is often referred to as Mexico's "Golden Age." During this, time the economy grew at an annual rate of over 6 per cent, or over 3 per cent in per capita terms (Cypher 1990). What's more, public investment appeared to crowd-in private investment. According to one study examining the period 1950 to 1990, for every 10 per cent increase in public investment there was a corresponding bump in gross private capital formation of 2-3 per cent (Ramírez 1994).

To some extent, policies geared toward buttressing domestic firms from foreign competition resulted in the learning of complex manufacturing capabilities and the creation of some industries and firms that still exist today. However, the policies were not geared toward the penetration of foreign markets and therefore the learning that was occurring in the country was not at the technological frontier and could not benefit from a process of learning by competing. Finally, the protective support for industrial learning was not given a well-defined end date and therefore did not provide the incentive for firms to get ready to compete in global markets without support (Fernández 2000). The results were therefore uneven, as we will see in Figure 1.

Market-led Industrialization

During late 1970s and early 1980s, much of the industrial development strategy was financed through oil revenue (or borrowing against expectations of future oil revenue). As a result, the Mexican government and private sector embarked upon a period of virtually gluttonous borrowing and public spending. The borrowing binge, coupled with a fixed nominal exchange rate, generated a large external debt, as well as causing rising inflation, growing real exchange rate appreciation, and renewed current account deficits (Kehoe 1995). From 1970 to the early 1980s, Mexico's foreign debt rose from $3.2 billion to more than $100 billion (Otero 1996). When oil prices suddenly dropped in 1982, a time of high world interest rates, Mexico announced that it was unable to meet its debt obligations—a "watershed event" for most developing countries (Rodrik 1999). A major devaluation plunged Mexico into economic crisis.

In response to the crisis, Mexico abandoned its state-led industrialization strategy to pursue a market-led strategy. Influenced by international institutions and a rising level of domestic constituents frustrated with past policy, in response to this crisis, Mexico completely re-oriented its development strategy after the 1982 crisis. The most decisive changes came under President Carlos Salinas de Gortari (1988 to 1994). Salinas articulated three over-arching goals: 1) achieve macroeconomic stability, 2) increase foreign investment, and 3) modernize the economy (Lustig 1998). As in the past, the heart of the plan lay in the manufacturing sector. By opening the economy and reducing the role of the state in economic affairs, Mexico

hoped to build a strong and internationally competitive manufacturing sector.

Meeting these goals required a top-to-bottom revamping of Mexico's foreign and domestic economic policies. From 1985 to the present Mexico has signed over 25 trade or investment deals, with NAFTA as the capstone (Wise 1998). To make investments less cumbersome for foreign firms, Mexico also reformed its technology transfer requirements. During the ISI period, Mexico's "Technology Transfer Law," was geared toward strengthening the bargaining positions of the recipients of foreign technology. All technology transfers had to be approved by the Ministry of Trade and Industrial Promotion, which monitored the extent to which technology transfer could be assimilated, generated employment, promoted research and development, increased energy efficiency, controlled pollution, and enhanced local spillovers. In 1990, this was dismantled with a new technology transfer law which relinquished all government interference in the technology process to the parties involved in FDI. Government-enforced conditions on technology transfer were phased out and technology agreements no longer needed government approval (although they must be registered). Moreover, the law now contains strict confidentiality clauses (UNCTC 1992).

These trade and investment policies set the stage for FDI in the manufacturing sector to be the engine of Mexican development. There were also changes in domestic policies in order to align the manufacturing sector with the new, neo-liberal macroeconomic, trade, and investment policies. In a marked split from the past, Mexico's overarching approach to industrial policy took a "horizontal" approach. Rather than targeting a handful of firms and industries as it had done under ISI, the state was to treat all firms and sectors equally, without preference or subsidy. In a horizontal fashion, the state liberalized imports along with exports, phased out subsidies and price controls, and privatized all but a handful of SOEs (Dussel Peters 1999, 2003).

Performance of the New Strategy

The performance of industrial development in Mexico has been uneven, at best. On the positive side Mexico has diversified away from primary products, upgraded the sophistication of some of its manufacturing export sectors, and increased the level of exports and investment. On the other hand, there has been very little technological learning for the majority of domestic firms, nor has there been linkage between the maquiladora manufacturing enclaves and the rest of the economy. Furthermore, Mexican manufacturing has become dangerously linked to the US economy where it is losing competitiveness to China.

Indeed, Mexico has transformed itself from a primary products-based economy to one that is more diversified. In 1940, agriculture accounted for 22 per cent of total output. By the early 1970s, agriculture had shrunk to less than 10 per cent and in 2005 was just 4 per cent of GDP. In 1940, manufacturing was 17 per cent of GDP. It reached a peak of 26 per cent in 1987 and fell to 18 per cent in 2005. The services industry accounted for 50 per cent of GDP in the 1960s and close to 70 per cent in 2005 (Reynolds 1970; World Bank 2008).

There has also been significant diversity within manufacturing and industrial upgrading within many sectors. Table 1 exhibits the top 10 Mexican Exports in 1980, 1990 and 2005. Although petroleum is the lead export in each period the composition of the rest of the top 10 is quite different in 2005 than it was in 1980. By 2005, all of the top 10 exports (which comprise approximately 75 per cent of total exports) except petroleum are manufactured goods.

Table 1: Mexico's Top 10 Exports to the World

	1980	**1990**	**2005**
Rank		**Product**	
1	Petroleum	Petroleum	Petroleum
2	Natural Gas	Motor vehicles	Motor vehicles
3	Fruit and Vegetables	Power generating machinery	Telecommunications equipment
4	Nonferrous metals	Fruit and Vegetables	Television receivers
5	Coffee, tea	Nonferrous metals	Motor vehicle parts
6	Fish	Iron and steel	Office machines
7	Motor vehicles	Electrical machinery	Electricity distribution equipment
8	Textile fibers	Organic chemicals	Lorries
9	Inorganic chemicals	Office machines	Electrical machinery
10	Matalliferrous ores	Miscellaneous manufactures	Electrical circuits

Source: United Nations.

The volume of trade and investment has been significant as well. Real exports between 1980 and 2007 increased by a factor of ten and FDI as a per cent of GDP has increased by a factor of 3 and is close to $20 billion each year (third only to China and Brazil in terms of FDI inflows to developing countries) (World Bank 2008; UNCTAD 2008). The majority of exports and FDI has been in the manufacturing sector, with electronics and the auto sector as the leading sectors.

Finally, there has been some scattered use of advanced technology and processes within the manufacturing sector, chiefly in the *maquiladoras*. Researchers drawing on the experiences of Delphi and General Motors, depict two other "generations" of maquiladoras in these firms that followed the first generation described above. From 1982 until NAFTA, MNCs in the *maquila* industry developed a higher level of technological sophistication and automation, a somewhat more autonomous level of decision-making relative to corporate headquarters, and a relative increase in the number of Mexicans in MNC management tiers. In terms of work organization, the gender mix became a bit more balanced and work was performed in a team atmosphere rather than in traditional assembly production. These firms experienced a "third generation" of innovation in the post-NAFTA period and are characterized where clusters are formed around technical centers, assembly plants, suppliers of components, and suppliers of services. There was also a greater level of technological development, with an increasing amount of higher skilled work, and engineering capabilities (Carrillo and Hualde 2002).

