Creating Ladders out of Chains:
China's Technological Development in a World of Global Production

by

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ABSTRACT:

With the advent of economic globalization, the terms of debate over the political and social conditions necessary to foster development in the Global South have shifted. Examining technological development, one important aspect of economic development, in China, I explore the prospects for and conditions conducive to development under globalization. My main finding is that the developing world has significant opportunities for development through combining the institutions of global capital, defined here as the financial institutions of the advanced economies, with co-ethnic technologists returning from abroad. Global capital serves to ameliorate the inefficiencies of China's financial sector. The co-ethnic technologists establish hybrid firms that possess foreign finance and a strategic commitment to develop core technological activities in China, a strategic orientation commonly associated with domestic firms and not foreign ones. I call this developmental path the global hybrid model.

Using two case studies from China's IT industry, I demonstrate that the hybrid firms outperform both other foreign-invested enterprises and domestic firms in technological upgrading. The domestic firms underperform the foreign-invested firms because the Chinese financial system severely misallocates credit. Credit misallocation undermines incentives for technological development among domestic firms. The hybrids and the other foreign-invested firms rely on the institutions of global capital to allocate capital more efficiently, but the hybrids contribute more to local technological development due to their strategic commitment to China. The shared ethnic identity between the hybrids' owners and the local economy provide these firms with the ideas and interests that motivate them to pursue this strategic commitment to China.

The global hybrid path provides several insights on the problem of development under globalization. By importing foreign financial institutions, the global hybrid model lowers the institutional bar for development because developing countries need not have highly capable states or well-functioning markets to develop. Yet, global capital alone is not sufficient to achieve development because global capital has no serious commitment to host country development. In place of the previously proposed solution of state discipline of foreign firms to create commitment, co-ethnic technologists provide the motivation for hybrid firms to contribute significantly to developing host economies.

Thesis Supervisor: Suzanne Berger
Title: Raphael Dorman and Helen Starbuck Professor of Political Science

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Source Abbreviations

Abbreviation	**Source Name**
AWSJ	Asian Wall Street Journal
CJ	*Caijing* [Caijing Magazine]
DB	Dewey Ballantine's report on China's semiconductor industry
DT	Digitimes
DYBG	*Diaoyan Baogao* [Investigation Reports], an internal MOST journal
EET	Electrical Engineering Times (online version)
ESJB	*Ershiyi Shiji Jingji Baodao* [The Twenty-first Century Economic Herald]
FT	Financial Times
JJCG	*Jingji Guancha* [The Economic Observer]
NFZM	*Nanfang Zhoumo* [Southern Weekend]
NYT	New York Times
SS	Silicon Strategies
SST	Solid State Technology (online version)
TCNA	Taiwan Central News Agency
TENS	Taiwan Economic News Service
TT	Taipei Times
USPTO	United States Patent and Trademark Office
WP	Washington Post
WSJ	Wall Street Journal

Acknowledgements

Almost eight years ago, I arrived at MIT with the vague idea of wanting to study how China would deal with the stresses and opportunities of economic globalization. I hope that this dissertation marks significant forward progress in my thinking and knowledge about development and globalization. Thanks for any progress made over my eight-year academic odyssey is due to numerous people and institutions. For research funding, I wish to thank the Industrial Performance Center of MIT, the Sloan Foundation, the Institute of International Education's Fulbright Program and the Taiwanese government as co-sponsor for the Fulbright Program. I would also like to thank my host institutions abroad: Qinghua University, Fudan University and National Chengchi University.

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Finally, I would like to thank my parents for everything.

Chapter One

Development under Globalization: Introduction and Framework

1. Preface

1.1 The Argument in Brief

Over the last decade, China has achieved remarkable economic development success following a new path unknown, or at least unarticulated, by scholars and policymakers alike. I call this developmental path the global hybrid model. The global hybrid route relies on the institutions of global capital, defined here as the financial institutions of the advanced economies, and a set of firms established by ethnic Chinese entrepreneurs that I dub hybrids. Global capital serves to offset the inefficiencies of China's financial sector. Hybrid firms combine foreign finance with a strategic commitment to develop core technological activities in China. The hybrids take the best of both worlds of foreign and domestic firms. Hybrids as foreign firms receive finance and the concomitant financial discipline from global capital, an option that remains generally unavailable to Chinese domestic firms. At the same time, hybrids also have the commitment to local development more commonly associated with domestic firms than foreign ones. This global hybrid path is important beyond China because it speaks to the wider debates on globalization and development.

During the last several decades, there has been a fierce debate about the appropriate policies for economic development between the Washington Consensus[1] promoted by the major international financial institutions, such as the World Bank and the International Monetary Fund, and the revisionist political economists[2]. Followers of

[1]See Stiglitz (2002) for full explication of the Washington Consensus.

[2] Major revisionist works include Stiglitz (2002), Amsden (1989), Wade (1990), C. Johnson (1982), P. Evans (1995), H. Chang (1994), V. Chibber (2003) and Woo-Cumings (1999).

the former view advocate free and unfettered markets buttressed by institutions to protect property rights. The revisionists challenge the Washington Consensus by arguing that development involves social and political processes to create the necessary institutions for economic growth.

Economic globalization, commonly understood as lower barriers to and increasing flows of international trade and finance, has raised doubts about the prospects for development in the developing world. In confronting globalization, the analytic and prescriptive differences between the Washington Consensus and the revisionists remain, but there is a new split among the revisionists. The Washington Consensus welcomes globalization as a boon to developing countries through expanding the scope of market forces, but the revisionists divide over the prospects for developing countries under globalization. The optimists, such as Ernst and Saxenian, see transnational networks as providing opportunities for developing countries to continue to learn the skills and competencies necessary to further their progress.[3] The pessimists, such as Stiglitz and Strange, see globalization eroding the capabilities of the state or state-societal alliances necessary for development.