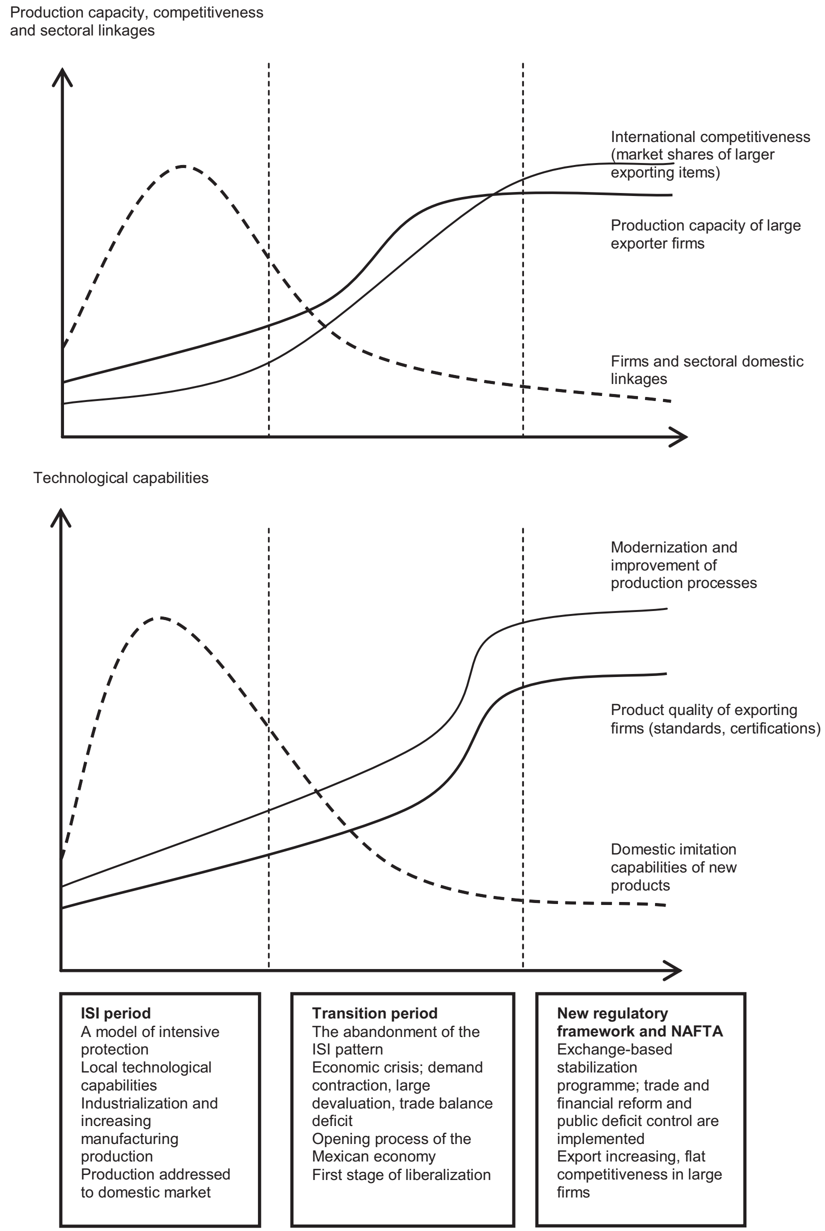
Despite improvements in diversification, sheer volume of exports and FDI, such benefits have come at considerable cost. Rather than spurring technological transfer and R&D activities, such transfers have shrunk considerably. FDI has been heavily concentrated by industry and region, is characterized by a growing gap between productivity and wage growth, and has limited linkages with the rest of the Mexican economy (Shafaeddin and Pizarro 2007; Puyana and Romero 2006; Dussel Peters 2008). In a large study covering 52 Mexican industries, Romo Murillo (2002) finds that foreign presence is negatively correlated with backward linkages. Other econometric analyses that looked broadly at the effects of FDI on the Mexican economy between 1970 and 2000 found that investment liberalization was significantly correlated with increases in FDI and subsequent exports, but also led to a higher incidence of imports and the displacement of local firms (Dussel Peters, Lara, and Gomez 2003), and crowding-out of domestic investment (Agosin and Machado 2005).

Rather than increasing the amount of R&D, FDI has been negatively correlated with R&D. R&D expenditures by the top twenty foreign firms fell from 0.39 per cent of output in 1994 to 0.07 per cent in 2002 (Dussel Peters 2008). Technological decisions for MNCs operating in Mexico are largely made in company headquarters far from Mexico, where technological developments occur and often remain (Unger and Oloriz 2000). A major assessment of FDI and R&D and innovation systems in Mexico concluded that "technological developments occur mainly in the home bases of MNCs and only a small portion is transferred to Mexico. This process ensures, on the one hand, that Mexico participates actively in the globalization of production, and on the other hand, that its participation in the globalization of scientific and technological activities is very poor. As companies transfer only some of their R&D to Mexico…..the present concentration of corporate R&D will by and large lead to an even stronger international divergence of technological development." (Cimoli 2000: 280).

The assessment attributes the poor performance of Mexico's FDI and trade-led learning strategy to a very weak institution response by Mexico's fledgling innovation system, low levels of interaction between manufacturing sectors and local institutions (finding that public sector or universities were not collaborating with firms), and low levels of technological capacity and coordination among universities.

The assessment characterizes Mexico as having a "maquila innovation system." This is a system that imports technology and equipment and hosts networking activities by MNCs in a manner divorced from the broader economy. The result has been that knowledge and technological advances are kept in developed economies. Imported inputs led to replacement of the learning capabilities that could be built in domestic suppliers of equipment and a virtual wipe out of many of the firms that had capabilities before reforms. And, for the personnel working on the limited amounts of R&D, they are doing so solely within a global MNC network largely divorced from interaction with domestic universities and research centers (Cimoli 2000).

Figure 1: Mexican Technological Capabilities



Sources : Cimoli 2000: 286.

These findings are depicted in the two graphs in Figure 1. The top graph exhibits production capacity, competitiveness, and sectoral linkages. During the ISI period there was considerable growth in firms' sectoral domestic linkages and an upward trend in the international competitiveness and production capacities of larger exporting firms. During the transition period out of ISI the international competitiveness and production capacities of large firms skyrocketed while the linkages between these exporters and local firms began to diminish in favour of imported inputs. In the post-NAFTA period, the level of competitiveness and capacity reached a plateau (albeit at a high level).

Cimoli's assessment reaches a similar conclusion in terms of technological capabilities, as seen in the second graph. Here, during the ISI period there was a great deal of domestic firm imitation and innovation of technologies, but these capabilities diminished throughout the reform period as larger foreign export firms (namely maquiladoras) increasingly imported technology. The imported technology did lead to an improvement of production processes and the product quality of exporting firms, which is now at the world technological frontier—albeit due to MNC decisions outside of Mexico.

More recently, the gains in trade and investment flows have become jeopardized. Throughout this transition, Mexico has become increasingly reliant on the US economy. By 2005, 86 per cent of all Mexican exports were destined to the US and 54 per cent of all Mexican imports originated in the US. Thus, when the US economy slows down, the Mexican economy does so as well.

Perhaps of greater concern is the fact that Mexico is losing its competitive foothold in the US economy despite its close proximity and favorable tariff access. Two separate studies examined the extent to which Mexican exports were under "threat" in the US economy. Threat was defined as whether a sector was a) losing market share in the US while China was gaining or b) gaining market share in the US while China gains faster. In 2005, more than 53 per cent of all Mexican exports are under some kind of threat and 97 per cent of all Mexico's high technology exports (representing 24 per cent of all

Mexican exports) were under threat (Gallagher, Moreno-Brid, and Porzecanski 2008; Gallagher and Porzecanski 2008). Indeed, many MNCs are now moving from Mexico to China. A recent study shows that Mexico has now become "proximity dependent." In other words, Mexico is not attracting any new foreign investment in sectors or regions that are not strategic for re-export to the United States (Sargent and Matthews 2007, 2008).

Case in Point: High Tech Exports

Mexico's FDI-led industrial development strategy is epitomized in the high technology electronics sector. Built-up during the ISI period, Mexican electronic firms were virtually eliminated after trade liberalization and replaced by a foreign enclave economy with few linkages, minimal R&D, and limited partnerships with universities beyond process innovation. Now, those foreign firms are struggling to compete with China's capabilities, even in the US market.

Mexican endogenous capacities for high tech manufacturing were seeded and cultivated by ISI policies from the 1940s to the 1980s. Mexico's larger size allowed it to promote the development of domestic IT sector during the ISI period, a sector that became relatively vibrant by the 1980s. Mexico's high-tech antecedents date as far back as the 1940s, when under ISI protection, national companies began to manufacture radios and radio components. From the 1950s up until 1980, Mexican firms manufactured televisions and as well as related parts. The government targeted the computer industry in the late 1970s as part of the strategy of the National Council on Science and Technology (CONACYT) to increase Mexico's national self-sufficiency in technology. CONACYT established the PC Programme (Programa de Computadoras) to develop a domestic computer industry (supported by the surrounding electronics industry) that could not only serve the domestic market but also emerge as a key exporter for Mexico.

MNCs were limited to 49 per cent foreign ownership of firms in the sector. They had to invest between three and six per cent of gross sales into R&D and create research centres and training programmes. And domestic parts and components had to account for at least 45 per cent of value added for personal computers and 35 per cent for mini-computers. New Mexican-owned firms could receive fiscal credits and low interest loans from government development banks. In search of domestic markets and export platforms, the foreign firms that came to Mexico were IBM, Hewlett Packard, Digital, NCR, Tandem and Wang. IBM and Hewlett Packard were the leaders, accounting for 63 per cent of all computer production. The other foreign firms were responsible for approximately 18 per cent, and wholly-owned Mexican firms made up another 18 per cent.

The hub of high technology exports became the western state of Jalisco (specifically the Guadalajara city region). Other regions of the country where these firms became concentrated were on the US-Mexico border region (TV monitors), and in the region surrounding Mexico City (electronic appliances). Guadalajara was the ideal region for high-tech FDI, as it had lower wages and weak unions, relative proximity to the US, low tariffs, and five major universities and numerous technical schools and industrial parks with the capability to host research activity and graduate an adequately skilled workforce (Gallagher and Zarsky 2007).

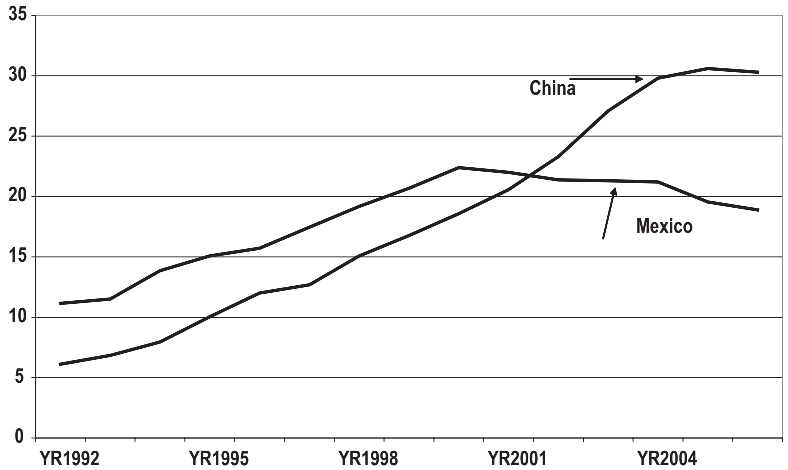
Furthermore, the government adopted a number of policies to attract MNCs to Mexico. At the national level, one program (called PITEX) allows firms to import their inputs duty-free as long as more than 65 per cent of their output is exported (Dussel Peters 2003). The Jalisco state government supplemented these federal programs with a regional plan to attract firms and suppliers. The state's Economic Promotion Law reduced or eliminated state and municipal taxes for firms that located to the region. In addition, the Guadalajara branch of the national chamber of commerce for the IT industry, CANIETI (Camara Nacional de la Industria, Electronica, de Telecomunicaciones e Informatica) works to attract large MNCs to the region and puts on numerous trade shows and workshops on the industry. A more regional organization named CADELEC (Cadena Productiva de la Electronica) was founded in 1998 with funding from CANIETI, the United Nations Development Programme, and two other federal agencies. CADELEC's mission is to match domestic suppliers with the large MNCs (CADELEC 2004; Palacios 2001).

The laissez-faire strategy was a success—at least in terms of attracting investment and increasing exports. Between 1994 and 2000, foreign direct investment in the electronics sector grew by five times and the value of exports quadrupled. At their peaks, exports from Mexico's electronics sector totaled $46 billion in 2000, and FDI inflows totaled $1.5 billion in 1999.

By 2000, IT was a key component of the Mexican manufacturing economy, accounting for nearly 6 per cent of manufacturing output, 27 per cent of all exports, 9 per cent of employment, and 10 per cent of FDI. Electronics are Mexico's largest manufactured export, and are second only to autos in terms of manufacturing GDP and employment (Dussel Peters, Lara, and Gomez 2003).

Fuelled by large FDI inflows, Mexico's IT industry became increasingly competitive during the second half of the 1990s. Mexico's share of world IT exports ballooned from eight-tenths of one per cent in 1985 to three per cent in 2000 (Dussel Peters, Lara, and Gomez 2003). By 2001, Mexico was the 11th largest exporter of IT products in the world economy. However, as shown in Figure 2, Mexico's competitiveness and concentration in high tech exports began to flatten and then decline, particularly when compared to China's.

Figure 2: Hi-Technology Exports/Manufactures Exports



Source: World Bank 2008.

Evolution of Domestic Firms

Unlike China, rapid MNC-led growth came at the expense of Mexico's domestic IT firms, which were virtually wiped out. The domestic high tech industry is nearly extinct, and few domestic input producers have become integrated into the global production chains of the IT MNCs operating in Mexico. Between 1985 and 1997, the number of indigenous electronics firms in Guadalajara declined by 71 per cent (Rivera Vargas, 2002). As shown in Table 2, 13 of the 25 indigenous electronics firms that were still in existence at the end of 1997 had been closed by 2005 (Gallagher and Zarsky 2007; Sargent and Matthews 2007, 2008). Indeed, as early as 1998, signs of this were already evident when the Economic Commission for Latin America and the Caribbean concluded that industrialization in the electronics industry had become almost completely "internationalized" and was beginning to resemble a "parallel economy" that had very few linkages in Mexico (ECLAC 1999). Since then, the literature has been quite extensive and too large to cover in this paper, but key contributions include two edited books by Enrique Dussel Peters (Dussel Peters 2003, 2004), and a volume by Rivera Vargas (2002).

Table 2: IT Plant Closings—Whole or Partly Owned Mexican Firms

Firm	Ownership (per cent)	Activity
Mitel	51/49 Mex-Canada	Telephone Components
Phoenix International	50/50 Mex-US	Plastic Injection
Encitel	100 Mex	CM of PCBs
Info Spacio	100 Mex	CM of printers
Logix Computers	100 Mex	Design and manufacturer of
Mexel	100 Mex	CM of PCBs
Unisys	100 Mex	CM of computers and peripher
Electron	100 Mex	Design and manufacturer of
Scale Computers	100 Mex	Design and manufacturer of
Advanced Electronics	100 Mex	Design and Manufacturer of PC
Compuworld	100 Mex	CM of hard drives
Microtron	100 Mex	Buffers and Carton Packages

Source: Woo (2001); Rivera Vargas (2002); author interviews.

The linkages between foreign high tech firms and national firms are even more dismal than the national average. Most of the MNCs are working with local firms that supply cardboard boxes, shipping labels, cables, wires, and disposal services. This finding suggests that although the share of national inputs has increased – though, at less than 2 per cent of all inputs, it still remains very small and the composition of those inputs has changed from national high-tech firms to national shipping and disposal firms (Gallagher and Zarsky 2007).

Table 3: China vs. Mexico in World IT Markets

	Computers	Peripherals	Telecom
	(country exports as a per cent of world exports)		
China			
2000 Market Share	6.0	4.0	5.7
2005 Market Share	28.8	15.7	18.3
Per centage Point Change	22.8	11.7	12.6
Mexico			
2000 Market Share	4.5	2.2	5.2
2005 Market Share	3.5	1.2	3.5
Per centage Point Change	-1.0	-1.0	-1.7

Table 3 compares Mexico and China in world high technology markets. In 2000, the year before China entered into the WTO, Mexico and China enjoyed global market penetration in computers, peripherals, and telecommunications at similar orders of magnitude. In just five years, China captured 15-29 per cent of global high tech markets whereas Mexico lost competiveness in each case (Gallagher and Zarsky 2007).