Using the case of technological upgrading (one aspect of economic development) in China's information technology (IT) industry, I demonstrate that opportunities for development exist under globalization. China's IT industry has flourished under globalization, but China's successful development does not conform well to any of the three viewpoints in the current debate. The pessimists see a developmental dead-end unless there is state intervention, but China's state lacks the capabilities to intervene

[3] The two principal beneficial networks in the view of the optimists are global production networks (GPNs) and transnational technological communities (TTCs).

successfully in the economy (see section five of this chapter). The optimists see transnational networks as the key[4], but in China, the Chinese state's relationship to firms structures the very ability of firms to take advantage of these network opportunities. Thus, the route to development is not simply one of opening up to transnational networks. The Washington Consensus would predict that the development of market institutions explains China's success, but China's market institutions are at best incomplete. Most damning to this market explanation is the very poor intellectual property rights (IPR) regime in China in precisely the type of technology-intensive sector, IT, where IPR is deemed to be critical for well functioning markets. Each of these three viewpoints offers valuable insights into the process of development, but they fall short of offering a satisfactory explanation of China's success.

The global hybrid model does offer an explanation that can account for China's success. Hybrids are a type of firm that combines foreign finance with a domestic-oriented strategy. They succeed in driving development because they combine the market discipline from the institutions of global capital with social mechanisms to make these market forces work to foster local development. The hybrid-led development thus combines elements of both the Washington Consensus (market mechanisms) and revisionist (social processes) camps.

Via foreign direct investment (FDI), China has imported market institutions in the form of the functioning financial institutions of global capital. By importing financial

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[4] Some of the network optimists realize that taking full advantage of these networks requires extensive state support of local participants in transnational networks (Ernst 2004ab). In effect, these scholars are not much different from the pessimists although they predict a different outcome i.e. the state plus networks equals development. This similar argument has the same problem that the revisionists have when explaining China's development in that it conflicts with what this work and many others (see Section Five of this chapter) have uncovered about the lack of capabilities of the Chinese state. In China, the effective state support to take advantage of the networks is lacking.

institutions, I mean the process of foreign-invested firms accessing foreign financial institutions for the financing of their Chinese operations rather than using the domestic Chinese financial system.[5] These acts of borrowing from abroad bring capital, but also the rules, understandings and other institutional practices that go hand-in-hand with the loan of capital itself.

However, the incentives (market signals) coming from these foreign financial institutions alone have not proven sufficient to spur China's impressive technological upgrading. To achieve this upgrading success, ethnic Chinese entrepreneurs[6] have had to interpret the market signals emanating from the foreign financial institutions. In China, certain ethnic Chinese[7] have interpreted these market signals differently from non-ethnic Chinese foreigners (and even some ethnic Chinese). These ethnic Chinese have taken the same market incentives as the foreigners, but have interpreted them in a way that leads them to proceed on a different technology strategy, a strategy predicated upon an intensive utilization and improvement of China's technology resources. By pursuing such a strategy, these ethnic Chinese entrepreneurs advanced China's technological development.

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[5] Thus, this importing of institutions constitutes a fundamentally different phenomenon than institutional transfer or imitation where simulacra of foreign institutions are built within the domestic political economy. Under imitation and transfer, there is a process of building domestic institutions using foreign ideas. Under importation, the institutions remain located abroad while their influence begins to enter the domestic political economy in which they are imported. See Jacoby (2000) on imitation and transfer of institutions.

[6] Technically, some of these people running firms are not the original founders so they are not entrepreneurs in the strict sense of the word. Here, entrepreneur is used as short hand for those who run firms.

[7] Saxenian and others argue that there are co-ethnic networks of technologists that span national boundaries, transnational technological communities (TTC). One of the most vibrant of these communities is the ethnic Chinese one that has a strong presence in many centers of IT, such as Taiwan and Silicon Valley. Most members of this ethnic Chinese TTC are not nationals of the People's Republic of China i.e. they are foreign nationals despite their Chinese ethnicity. The ethnic Chinese entrepreneurs that are driving upgrading are linked to these TTCs. The role of these networks is discussed in Section Four of this chapter and in Chapter Two.

The implications of China's global hybrid model for developing countries confronting globalization are two-fold. First, FDI dramatically lower the bar to development. Countries need not have highly capable states or well-functioning markets to pursue development. FDI can potentially offer the functioning market institutions many developing countries lack. Second, FDI is insufficient to realize development. The foreign-invested economic actors linked to these foreign market institutions need something beyond mere market incentive to pursue the activities that will fully realize host country development. Efficient markets are not sufficient to elicit a substantial contribution to local development by foreign-invested enterprises. Many revisionist political economists have been suspicious of FDI precisely because they feel foreign investors will not contribute much to development, at least not without strong pressure and discipline imposed by the host state. What the more state-oriented among the revisionists did not anticipate were other means beyond state discipline to socialize FDI to contribute to development. In China, the alternative is ethnic Chinese entrepreneurs that link up with the FDI. In some developing countries, such as Russia and India, entrepreneurs from co-ethnic transnational technological communities may play a similar role. In others, if development via FDI is to be realized, alternative mechanisms to motivate foreign-invested firms to commit to local development must be found.

1.1.1 Technological Upgrading in China: The Causal Mechanisms

From Marx's *Das Kapital* to contemporary endogenous growth theorists (Romer 1990; Helpman and Grossman 1991), most economists recognize that technological upgrading is a major driver of economic growth. Economists and political economists examining cases of successful development have also recognized that technological upgrading is critical to development (Khan 2000; Kim and Ma 1997; Pack and Westphal 1986; Amsden 1989, 2000; Amsden and Chu 2003). Even for those who view technological development as merely a secondary cause of development[8], technological upgrading has obvious implications for international employment and trade patterns and international power relations. Those nations better able to achieve technological upgrading tilt these patterns and relations in their favor.