In response to competitive pressure, MNCs in Mexico have been upgrading their product mix. For the most part, they have been able to redirect their generic manufacturing capacities to other products and clients. Jabil Circuit, for instance, shifted production to communications switches, specialized hand-held credit card processing machines, Internet firewalls, and electronic controls for washing machines. Solectron is assembling components for mainframes and AX-400 conductivity transmitters. SCI-Sanmina now assembles MRI scanners for Phillips and electronics auto components for Ford and GM. Not all of the MNCs were able to upgrade with this agility, and, even in such a ramp up, national firms continued to be out in the cold. Indeed, most of the CMs have resorted to internet based open supplier bidding and the winners are other foreign firms (Gallagher and Zarsky 2007; Sargent and Matthews 2007, 2008). Mexico is also loosing ground to China in "non-proximity [to USA market] dependent, technology intensive EPZ manufactures" (Sargent and Matthews 2008).

In short, during in the 1990s Mexico was a poster child for neo-liberalism, throwing open its borders to trade and foreign investment, embracing NAFTA, and ending the government's role in fostering industrial learning. The evidence shows that although Mexico was initially successful in attracting multinational corporations, foreign investments waned in the absence of active government support and as China became increasingly competitive. Moreover, the FDI-led innovation and growth strategy created an "enclave economy", the benefits of which were confined to an international sector and not connected to the wider Mexican economy. In fact, MNCs put many domestic firms out of business and transferred only limited amounts of technology. The prevailing consensus that Mexico's development model has not performed well should not be interpreted as an argument for returning to the ISI policies of the past. As shown in Figure 1, even during the ISI period, Mexico's level of competitiveness, product sophistication, and production capacities we relatively weak. By the end of the ISI period even the domestic imitation capabilities and the domestic linkages started to cascade as well. Indeed, it is clear that the goal of integrating with the world economy was a good one. The problem has been that Mexico's hands off approach centered on the belief the market would automatically allocate such capabilities. As we will now see, China has similar goals but has followed and continues to follow a different path to achieve them.

III. Crossing the River by Touching Each Stone: Technological Learning in China

Like Mexico, China embarked on a process of economic reform over a quarter

of a century ago. Like Mexico, it has sought to attract FDI into manufacturing and high technology sectors in order to gain access to technology and marketing channels for exports. Nevertheless, China's industrial development is very different from Mexico's in two important ways. First, in contrast to Mexico's rapid opening of markets and integration into the world economy, China has taken a more gradual and experimental approach to integration, upgrading, and industrial development. Secondly, alongside reforms, China continued a parallel set of targeted government policies to support and nurture industrial development. Its nurturing of industrial development has been geared toward learning through R&D and training for development of capabilities of domestic firms in order to increase value added in exports.

From Mao to the Market: Economic Reform in Context

In a somewhat similar fashion to Mexico, China underwent a period of state-led industrialization from the late 1940s until 1978. This period has been referred to as the period of "Big Push Industrialization". As in Mexico, during the Big Push the Government's goal was move towards rapid industrialization through import substitution. The basic strategy was to invest in the strategic industries identified by government decision-makers. The industries selected included those with the largest potential for backward linkages. Integration with the global economy was extraordinarily low (Naugthon 2007).

Eighty per cent of the targeted industries were "heavy" industries, such as steel, which were linked with coal, iron ore, machinery and other sectors. A number of other industries such as chemical fertilizers, motor vehicles, and electric generating equipment were also among those created by the government. Almost all of these industries became dominated by State Owned Enterprise (SOEs) and the planners assigned them production targets and prices. The government also allocated labor force to industrial firms. On one hand this effort was successful as the industrial base of the country was created. From 1952 to 1978, industrial output grew at an annual rate of 11.5 per cent and the share of industrial sector in GDP increased from 14 to 44 per cent while the share of agriculture fell from 51 to 28 per cent (Naugthon 2007).

However, these policies also involved some shortcomings. First and foremost, the focus on industrialization neglected the growth of household consumption and the development of the countryside. Whereas capital formation grew at more than 10 per cent per year from 1952 to 1978, private consumption grew only 4.3 annually. Employment generation was also low given the capital intensive nature of the main targeted industries. Perhaps the gravest shortcoming was the lack of technological capabilities of the targeted firms. Further, human capital formation did not expand enough for these sectors to become efficient and competitive internationally (Naugthon 2007).

Chinese economic reforms started in 1978, two years after the death of Mao Zedong. In this year, China embarked on a programme of economic reform aiming at strategic integration into the world economy by following a "dual track" policy. The policy consisted of liberalizing FDI and inflow of imported inputs to selected industries while buttressing those sectors to the point of maturity and nurturing other sectors until they were ready to face competition with imports. Since then, according to the literature, China's industrial strategy has been three-pronged. First, government policy aimed at creating endogenous productive capacity, in the form of targeting specific industries through state ownership (SOEs) or government support, paying increasing attention to science and technology policy, and linking the SOEs with the private sector and research institutes. Secondly, and very importantly, Chinese support for domestic industry has always had an eye on markets outside of China. China has also gradually and strategically integrated into world markets in order to gain access to technology, finance, and world markets,

Thirdly, in undertaking economic reform, China's new leaders followed an experimental approach. Unlike Mexico, there was a much more experimental (trial and error) and less certain attitude toward reform. The Mexican Government was ideologically committed to reforming towards a market economy and free trade. In a sense, free trade and a market based economy was seen as an end by itself in the case of Mexico; it was taken for granted that such a transition by itself would enhance learning through trade and lead to the deepening of industrialization and promotion of growth. By

contrast, Chinese policy was based on using the market and trade as a means to development. Hence, in the eyes of Chinese policy makers, market and government policies were to supplement each other while the weight of each would change as the economy would develop.

"It was never conceivable to Chinese policy-makers that their economy would postpone economic development until after an interlude of system transformation. It was always assumed that system transformation would have to take place concurrently with economic development, and indeed that the process of economic development would drive market transition forward and guarantee its eventual success. Individual reform policies were frequently judged on the basis of their contribution to economic growth (rather than to transition as such). In the beginning the approach was followed because reformers literally did not know where they were going: they were reforming "without a blueprint" and merely seeking ways to ameliorate the obvious serious problems of the planned economy. But even after the goal of a market economy gradually gained ascendance in the minds of reformers, it was not anticipated that market transition would be completed until the economy reached at least middle-income status. And in fact, that is exactly what eventually happened." (Naugthon 2007: 86).

Deng Xiaoping referred to this strategy as "crossing the river by feeling each stone," (Naugthon 2007). This approach stands in stark contrast to the Washington Consensus approach adopted in Latin America and Mexico which advocated for swift "shock" transitions to a market economy (Williamson 1990).

China's gradual and experimental approach to reform allowed for the development of domestic firms and industries before liberalizing fully. More importantly, it also created an environment so that the potential "losers" from liberalization would be less numerous (Naugthon 2007). Components of market and planned economies coexisted in this dual track policy which has been referred to as a socialist market economy in the literature (see, for example, Singh 1993).

The Role of R&D

Unlike Mexico, where it was assumed that technology would be transferred through trade and FDI, conscious attention to science and technology (S&T) policy and research and development (R&D) has been a cornerstone of China's industrial development and integration into the world economy. The Chinese government learned in practice that technology acquisition from abroad through MNCs alone will not necessarily lead to the transfer and development of technology; there was a need for increasing the absorptive capacity of domestic firms and the development of indigenous technological capacity building. To accomplish this, the strategy of the Chinese government included government support, indigenous R&D and innovation investment within individual firms, and creation of R&D institutions. It also included alliance among firms in an industry and their cooperation with research institutes and universities, as well as foreign firms, targeting, in particular, the industries considered to be strategic for industrialization (Qian 2003).

Government policy ranged from direct investment, provision of guidance, institutional and financial support, creating a favourable environment for innovation as well as introduction of competition into the domestic market for the strategic industries (e.g. telecommunication) (Fan, Gao, and Watanabe 2007: 359) and development of national standards and patents for main IT products (Wang and Wang 2007). The S&T strategy of the Government also aimed at a long-term goal of upgrading the industrial base of the country. It was selective, targeted and responsive to the market dynamic with growing emphasis on the private sector (including MNCs). Beginning in the early 1980s China put in place a number of policies that not only aimed at conducting basic research but also put equal emphasis on the deployment and diffusion of technology. Table 4 provides a snapshot of China's key S&T policies between 1982 and 2000 (see also the case of Mobile communication industry and high-definition disc player industry below).

The government apparatus for guiding the S&T consisted of six different entities: the Chinese academy of Science together with 5 relevant Ministries, including the Ministry of Information Technology which was specifically created for supporting IT industries (Xiwei and Xiangdong 2007: 318). The

Table 4: Development of China's National Innovation System

Policy	Dominant Feature	Year
Key technology R&D program	Encouraging efforts in key technologies	1982
Resolution on the reform of S&T system (CCCP)	Adopting flexible system on R&D management	1985
Sparkle system 5	Promoting basic research in agriculture1	1985
863 program	High-tech promotion	1986
Torch program	High-tech commercialisation, high-tech zones	1988
National S&T achievements spreading program	Promoting product commercialisation	1990
National engineering technology research centre program	Technology transfer and commercialisation of research	1991
Climbing program	Promoting basic research	1992
Endorsement of UAEs by SSTCC	Promoting university and industry linkage	1992
S&T progress law	Technology transfer, S&T system reform	1993
Decision on accelerating S&T progress (CCCP)	Promoting URI-industry linkage	1995
Law for promoting commercialisation of S&T achievement	Regulating the commercialisation of S&T achievement	1996
Super 863 program	Commercialisation, break-through in key areas	1996
Decision on developing high-tech industrialization	Encouraging technology innovation and commercialisatio	1999
Guidelines for developing national university science parks	Accelerating the development of university science parks	2000

Source: Xiwei and Xiandong, 2007.

national system of innovation was geared to basic research as well as R&D in selective activities. The 863 Programme (1986) aimed at high basic and applied research in seven areas and 15 topics with the cooperation of private enterprises. The seven areas included, in order of priority given by the planners, information technology, laser, automation, biotechnology, new material technology, astro-technology and energy technology (Fan and Watanabe 2006: 311). The "climbing programme" of 1992 was oriented towards acceleration of basic research. By contrast, from inception in 1988, the Torch programme was market-oriented and geared mainly towards the commercialization of R&D results. Its objectives ranged from enabling an environment for high-tech industries, to creation of high-tech zones, executing projects in the aforementioned selected (7) areas, and training and facilitating international cooperation (Fan and Watanabe 2006: 312). In 1995 the government passed the "Decision on Accelerating Scientific and Technological Progress" in order to intensify the technological development (Walsh 2003: 105).

The ninth 5 year plan (1996-2000) specifically emphasized the development of capabilities to increase domestic value added in assembly operations in computer industry and its peripherals. This was followed by the emphasis on innovation in integrated circuits and software technology in the tenth 5 year plan (2001-5) under the so-called "Golden Projects" (Xiwei and Xiangdong 2007: 321).

The national system of innovation (NIS) was dynamic in terms of both institutional development and the change in the relative role of Government and private enterprises. The S&T system of China consisted of universities, research institutes and public and private enterprises, including foreign firms. The interrelationship between universities/research institutes and industry is regarded as unique (Chen and Kenney 2008). Furthermore, the system went through continuous reforms in terms of policies and the involvement of actors in R&D. To benefit from "collective efficiency" through clustering, a number of high-tech zones (technology parks) were established (by 1992, 52 high-tech zones had been established) (Xiwei and Xiangdong 2007: 319).[5]

Close links were also developed among enterprises, universities, and research institutes. Further, commercialization of R&D was encouraged. In particular, over time, the role of private enterprises in R&D increased significantly. Table 5 shows the evolution of R&D in China from 1987 to 2003 where the number of R&D institutes increased by 67 per cent. By 2003, however, the number of public institutes decreased while the private sector (enterprise) led institutes more than doubled. This trend is mimicked in terms of spending. In 1987, 60.7 per cent of R&D expenditure was undertaken by public institutes. By 2003, the share of private sector was 62.4 per cent and that of research institutes and universities was 36 per cent (Table 5). The distinction between private and public entities involved in

R&D is, however, blurred as some universities and research institutes own enterprises engaged in research (Chen and Kenney 2008).

Expenditure and policy has not been horizontal, but has been targeted to specific sectors and industries as outlined above. In allocating R&D expenditures, China has targeted a handful of sectors, namely the electronics, semiconductor, and automotive sectors, to eventually serve as "national champions" (Xiwei and Xiangdong 2007).

Table 5: Evolution of R&D in China, 1987 to 2003

	Number of R&D Institutes		**R&D Expenditure** *(in 100 million yuan, %)*	
	1987	**2003**	**1987**	**2003**
Public Research Institutes	5,222	4,169	106.8 (60.7)	399 (25.9)
University R&D Units	934	3,200	7(4)	162.3(10.5)
Enterprise R&D Units	5,021	11,300	62.1(35.3)	960.2(62.4)
				1521.5
Total	**11,177**	**18,669**	**175.9(100)**	**1521.5(100)**

Source*: Xiwei and Xiandong, 2007.*

The comparison of China and Mexico is striking both in terms of input to and the results of the S&T policies. Table 6 compares China with Mexico and a number of developing and developed countries in terms of expenditures on R&D. China's expenditure on R&D (as a per centage of GDP and in per capita) far exceeds that of Mexico in terms of both level and change over time. In fact, the difference in the performance of the two countries becomes more revealing when one compares the growth rates of expenditures in absolute terms. Over 1996-2004, Mexico's expenditure (in terms of US$ and PPP) merely doubled while China's increased by a factor of five. China's indicators for R&D are the highest in Asia after Singapore, Rep. of Korea and Taiwan; they are also higher than those of Spain and Italy. In 2004, the number of people working on R&D in China was over 1.15 million (Table 7), or 13.4.per 1000 of population, as compared with the 60039 people (0.59 per 1000 of population) working on R&F in Mexico in 2003 (Table 6 and UNCTAD, 2007). In 2003, there were 17.1 research institutes per million people in China.

Another difference between the two countries is the change in the role that private enterprises played in R&D. The relatively hands-off approach deployed by the Mexican government on the activities of private firms did not motivate them to increase their involvement in R&D as was the case in China, where the government provided guidance and support. According to data provided by UNESCO, the share of business enterprises in gross domestic expenditure on R&D in Mexico increased from 22.4 per cent in 1996 to 31.7 per cent in 2004.

Table 6: Expenditure on Research and Development in a Selected Developing and Developed Countries*

Countries	Year	Share in GDP	Per capita
Asian developing countries and Mexico			
Rep. of Korea	2005	2.99	666.3
Taiwan province of China		n.a	n.a
Singapore	2005	2.36	702.2
China:			
	1996	**0.57**	**15.7**
	2005	**1.34**	**89.6**
Hong Kong SAR	2004	0.74	231.3
Malaysia	2004	0.63	64.6
India	2005	0.61	20.8
Pakistan	2005	0.43	10.1
Mexico:			
	1996	**0.31**	**22.4**
	2004	**0.41**	**40.4**
Thailand	2004	0.25	29.7
Vietnam	2002	0.19	4.5
Sri Lanka	2004	0.19	7.4
Philippines	2003	0.14	6.2
Indonesia**	2005	0.05	1.4
Developed countries:			
Israel	2005	4.95	1317.4
Japan	2004	3.18	440.1
Switzerland	2004	2.94	1024.4
United State	2004	2.68	1058
Germany	2005	2.51	736
France	2005	2.13	650.8
Australia	2004	1.77	541.5
United Kingdom	2004	1.75	560
Belgium	2005	1.82	588
Spain	2005	1.12	305.8
Italy	2005	1.1	307.3

Sources : UNESCO: Online database on Expenditures on R&D.
*. GDP and per capita GDP are in PPP **. Partial data

Table 7: Number of Personnel Engaged R&D in China (1996-2004)

	1996		2004	
	No.	**%**	**No.**	**%**
Government	232000	29	243702	21
Business	376700	46	696840	60
Higher education Others	148100	18	212075	18
	47200	7	-	-
Total	**804000**	**100**	**1152617**	**100**

Source: Based on UNESCO Statistics of Science and Technolo online.