Empirically, successful technological upgrading has combined three features: sources of technology, functioning financial institutions and motivation. For developing countries, technology often comes from abroad and the main task initially is assimilation and learning of these technologies by local firms and other institutions. Some local firms also build up capacities to generate their own technologies, often on the basis of large and growing economies of scale and scope (Amsden and Chu 2003; L. Kim 1997).[9] Functioning financial institutions provide the means (capital) and incentives for wealth generation. Even in the developed world, the precise institutions of finance vary. Among successful developers, there have also been a wide variety of mechanisms that function reasonably well. In developing Taiwan, a state-run banking system tight-fisted with its capital was complemented by a variety of informal financial mechanisms. In

[8] Dani Rodrik (2003) and other economists see technical improvements as being driven by three more fundamental sources of growth, geography, trade and institutions. In short, upgrading is an intermediate variable between the fundamentals and the outcome, growth. Practically, their argument is not really different from the recent work on technological development as a source of growth. The recent scholarship is aware that behind this technological development, there are institutions creating situations more or less conducive to technological learning (Pack and Westphal 1986; Aoki *et al* 1997; Helpman and Grossman 1991).

[9] The most comprehensive ideological framework for moving from assimilating from abroad to developing homegrown technologies is the "three note chord" of technonationalism (autonomy, nurture and diffuse) presented in Samuels' *Rich Nation, Strong Army* (1994).

Korea during its developmental heyday, banks provided generous credit to certain firms and rigorous state monitoring of the borrowers accompanied this easy credit. On balance, the successful developers created mechanisms, no matter how opaque or incomplete by developed world standards, to provide the capital and discipline for creating economic value. Finally, motivation to locate productive technology activities in the developing economy is necessary. Historically, firms in places such as Taiwan and Korea had a mix of nationalist ideology, state monitoring and support and corporate self-interest to provide this motivation. Foreign firms lack the nationalist commitment to development so many scholars have assumed state monitoring and incentives for foreign firms have to be that much greater to make up for this lack of patriotic purpose.

Since states historically have played a major role in all three areas, one might expect states to continue to play a prominent role in upgrading. Alternatively, one might anticipate global networks taking charge of development, particularly in countries with weak policymaking capabilities like China. In China, one sees neither of these processes. The state's efforts to direct upgrading have failed and even backfired. Yet, transnational networks are not alone in the driver's seat either. Nor in China does one see that very rare event in the developing world, well-functioning market institutions that keep market failures to a minimum.

Instead two social institutional variables[10], state-firm relations and firm operational strategies, create and shape the opportunities for upgrading in China.

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[10] By social, I mean those phenomena juxtaposed to purely economic phenomenon (e.g. supply and demand or the profit motive). By institutions, I use North's broad definition encompassing of institutions as, "any form of constraint that human beings devise to shape human interaction (North 1990: 4)."

State-firm relations determine which firms have access to what type of financial institutions. Some firms are allowed to access foreign financial institutions while cut off from the formal domestic financial system. Other firms are unable to access foreign finance or are offered far more favorable terms from the Chinese state banking system. A firm's operational strategy (OS) determines its motivation to upgrade in China as opposed to doing so elsewhere. The OS is an interpretative lens for market signals. Those firms that have a strong motivation to upgrade in China, a China-based OS, will interpret the same market signals in a manner different from firms with a non-Chiba-based OS. There is a social basis to the OS variable because those firms with a China-based OS have this strategy because of the socio-cultural knowledge and ideas that are part of their ethnic Chinese identity (see section 2.2). The state-firm relations determine which firms can access functioning financial institutions and then the operational strategies of individual firms determines if those firms accessing foreign finance interpret the market signals in a manner more or less beneficial to China's development.

In China, the relationship of firms to the state determines their sources of finance and these sources of finance in turn impact their ability to upgrade. Sources of finance that provide credit with hard budget constraints give firms incentives to upgrade. Firms have hard budget constraints when they do not receive free help in covering their own financial obligations. With hard budget constraints forcing firms to meet their financial obligations, firms have to remain competitive to survive. For technology firms[11], a critical part of their competitiveness is their technology so they have every incentive to

[11] By technology firms I mean those firms whose products have a high technological-intensity i.e. the scientific and technical knowledge required to create these products is high. I do not mean technology in the broad sense of knowledge in general e.g. McDonald's has mastered the "technology" of running the fast food business.

improve their technologies to keep pace with competitors. Finance that provides credit with soft budget constraints deprives firms of the incentives and even the capabilities to upgrade. Firms have soft budget constraints when they do not have to pay for some or all of their financial obligations themselves. These firms can rationally expect to survive even if not competitive because others are willing to bail them out. Thus, they lack incentives to upgrade. Worse, the absence of the threat of extinction encourages these firms to become very lax so firm capabilities suffer. A third possibility is no source of finance. Firms without financing will not be able to invest in technological development.

There are four types of firms in China: the favored domestic firms, the neglected domestic firms, the hybrid foreign-invested enterprises (FIEs) and the regular FIEs. While globalization has presented most of these firms with access to technology through transnational technology communities (TTCs), financing and motivation have varied across firm categories. Due to different state-firm relations, FIEs rely on foreign finance and domestic firms do not. Hybrid FIEs differ from regular FIEs because the hybrids have a China-based operational strategy. This operational strategy (OS) is a mix of interests and ideational factors that causes these firms to perceive China either as the vital center of their operations (the China-based OS) or as just another location among many (the non-China-based OS). Behind the hybrids' China-based OS is shared ethnicity with the host economy that gives the entrepreneurs running these hybrids both the interests and ideational motives to make China the vital core of their operations (see section 2.2) although not all ethnic Chinese entrepreneurs adopt a China-based strategy. Thus, variation in firm-state relations (finance) and operational strategy (motivation) determine the variation in technological upgrading.