Table 8: Expenditure on R&D (10 million Yuan)

	2001		2005	
	No. (1000)	**%**	**No. (1000)**	**%**
Basic research	522	5	1310	5.3
Applied research	1759	16.8	4330	17.7
Experimental	8143	78.1	18850	76.9
Total	**10425**	**100**	**24500**	**100**

Source: People’s Republic of China 2006: Table 21-38.

By contrast, the corresponding figures for China increased from 43.3 per cent to 68.3 per cent (Xiwei and Xiangdong 2007).[6] Similarly, their contribution to the sources of R&D funding in China increased from 18 per cent in 1985 to 32.4 per cent in 1994 and 60.2 per cent in 2003 (Xiwei and Xiangdong 2007). In other words, unlike the case of Mexico, private enterprises have become the driving force in R&D activities where seven firms were main actors involved in targeted technology areas.[7]

The results of the implementation of S&T policy are striking for China when compared with Mexico’s experience. Table 9 shows that, on average, more patents are filed in China each year than in all of the Latin American countries combined, let alone Mexico. Furthermore, whereas in LAC only 13 per cent of all patents are held by residents, in China that figure is above 75 per cent. Similar results are also evident when comparing the number of articles published by Chinese scholars with the number published by of Latin American scholars.

Moreover, the relative importance of inventions has increased sharply over time (Table 10). It is true that the share of domestic firms in total patents and in patents granted for invention has decreased since the accession to WTO in 2000 (Tables A.1 and 10) because of the increasing involvement of foreign companies in China. Nevertheless, the number of invention patents granted to domestic firms has accelerated sharply during the period from 2000 to 2005. The annual average growth rate of invention patents granted to domestic firms was 27.3 per cent during 2005 as compared with 18.3 per cent during 1990-2000 (based on Table A.1). As a result, the share of invention in total patents granted to domestic firms has almost doubled from 2000 to 2005 (Table 9).

Table 9 : Selected Science and Technology Indicators

	1980-2005	2000-2005
East Asia and Pacific		
Patent applications, nonresidents	27,119	64,235
Patent applications, residents	17,387	44,106
Patent applications, resident share	**64.12%**	**68.66%**
Research and development expenditure (% of GDP)	0.89	1.09
Scientific and technical journal articles	11,505	24,804
China		
Patent applications, nonresidents	24,236	58,876
Patent applications, residents	18,785	43,509
Patent applications, resident share	**77.51%**	**73.90%**
Research and development expenditure (% of GDP)	0.98	1.21
Scientific and technical journal articles	10,386	22,979
Latin America and the Caribbean		
Patent applications, nonresidents	19,044	29,850
Patent applications, residents	3,792	4,056
Patent applications, resident share	**19.91%**	**13.59%**
Research and development expenditure (% of GDP)	0.57	0.57
Scientific and technical journal articles	9,666	16,472
Mexico		
Patent applications, nonresidents	7,051	12,745
Patent applications, residents	540	498
Patent applications, resident share	**7.65%**	**3.91%**
Research and development expenditure (% of GDP)	0.39	0.41
Scientific and technical journal articles	2,026	3,488

Source: World Bank 2008.

Table 10: The Share of Invention in Grated Patents (1990-2005)

	1990	2000	2005
Share of invention in total granted patent	16.9	12	24.9
Share of domestic invention in total invention	29.9	48.7	38.8
Share of invention in total domestic patent	5.9	6.5	12.1

Source: Based on table A.1

Training

In tandem with R&D, China has a high level of support for tertiary education and training. Over 20,000 scientists and engineers graduate from Chinese universities each year (MOST 2006). The high level of education in science and technology, as well as the existence of facilities for vocational education, facilitates the training of skilled manpower for technological development. In 2005, the number of graduates in the fields of science and technology from universities and junior colleges was 1,256,000, or over 1000 per million people. In the same year the corresponding number of graduates from postgraduate courses was 95000, or over 90 per million.[8] Continuous attention to education was a characteristic of the overall Chinese development strategy before, as well as after the reform period. According to the World Bank, government expenditure on tertiary education per student was 90 per cent of GDP per capita in 1999 (in Mexico that figure was 48 per cent for the same year) (World Bank 2008).

Comprehensive information on the training programme of the Government is lacking. Nevertheless, there are indications that the Government focussed on enhancing the high-tech skills and education by establishing state funding training centres (Walsh 2003: 71). Some universities were also involved in training, with a number of them befitted from partnership with MNCs for training in addition to R&D (Walsh 2003: 83). The Beijing University of Post and Communication is one example of cooperation with MNCs in training. Foreign investors also independently provided some training of local staff (Walsh 2003: 96).

Table 11: The number of graduates in vocational secondary schools and the number of students studying abroad (1978-2005)

	Vocational schools (1000)	Students abroad
1978	79	9
1990	893	35440
2000	1763	56767
2005	1700	189728

Sources: People's Republic of China 2006: Table 2-10.

The government created a large number of vocational schools. In 2005, there were 198,566 vocational schools in China, out of which 11,611 were secondary schools and 4,230 were technical training. The number of graduates for vocational secondary schools increased by over 21 times between 1978 and 2005 (Table 11). Further, the government policy to send students abroad helped the development of domestic skills in research and development even though some of them never returned to China. The combination of these factors allowed rapid expansion of persons engaged in scientific and technical activities in more recent years, resulting in an increase by over 21 per cent during 2001-05 when 3,810,000 were engaged in this area (Walsh, 2003). There remains, however, a lack of upper management staff despite the fact that some Chinese who have studied and have worked abroad have returned to the country.

Other Measures to Build-up Capabilities of National Enterprises

In contrast to Mexico, the main motive behind the development of capabilities of domestic firms was the realization by the government and national enterprises that the transfer of technology from MNCs did not occur automatically (Fan, Gao, and Watanabe 2007: 360). Under joint ventures there was a limit to the transfer of technology to Chinese partners (Walsh 2003: 113). The effort to develop capabilities of domestic firms, in turn, simulated the rivalry among MNCs to be involved in R&D programmes of domestic firms in order to not be denied access to the large Chinese market.

The Chinese Government has followed a gradual and dual policy in developing the capabilities of domestic enterprises. It has gradually increased the role of private firms in the process of industrialization and export expansion. For example, the share of private enterprises in exports has increased 18 per cent in 1985 and 60 per cent in 2005 (Naugthon 2007). At the same time, it has implicitly, or explicitly, established a division of labour between SOEs and private enterprises. The private enterprises have emphasized, as expected, short-term opportunities and low-cost production and sale to achieve high profitability. By contrast, SOEs' concentrated on long-term goals through investment for development of new products rather

than profitability *per se* (Li and Xia 2008). In their efforts, SOEs benefited little from spill-over effects from MNCs (Girma and Gong, 2008). SOEs were privileged to have better access to government funds and loans from the banking system (Li and Xia 2008).

In their applied R&D, SOEs benefited from a programme called "National Science and Technology Diffusion" which was specifically designed for, and devoted to, them. This strategy is criticized for not having market oriented goals in the case of SOEs. In our view, however, it has been plausible, to reform SOEs gradually in order to prevent the long-term objectives of the Government from being undermined. particularly that they had had social objectives and responsibilities in addition to their long-term technological goals.

To provide sources of investment for domestic firms, China established two funds: the Export Development Fund for the larger firms and the Fund for Small and Medium Enterprise Incursions into International Markets for suppliers. The government also offered value-added tax refunds to exporting firms, and the Chinese Export-Import Bank provided loans with preferential interest rates.

Chinese domestic firms enjoyed the advantage of familiarity with the domestic market as well as allocation of a significant part of the domestic market to them by the government (e.g. in the telecom equipment industries) (Fan, Gao, and Watanabe 2007: 358). Still, the new comer domestic firms in China, like enterprises in other developing countries, suffered from two main disadvantages, as compared with MNCs, in development of capabilities for and commercialization of new technology: resource disadvantages and reputation disadvantages particularly in the IT sector where the technology is complicated and changes rapidly (Gao et al. 2007). Provided with incentives as well as support by the government together with some capabilities developed during the import substitution period, however, a number of firms have managed to break into the market by developing frontier technologies (see below). In addition to the support from the government, the leading domestic firms collaborate with customers and cooperation with MNCs (Gao et al. 2007).

The Role of FDI

The contribution of MNCs to the financial resources needed for R&D has been small. Nevertheless, they have become increasingly involved in R&D in China. Foreign high-tech R&D in China has gone through three phases: explanatory and strategic partnership (early-mid1990s), expansion (mid-late1990s) and consolidation (late 1990s. cuurent) (Walsh 2003: 86-91). During 1990s, foreign investment in R&D was more of a "show" rather than genuine actions such as establishing R&D as it was a pre-condition for obtaining approval to establish joint ventures. During the second phase, the MNCs also started to expand training centres. It was during the third phase when the MNCs became interested in moving up the value-added production chain to upgrade their products and thus needed to invest in local R&D (Walsh 2003: 86-91)

Meanwhile, the Chinese government also provided the MNCs "a range of preferential policies, including tax rebates, construction loans, access to modern facilities and other incentives", particularly in the case of IT industries (Walsh 2003: xiii and 56). While encouraging foreign firms to undertake R&D in China, the authorities initially entered into partnerships with a number of foreign firms to create inter-firm rivalry and to accelerate technological development (Walsh 2003: 77-78 and 80-82). As a result, wholly foreign-owned firms established R&D facilities in the country (Walsh 2003: 79). Attracting multiple foreign partners was particularly successful in the IT industry. It is estimated that around 120 to 400 foreign R&D centres were operational in 2003 (Walsh 2003: xiv). In the case of IT industries, since early 1990s, almost all main MNCs involved in this industry have established R&D centres in China. In Beijing alone,18 main centres were established between 1993 and 2003.[9] Domestic firms also benefited, to some extent, from the partnership with MNCs. For example, Legend, Stone, Founder and Great Wall learned a great deal about modern manufacturing in addition to technology development (Walsh 2003: 79). Nevertheless, the Chinese authorities realized that joint ventures with MNCs alone would not be sufficient for technology transfer.

Generally speaking, in China, unlike Mexico, FDI has crowded in domestic investment as government efforts aimed at building capabilities of

domestic firms. As predicted by TCB, such capabilities in turn motivated MNCs to invest in R&D. As domestic firms were involved in development of their technological capabilities, many MNCs were motivated to join them in their R&D in order to access the domestic market, particularly since the government also provided them with other incentives as mentioned previously.

In China, efforts to indigenously develop technological capabilities and to bring such technologies to market have been coupled with a targeted but aggressive acquisition of foreign technologies through foreign direct investment. The strategy has been to either develop a sector or technology nationally, or to "import" the technology through FDI. Initially, licensing FDI was conditioned to arrangements for transfer of technology and provision of linkages to local firms, joint ventures and partnership. In 2001, such condition have been dropped; however the government encourages MNCs to invest in R&D, particularly in information technology, "by offering a range of preferential policies" that includes tax rebates, construction loans, access to modern facilities, and other incentives" (Walsh 2003: xiii and 56). Whereas national Mexican firms only capture approximately 5 per cent of the inputs of foreign firms, in China that number is well over 20 per cent (Gallagher and Zarsky 2007).

Case in Point: High Tech Industries

China is the most impressive contemporary case of latecomer high technology development.[10] For twenty-five years, the country gradually and quietly built manufacturing capacities and integrated into world markets. China has been at the core of MNC location strategies because of its multiple location specific assets: a large and growing internal market *and* a low-cost export platform for manufactured goods. Furthermore, China provides a match between national linkage capability between MNCs and domestic suppliers. Now the country is on the verge of having formidable flagship firms of its own in the IT industry.

High tech FDI in China has gone through four phases: sale, marketing, licensing and technical services; manufacturing and production; product design, localization and redevelopment and finally R&D (Walsh 2003: 75-76). Much is made of China's low wages as a major factor driving MNC outsourcing to

China and IT development more generally. There is little doubt that wages are low: the average manufacturing wage in China was estimated to be 61 cent an hour in 2001, compared to $16.14 in the US, and $2.08 in Mexico (Federal Reserve Bank of Dallas 2003). But the story of China's success and likely emergence as the center for global IT production goes beyond low wages and generic product manufacturing capabilities.

The development of the IT industry is due to a combination of government intervention, foreign investment, and entrepreunarlism in China. In 1986, four Chinese scientists recommended to the government that IT be designated as a strategic sector. The request was approved, and, in 1988, China's National Development and Reform Commission (formerly the State Planning Commission) designated high tech as a "pillar" industry worthy of strategic industrial policy (MOST 2006). It was coupled with the MOST's National High Tech R&D (or 863) Program that supported R&D efforts of local governments, national firms, and regions. The goal was to foster a vibrant high tech sector with national firms that could eventually compete as global flagships**.** The strategy was to establish domestic firms and bring foreign firms to China in order to build their capacity to produce components and peripherals for PCs. To this end, IBM, HP, Toshiba, and Compaq were all invited to come to China and form joint ventures with such Chinese firms as Legend, Great Wall, Trontru, and Star. China required the foreign firms to transfer specific technologies to the joint venture, establish R&D centers, source to local firms, and train Chinese employees as mentioned above (USDOC 2006). By the 1990s, all of the major contract equipment manufacturers also formed joint ventures with Chinese firms under similar arrangements. According to the tenth five year plan, ending in 2005, the government planned to invest more than $ 120 billion in the IT industries in order to raise the share of the sector to 7 per cent of GDP (Walsh 2003: 71)

The strategy has paid off. "By carefully nurturing its domestic computing industry through tightly controlled partnerships with foreign manufacturers," concludes Dedrick. "China has become the fourth-largest computer maker in the world" (Dedrick and Kraemer 2002: 28). Table 12 shows that the majority of foreign electronics firms in China are either joint ventures or domestic/state-owned enterprises (SOEs).

Given the large nature of the economy and the fact that China serves as an export platform, China has had a great deal of bargaining power vis-à-vis MNCs. First, China had location specific assets that could not be ignored. Not only did China offer an export platform like those of Taiwan and South Korea, it also had a large and growing domestic market which is a major bargaining chip for any country trying to lure FDI. In essence, foreign firms traded market access for technology transfer. China's domestic market continues to grow rapidly, propelled not only by a rise in personal income but also by active government promotion strategies as previously mentioned.

Table 12: China: Major Consumer Electronics Firms by Ownership Type

Sector	Foreign-Owned	Joint-Ventures	Domestic Firms and SOEs
Mobile Phones	Motorola	Motorola/Eastcom Nokia/Capitel, Southern Siemens/Mil Subsidiaries Samsung/Kejian Sagem/Bird	TLC
PCs	HP Dell	IBM/Great Wall Toshiba/Toshiba Shanghai Epson/Start Taiwan GVC/TCL	Lenovo Founder Tongfang
"Brown Goods"		Sony/SVA Philips/Suzhou CTV Toshiba/Dalian Daxian Great Wall Electronics/TCL	Changhong Konka Hisense Skyworth Haier Panda Xoceco
"White Goods"	Siemens	Samsung/Suzhou Xianxuehai Electrolux/Changsha LG/Chunlan Mitsubishi/Haier Sanyo/Kelon Sigma/Meiling Hong Leong/Xinfei Toshiba Carrier/Midea	Changling Gree

Source: Rodrik, 2006.

In addition to domestic market access, global MNCs have been willing to work in the confines of Chinese policy because of China's active support for and subsidies to the high tech industry. According to a comprehensive study by Dussel Peters (2005), a key program has been the establishment of high tech industrial parks. Much of the FDI flows to these parks where it is matched with national firms who are the recipients of numerous incentives and assistance programs. Despite the potential market pay-offs, foreign firms are now starting to get nervous about technology transfer arrangements, especially as Chinese IT firms begin to emerge as flagship companies**.** Indeed, OECD governments have begun to dub China's policies as "forced transfers" and have undertaken investigations and task forces in order to eliminate or reduce them (USDOC 2006).

Another key element of the strategy is a high level of support for high tech R&D and education. According to MOST, the bulk of R&D expenditure has been allocated to the IT industry. R&D funds are distributed to SOEs, local governments, and Chinese owned firms. The 2004-2008 five year plan calls for increased subsidies to SOEs (MOST 2006: Table 5.2). Support for local government is targeted at the cities which house R&D centers within industrial parks. Local governments often match national government funding for R&D programs.