This dissertation makes two claims:

1) In China's IT sector, FIEs (foreign invested enterprises) contribute significantly more to China's technological upgrading than domestic firms.

2) In China's IT sector, a certain type of FIE, the hybrid FIE, contributes significantly more to China's technological upgrading than the regular (i.e. non-hybrid) FIEs.

I test these claims based on evidence from extensive interviews (over three hundred) with industry participants as well as a broad review of the relevant secondary sources of the industry. Both types of FIEs contribute more to upgrading in China than do the two types of domestic firms. Among the FIEs, the hybrid FIEs are more likely to contribute than the regular FIEs. I measure the contribution to technological upgrading using two metrics: 1) the total number of workers/suppliers to whom new technical skills and knowledge are imparted and 2) the level of skills and knowledge passed on to workers/suppliers.

The hybrids are the most successful upgraders because they have both disciplined finance (i.e. credit with relatively hard budget constraints) from foreign financial institutions and the motivation to upgrade in China due to their China-based OS. This access to foreign finance is the result of the arrangement between the Chinese state and FIEs to allow both types of FIEs to invest in China while limiting their access to the Chinese state financial system. The successful upgraders obtain technology from TTCs, but so do most of the firms that have failed to upgrade. Thus, technology flows from the developed world are necessary but not sufficient to explain upgrading. The unsuccessful domestic upgraders lack finance (neglected domestic firms) or financial discipline (the favored domestic firms) due to their particular relationships to the state. The favored firms have a close relationship to the Chinese state, which provides them with state finance and procurement without any effective state monitoring. The resulting soft budget constraints undermine both firm capabilities and incentives for upgrading. The neglected firms have a distant relationship with the state so they are unable to gain access to the state financial system. Cut off from credit, they are unable to afford the costs of upgrading. The regular FIEs have the capabilities to upgrade due to their financial discipline and access to transnational technology networks, but undertake less upgrading in China than the hybrids because they lack the China-based operational strategy.

In short, the state's relations to firms determine their sources of financing. In turn, the sources of financing help determine the technological upgrading effort of the firms. The upgrading effort only partly explains the commitment to pursue technology activities in China, which is referred to as Technology Strategy in Figure 1 and Table 1 below. The foreign sources of financing send both types of FIEs the same market signals, but only the hybrids' interpretive lens of a China-based operational strategy processes these signals to mean that the firm should pursue technology activities in China. The combination of the sources of financing and the operational strategy of the firm together determine the Technology Strategy, which in turn determines the upgrading outcomes in China. The thesis maintains that greater corporate technological efforts in China will on average lead to higher technological contributions to China, and the research found much evidence to support this contention. State-firm relations explain why domestic firms fail to contribute to upgrading as much as foreign firms (Hypothesis

One). The China-based operational strategy of the hybrids explains why hybrids contribute more than regular FIEs (Hypothesis Two).

Figure 1 Causal Flow

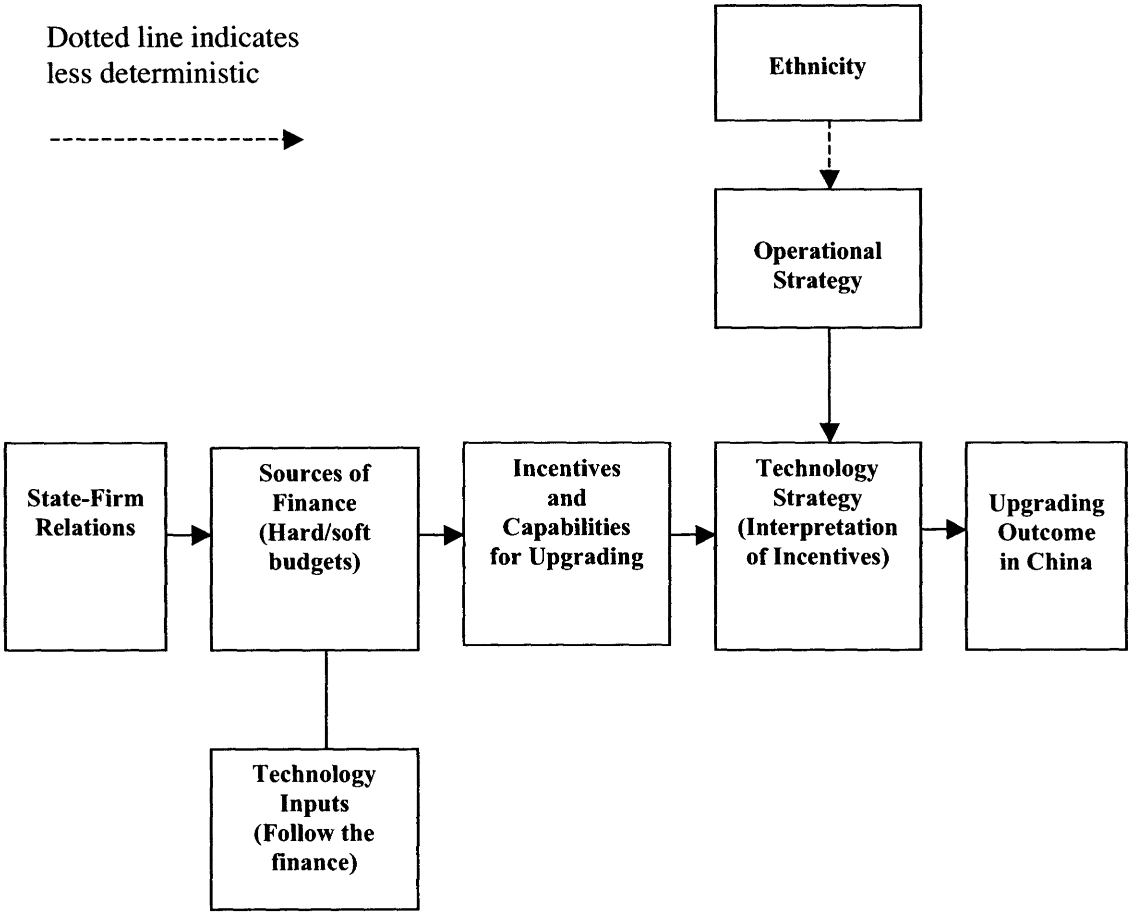


Table 1 Factors Determining Contribution to China's Technological Upgrading

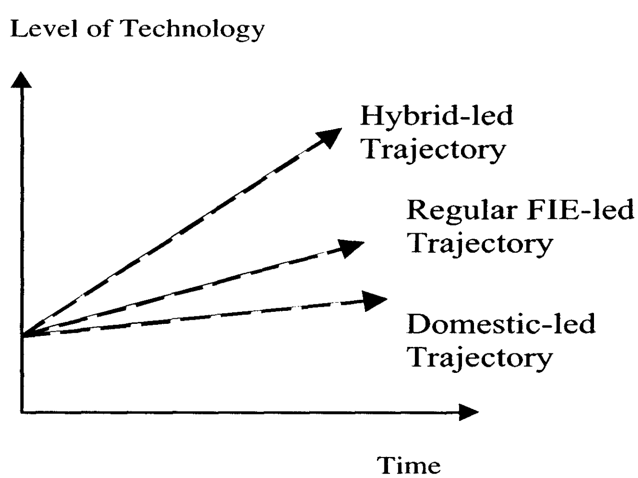
Firm Type	Finance	Technology Inputs (Follows finance)	Capabilities and Incentives to Upgrade	Operational Strategy (Motivation/ Interpretive Lens)	Technology Strategy (Technology Activities in China)	Contribution to Upgrading in China
Neglected Domestic Firms	Little Access to Finance	No access to finance so no access to technology inputs.	**Low capabilities**: No finance No technology	China-based OS but no capabilities to undertake technology activities	Do not pursue upgrading because of low feasibility and high risk	**Low**
Favored Domestic Firms	State banks and procurement offer unmonitored and lavish financial support i.e. **soft budget constraints**.	Have access to finance so have access to technology inputs.	**Mixed Capabilities** Access to finance Access to technology Soft budgets undermine capabilities **Disincentives** because of soft budgets	China-based OS but disincentives to upgrade so motivation irrelevant.	Generally do not attempt to do technological upgrading; the few attempts are poorly executed	**Low**
Regular FIEs	Access to finance but finance offers **harder budget constraints** relative to Chinese state banks/procurement	Same as above.	**High Capabilities** Access to finance Access to technology **High Incentives** Hard budget constraints plus technology-based competition	Non-China-based OS so lacks positive bias of interpreting market signals in favor of placing activities in China	Try to enhance technological capabilities but not necessarily in China	**Variable (Low to Moderate)**
Hybrid FIEs	Same as above	Same as above.	Same as above	China-based OS interprets market signals in a manner favoring activities in China	Try to enhance technological capabilities in China	**High**

To place the causal argument in terms of the discussion about China's development under globalization, the hybrids are those firms receiving market signals from foreign financial institutions but these firms influenced by their Chinese ethnicity interpret those markets signals in manner (the China-based OS) that dictates that they adopt a corporate strategy conducive to pursuing technological development in the host country, China. The regular FIEs receive the same incentives from foreign financial institutions but their interpretative lens (the non-China-based OS) is decidedly different. Their processing of these market incentives does not lead them to commit to utilize extensively China's resources for their technology activities. Thus, they embark on a technology strategy that at best only moderately contributes to China's development despite using relatively functioning foreign institutions just like the hybrids. The domestic firms fail to contribute because they operate under conditions of market malfunction in the area of finance. Financial resources are not distributed according to these firms according to which firms can maximize the return of the invested financial resources. Instead, a political logic of state favoritism determines the allocation of domestic finance.

The IT industry's modularity (the segmentation of production into narrow functions done by specialized firms) serves as a background condition. By background condition, I mean a condition that affects all the actors (in this case, firms) equally. Modularity is important to the final outcomes because without modularity small firms focusing on very narrow segments of the value chain could not thrive as they do in China. In the absence of modularity, building firms with large scale and scope economies in China would be necessary, but neither the state nor the technology firms are up to the task. The state lacks the industrial policymaking capacity to create such firms as will be discussed later in this chapter. The new firms that lead China's technological upgrading would not be able to build the scale and scope necessary to compete in a non-modular industry because of their small size. Thus, if the industry were not modularized, then one would expect much less upgrading across all firm types. The IT industry effects and their applicability to other sectors will be discussed in detail in Chapter Three.

The findings of this research suggest that China theoretically faces three quite different trajectories of technological development dependent on the three main types of firms. If China allows hybrids to continue to function relatively freely in its economy, China can expect a relatively rapid accumulation of technical knowledge and skills. If for some reason hybrids did not exist (for example, there were no overseas Chinese to found these hybrid firms) but regular FIEs were still allowed into the economy, China could expect a slower pace of technological upgrading (labeled as Regular FIE-led Trajectory in Figure 2). If China rejected foreign investment and tried to develop solely through domestic enterprise, then China could expect an even slower pace of technological upgrading (presented as Domestic-led Trajectory in Figure 2).