In short, China's high tech promotion strategy had two prongs: build up capabilities of domestic firms and stimulate investment and technology transfer by MNCs. The results of China's high tech program have been impressive. By 1989, the Legend group had evolved into Legend Computer and formed a joint venture with Hewlett Packard. By 2000, Legend had emerged as the number one seller of personal computers in the Asia Pacific region and held more than 20 per cent of the Chinese PC market. In early 2005, Legend, which had morphed into Lenovo, acquired IBM's global desktop and notebook computer divisions. With the IBM deal, Lenovo became, after Dell and HP, the world's third largest PC maker (Spooner 2005). Hassee Computer is another fast growing domestic computer firm. Domestic manufacturers together have dominated 70 per cent of the market for PC sales (Walsh 2003: 108). Founder became a leading firm in developing laser typesetting technologies and electronic publishing. Datang is the leading company in development of 3G (TD-SCDMA) technology. Huawei is a giant

producer of telecommunication equipment. A collection of several domestic firms developed their own brand of Mobiles telephone and high definition disc players (see below). Table 13 exhibits a few other Chinese firms including lesser known ones that have made significant innovations. Despite numerous problems at the beginning, particularly the lack of recognition of their capabilities and relative merits of their product by Chinese customers, they succeeded to penetrate into the internal and international market. They were highly motivated to develop "leading technologies and leading products;" focused on a single product, collaborated with leading local providers of equipment and components, sought cooperation with MNCs and collaborated with their customers. Government support was integral throughout the process (Gao et al. 2007).

Table 13: Leading Innovative Domestic High Technology Companies in China

Company Name	Founding	Major technical acheivements
Huawei Technology	1988	Large-scale switch systems next generation network optimal network data communication
Shenzhen Zhongxin Technology Co.	1985	Large-scale switch systems next generation network TD-SCDMA
Datang Telecom Technology	1998	TD-SCDMA SCDMA
Dawning Information Industry Co.	1995	Wormhole routing chip parallel optimising compiler scalability, usability, manageability, and availability (SUMA) tech
Beijing Genome Institute	2002	Large-scale genome sequencing
Sibiono Gene Technology	1998	Gene therapy medication for head and neck squamos cell carcinoma
China National Petroleum Co.	1955 (1988)	Integrated seismic data processing software ABS technology Top drive drilling equipment Multi-branch horizontal and large displacement well drilling tech Two-state catalytic cracking technology

Source: Fan et al (2007).

Overall, by 2003, China's electronics sector generated $142 billion in exports and employed four million workers. Between 1993 and 2003, the growth rate of high tech exports was 50.2 per cent for computers and peripherals, and 21.9 per cent for telecommunications and related equipment (Table 13). Like Lenovo, many Chinese firms started as State Owned Enterprises (SOEs) and were gradually privatized as they gained capacity and competitiveness. In 1993, 26 per cent of computer and peripheral firms and 54 per cent of telecommunications firms were SOEs. By 2003, only 6 per cent of computer and 18 per cent of telecom firms were SOEs.

Although national firms, including SOEs, are in the minority, they are filing and being granted more patent applications than foreign firms. According to MOST, Chinese firms were granted 112,103 patents in 2002, whereas foreign firms were granted only 20,296. Close to half of these patents were in the form of utility models—patents for incremental innovations where local firms create variations on project and process execution. This reveals that a significant amount of learning is going on in Chinese firms. Another half of the patents granted, however, are in the form of design patents, which totaled 49,143 in 2002 (MOST 2006).

IV. Summary and Implications for Development Policy

It is clear from this analysis that Mexico and China have followed very different policies for acquiring technological capabilities. Mexico was the "champion of liberalization" but China's may be described as neo-developmental – evocative but not a clean replication of the NIC developmental states (see: ECLAC 2001). Alongside reform, China put in place functional and targeted government policies.

Perhaps more importantly, we have shown how Mexico's was a policy of dismantling a past set of policies and China's was a strategy of building new policies for the future. Mexico knew where it wanted to be and thought it had an easy way to get there: dismantle the old policies and learning and growth would follow. China also had the same goal but was more modest about how to achieve it. China has implemented a two pronged policy. While reforming the economy, it has taken a more gradual and experimental approach to liberalization and integration into the world economy.

Meanwhile, it has continued a parallel set of targeted policies in support of development of indigenous capabilities for technological learning.

As early as 1990, the Mexican Government relinquished all interference in the technology process leaving it entirely to the parties involved in FDI; MNCs were also provided various incentives, particularly in export processing zones, without having to meet performance commitments. Economic liberalism also led to a reduction in government investment in R&D, education and training. The assumption was that the market forces would take care of these issues.

Through trial and error, China has learned that reliance on market forces and FDI alone will not automatically lead to the transfer of technology and increase value added in exports. There was a need for developing the capabilities of domestic firms. While formulating and implementing a comprehensive but selective and targeted strategy aimed in particular at IT industries, the government developed an institutional framework for S&T development and a dynamic national system of innovation. It consisted of the Chinese Academy of Science, relevant ministries, the private enterprises, universities and research institutes. Close links were established among these entities in the public and private sectors. Both basic research, and application and diffusion of technology have been emphasized from early 1980s.

A shortcoming of this paper is the lack of ability to examine in full the independent effect that these government policies have on learning and industrialization relative to other facts – such an undertaking is an impossible one given the limits of current data and methods. Nevertheless, the results of our study are consistent with those of a number of other empirical studies in the TCB literature of capability building theory and other Neo-developmentalist literature (Wade 1990; Paus 2005; Puyana and Romero 2006; Amsden 2000; Paus and Gallagher 2008; Singh 1993; Chang 2005; Shafaeddin 2005; Lall 2005). This body of literature makes a strong case for the need for governments in pursuit of industrialization to nurture domestic firms in a globalizing world. The contrast in philosophy and policy for Mexico and China decisively confirms this general finding.

FOOTNOTES

[1] For more details on List's ideas see (Shafaeddin 2005) particularly pp 47-50.

[2] See for example the reference in (Bruton 1998: 930). There are at least two versions of the theory, TCB and (Lazonick 1991). Lazonick's theory is concerned basically with large firms of developed countries and thus not discussed here.

[3] For a good presentation and development of the theory see (Lall 1993).

[4] For more details see (Pizarro and Shafaeddin 2007).

[5] They were mainly located in Beijing, Shanghai and Shenzhen. 67 per cent of 33392 high-tech enterprises were located in high-tech parks (Fan, Gao, and Watanabe 2007: 356).

[6] The terminal year for China was 2005.

[7] These include Huawei, Shenzhen Zhongxin, Datang, Dawning, Beijing Genom Institutes and China National Petroleum.(see: Fan, Gao, and Watanabe 2007).

[8] Based on (People's Republic of China 2006), tables 21-13 and 21-9.

[9] They include Intel, SAP, Motorala, Lucent, Turbolinux, Nokia, IBM,Ericson, Agilent, Mirosoft, Matsushita, NEC and Samsung (Chen 2008: Table A1).

[10] For a brief history of development of the industry up to 1993 see (Ye 2008).

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Appendix

Table A.1: Applications for Patents Received and the Number of Patent Granted in China

Items	1990		2000		2005	
	Examined	Granted	Examined	Granted	Examined	Granted
Inventions	10137	3838	51747	12683	173327	53305
Domestic	5832	1149	25346	6177	93485	20705
Foreign	4305	2689	26401	6506	79842	32600
Utility models	27615	16952	68815	54743	139566	79349
Domestic	27488	16744	68461	54407	138085	78137
Foreign	127	11644	354	336	1481	48946
Design	3717	1798	50120	37919	163371	81349
Domestic	3265	1411	46532	34652	151587	72777
Foreign	452	387	3588	3267	11784	8572
Total	**41469**	**22588**	**170682**	**105345**	**476264**	**214003**
Domestic	36585	19304	140339	95236	383157	171619
Foreign	4884	3248	30343	10109	93089	42384
Share of domestic (%)	88.2	85.5	82.2	90.4	80.4	80.2

Sources: People's Republic of China 2006: Tables 21-44 and 21-46.

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