Figure 2 Three Technology Trajectories



1.2 Research Methodology

The primary research consisted of 323 semi-structured interviews with government and business participants in China's IT industry. To check my interview findings against broader trends and other information sources, I also conducted extensive secondary research including Chinese news reports, commentaries by Chinese economists and technology policy experts, and internal government documents as well as Western news and industry sources. The bulk of the interviews (214) were conducted in 2001-2002. Thirteen were conducted in the summer of 1998 and the rest were conducted in 2003-2004. All of the interviews were with people currently involved in business or government in China or with knowledge about particular firms or government policies. I conducted all the interviews by myself except for 5 interviews as part of a joint research trip to southern Zhejiang I took with scholars from Ministry of Science and Technology and universities in Hangzhou, 22 interviews conducted jointly with two MIT electrical engineering professors and 1 interview conducted jointly with another American scholar.

I had conducted prior research that provided me with some understanding of the global IT industry. Before my main fieldwork period of 2001-2002, two MIT electrical engineering professors (Professors Akinwande and Sodini) and I had already a framework to analyze the IT industry based on our research on the IT industry for the Industrial Performance Center's Globalization Project. This framework helped me to understand what activities firms were doing and estimate the technical sophistication of their activities. Chapter Three explains this framework.

Given that much of my information was based on interviews and I do not have a PhD in electrical engineering, how could I determine which firms were actually engaging in real technological activities? Most firms in high-tech have an incentive to boast about their technological capabilities to outsiders. Furthermore, many firms in China are solely doing illegal or legally dubious reverse engineering activities that they understandably would be reluctant to admit to an outsider. I used my prior knowledge of the industry, but this was insufficient given all the incentives for insiders to distort information to outsiders. Much more critical than my prior knowledge was my ability to elicit information from interview subjects about other firms they were familiar with due to business connections. To confirm information about interviewed firms, I checked with their suppliers because these firms knew what activities the customer firm could undertake themselves. While one supplier's word is not sufficient since they too might also want to inflate their own technical prowess at the expense of their customer, I interviewed a number of suppliers to control for this incentive to boast. For example, I interviewed the majority of the major Taiwanese hardware suppliers to Chinese computer and telecommunications firms and received a consistent response confirming the lack of technical skill among the Chinese firms with the exception of Huawei. I also interviewed customers of the IT firms to understand what they could actually deliver. For example, I interviewed a number of IC design houses about their experience with various Chinese and leading Taiwanese foundries (manufacturing service) to check the claims of the Chinese foundries. I also interviewed consultants to various companies because these consultants were often privy to internal company information. Finally, I interviewed the financiers, predominantly venture capitalists, about the specific companies where they had conducted due diligence to assess the technological capabilities of the firms. The venture capitalists were useful because they had technically trained staff with the greatest incentive to learn about the details of potential investment targets. Similarly, I checked the claims government officials made about the efficacy of various policies with the "consumers" of such policies, the firms. Given the networked nature of the industry, many interviewed firms were simultaneously subjects of study in of themselves and sources of verification about the claims made by their customers, suppliers and government policymakers.

The geographic distribution of interviews (see Table 2) reflects the distribution of China's IT industry with its main IT clusters in the Pearl Rover delta (Guangdong), the Yangzi River delta (greater Shanghai) and the Beijing-Tianjin area. I had 1 interview in Chengdu (Sichuan Province) and 2 in Xian (Shaanxi Province). Both of these cities are located in western China and focal points for the Chinese government's Western Development Project and have strong technical institutes of higher education although their IT industry lags behind the coastal areas.

Table 2 Geographic Distribution of Interviews

Region	**Number of Interviews**
Beijing	98
Shanghai	82
Guangdong	42
Taiwan	33
Jiangsu	32
Zhejiang	20
Tianjin	6
International	7
Western China	3
Total	**323**

Note: Interview data through March 31, 2005.

The breakdown by the type of interview subject is presented in Table 3.

I interviewed a number of academics, but I did not count these interviews unless the interviewed academic had in-depth knowledge to offer about a particular firm or had served in a relevant government post.

Table 3 Interview Types

Interview Type	**Number of Interviews**
Foreign Business	152
Domestic Business	80
Government	81
NGOs	5
Academia	5
Total	**323**

Note: Interview data through March 31, 2005.

1.3 The Globalization of the IT Industry in China

The IT industry closely approximates the ideal-typical globalized industry with no trade barriers. This industry has relatively low tariff barriers due to the World Trade Organization's Information Technology Agreement (ITA). The ITA by 2000 had eliminated tariffs and duties in signatory nations[12], which by the terms of the agreement had to comprise over 90% of the world's IT trade in 1997 when the ITA went into effect.[13] There are also other international bodies in the IT sector pushing for open trade, such as the World Semiconductor Council, which has succeeded in reducing tariffs to

[12]The developing nations signing the agreement are allowed longer periods of time to adjust their tariff schedules. What is more, the nations that are WTO members but not signatories of the ITA still enjoy the tariff benefits from the lowering of tariffs by ITA signatories, which include the Triad of advanced economies, the EU, the US and Japan. Thus, this adjustment mechanism actually works in favor of the developing world contrary to the predictions of the globalization pessimists.

[13] The ITA should now encompass nations responsible for well over 90% of the world IT trade as China, a large IT producer and trader, has recently become a member of the ITA following its WTO accession.

zero in the dominant semiconductor-producing and consuming economies, the EU, Taiwan, Korea, Japan and the US.

China has opened up to trade and investment. Albeit often unwittingly or reluctantly, China has permitted large international financial inflows, with the strong qualification that these flows have been FDI rather than "hot money" i.e. speculative short-term loans.[14] China's IT industry has extensive trade flows and is more open to imports than some of China's sectors.[15] China's IT sector is also much more open than some past developers, such as Japan. China's opening up to foreign investment in the 1990s culminated in 2003 when China became the largest national recipient of FDI for the first time in history (NFZM, July 15, 2004).

1.4 Examining China's Basic Factor Inputs

It is common for economists to conceive of basic factor inputs (capital and labor) as driving economic growth. In the case of China, do these basic factors explain China's surprising ability to upgrade technologically?

Is it simply China's immense population that accounts for its rapid technological upgrading? If population size alone mattered, why do other populous developing nations,

[14] The Chinese state did not even let foreigners invest in the main Chinese stock markets, restricting them to the small B share market, until 2004. Interestingly enough, stock investments have not been viewed as a hot money problem. Consequently, Thailand, the Philippines and Singapore actually ended their two-tier systems of shares segregating foreign from domestic buyers in the wake of the 1997 crisis (Walter and Howie 2003: 181). On the other hand, under its WTO accession agreement, China has committed to opening part of its banking sector to foreign firms. In general, China has been quite open to FDI inflows, but has not adhered to the Washington Consensus of unimpeded financial flows, which Stiglitz (2002) has rightly criticized for bringing in the bane of hot money. In this dissertation, globalization is not meant to be simply adhering to the Washington Consensus principles, but just the state of being in a situation of relatively open financial and trade borders compared to historical experience.

[15] In general, China's trade is open as the effective tariff rate is only 3.6%, which is lower than the nominal rate of 11.1% due to the many exemptions and benefits enjoyed by firms in a variety of special industrial zones in China (YF Tao 2003: 3).

such as Indonesia, Pakistan or Brazil, not exhibit similar rapid technological upgrading? India may have a similar phenomenon, but it appears to be on a rather smaller scale (Clarke 2004). In any case, size alone clearly is not the determining factor as some of these behemoths are basket cases and some rather small nations, such as Taiwan and Singapore, have climbed all the way to the elite club of rich nations. Furthermore, if population was the key, why did China only recently start rapid technological upgrading?

Is it simply the sheer size of the FDI? China's FDI flows have been enormous in recent years, and are a much larger share of GDP than for the average developing country. However, as a percentage of GDP, China's FDI flows are not much different from a host of other FDI-welcoming developing nations. Malaysia has received an enormous amount of FDI given the size of the nation and has a large IT sector, but Malaysia has not undergone the extensive upgrading that China has (B. Ritchie 2002: 30). If one analyzes China's FDI, one quickly discovers that only a small amount goes to the firms actively engaged in the most technological sophisticated activities. FDI alone has not guaranteed the use of funds for technological sophisticated activities. Indeed, what is truly startling is the much large number of firms upgrading in China compared to other countries that are much richer. Mexico, Brazil and Malaysia on a per capita basis are much better off than China; yet, they have not been able to generate the technological activities that China has.

One factor in which China does stand out from the crowd is its absolute number of educated people. In part, this is unsurprising given the large population of China, but it is nevertheless impressive given the relative poverty of China compared to much of the world. Having the appropriate human resources is undoubtedly a necessary condition for

Table 4 Stock of FDI as Percentage of Gross Domestic Product

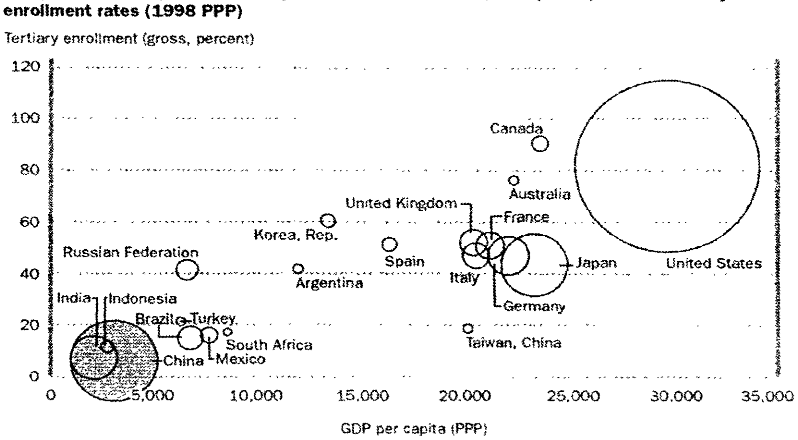
Source: UNCTAD, *World Investment Report 2003* (New York: United Nations, 2003), pp. 197-198, 278-286.

	1980	1985	1990	1995	2000	2001	2002	GDP per capita 2001 (US dollars)
Mexico	3.6	10.2	8.5	14.4	16.8	22.5	24	5651.2
China	3.1	3.4	7.0	19.6	32.3	33.2	36.2	852.5
Malaysia	20.7	23.3	23.4	32.3	58.6	60.5	59.4	3856.6
Brazil	7.4	11.5	8.0	6.0	33.2	43.1	52.1	3181.1
Developing World	4.9	6.2	8.2	8.9	16.5	17.9	18.7	_____

technological upgrading, but it is not sufficient to explain the timing of China's development. China has been quite successful in educating people for several decades (D. Zweig 2002: Chp. 4), but has only recently seen a spurt of technological upgrading in one particular economic area, the foreign-invested sector. Furthermore, many of China's educated have gone abroad and the returnees leading the upgrading have only recently returned. Only under new circumstances generated by China's internal politics did China's human capital begin to fulfill its promise for development.

Figure 3

Comparisons of major countries by economic size and PPP, GDP per capita, and tertiary enrollment rates (1998 PPP)



Source: World Bank staff analysis.

2. The Independent Variables

2.1 First Independent Variable: State-structured Sources of Finance

2.1.1 The State and Domestic Firms

A number of scholars have recognized that the Chinese state does not grant all firms equal access to China's formal financial system. In *Selling China*, Huang (2003) posits a political pecking order in which the state favors state-owned firms and discriminates against private ones. The state-owned and private firms within Huang's political pecking order of firms match closely the categories of favored and neglected used here. The state-owned firms are showered with finance and the private firms are cut off from the state-banks. In short, the state determines access to capital. This view is not Huang's alone. Adam Segal (2003), Kellee Tsai (2002) and the International Finance Corporation (Gregory *et al* 2000) also argue that private firms are cut off from the state financial system that favors state-owned firms. We need, however, to recognize that many firms that are not considered state-owned after these many years of enterprise reform in China are still closely connected to the state and receive both financial and procurement patronage. Indeed, Segal (2005) has recently pointed out that some private firms, such as Lenovo, are clearly favored by the state. Thus, the conception of favored domestic firms used here includes all domestic firms enjoying generous state finance and procurement regardless of their formal designation as state-owned or private.[16] Those firms that do not enjoy state favor, the vast majority of which are outside the formal state-owned state, are neglected enterprises.

[16] There is a large range of official and semi-official sub-categories of state-owned and private firms as well as local state and quasi-private firms known as collectives. In any case, I argue that the official designations do not matter. What matters is the relationship between the particular firm and the state.

The state connections do not directly explain the technological strategies of domestic firms. Rather, the state determines which firms receive finance and on what terms. These financial arrangements directly explain the technological upgrading behavior of domestic firms.

2.1.1.1 Favored Domestic Firms

This thesis accepts the notion of technological upgrading as entailing high risks and high costs. The risk is high because learning or developing new technologies is difficult. To learn or develop new technologies, a firm must invest human and financial resources so the process is costly. Firms need financial resources to overcome the costs and incentives for technological upgrading to overcome the risk. Larger profits than the firm would enjoy in the absence of upgrading provide the incentive to upgrade (M. Khan 2000: 40-53)[17].

Why are favored domestic firms, showered with easy credit and procurement from the state, less likely to upgrade? Upgrading is inherently risky, but one could plausibly argue that softening of budget constraints would free these firms to take greater risks. Being less risk adverse, firms hypothetically would be willing to take on challenging technological projects despite the inherent risk of new technology projects. The evidence from other studies (Kornai 1995; Kornai et al 2003; X. Liu 2001) as well as this one suggests that even when such firms are willing to try to undertake technological

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[17] Khan (2000: 47) notes that often in developing countries the financial markets are inefficient so that government intervention is necessary to ensure rents for learning and innovation i.e. government lowers some of the risk for entrepreneurs. He also mentions that efficient insurance markets would take out some of the risk, but he then concedes that efficient insurance markets are a fiction even in the advanced capitalist world. Thus, the problem seems to be the inefficient capital markets in the developing world. As this dissertation will show, many of China's successful firms tap into the financial institutions of the advanced economies.

activities under soft budget constraints such as the Chinese state provides, they will not conduct them in an effective manner. This is a probabilistic judgment rather than an absolute one. These firms do not completely lack the capabilities to upgrade, but the likelihood of their upgrading is low because of the curse of state favor. The state undermines favored firms' ability to upgrade in three ways: bureaucratic goals, firm incapacity and disincentives to upgrade.

The bureaucratic goals mechanism applies only to those favored firms that are state-owned enterprises (SOEs). Bureaucrats do not run the other favored firms so these firms escape this particular malady. In SOEs, the bureaucrat-manager is given many goals other than profitability. Officials higher up the hierarchy set the goals by which the bureaucrats-as-managers will be judged (Kornai 1995; Huang 2003: 137-140). Among these goals are preserving the SOE and increasing the scale and perceived technological prowess of the firm. Preserving the firm mitigates the desire to undertake anything risky, such as learning new technical skills. Increasing the scale and perceived technological intensity of the firm induces the bureaucrat-as-manager to buy expensive capital equipment that makes the firm appear cutting edge and increases the apparent scale of the firms as the new equipment (at least if properly used) increases productivity. The new capital equipment also increases the fixed capital of the firm, another measure of scale.

These investments in capital equipment and increasing scale also serve the purpose of promoting the survival of the bureaucrat's domain, the SOE, because the firm becomes too large or too important (in the eyes of national planners) to fail. China did go through a process starting in the wake of the Fifteenth Party Congress in the autumn of 1997 of continuing to support the large SOEs while letting go of the small-and-medium-sized SOEs (the "grasp the large release the small" policy or *zhua da fang xiao*). The campaign and its aftermath only served to convince SOE managers that their firms should look big though these incentives were implicit in the system prior to this policy.

In sum, the bureaucratic goals induce a policy of capital investment without skill investment. Huang, Gilboy, Wu (1996) and Jefferson and his colleagues (1999) have documented this tendency within Chinese SOEs. Wu Renhong points out that Chinese SOEs spend one dollar on assimilation for every ten on technology acquisition. In contrast, the Japanese and Koreans spend ten dollars of assimilation for each dollar spent on acquisition. Assimilation is the process by which a firm learns how to use a technology acquired. Jefferson and his colleagues (1999) present evidence that SOEs invest less in skills even compared to other Chinese firms. They calculated that the marginal productivity of TVE (township and village enterprises) technicians was 250 percent higher than that of the technicians in SOEs. TVE technicians had four times the marginal productivity when new expenditures on productivity were incorporated into the calculus.

In the firm incapacity scenario, the easy access to state finance and procurement encourages all sorts of inefficiencies in the favored firms that prevent these firms from doing much of anything well. These firms may attempt to do technological upgrading, but their general inefficiency in operations make it difficult for them to upgrade effectively. Liu Xielin (2001: 39 and 43) and Kornai and his colleagues (2003: 1105) note this problem of soft budget constraints undermining upgrading. This problem applies to state and non-state favored firms.

Procurement by the state plays a critical role in determining the incentives for upgrading among favored firms. State procurement encourages firms to forgo high risk, high reward upgrading for the less risky if potentially smaller profits to be made from feeding at the state's trough. With the opportunity to make profits with the skill set they already have, these firms lack the incentives to upgrade their skill set to be competitive in the marketplace. From the literature on China's industrial policy (see Section 5 of this chapter), we know that the Chinese state does not monitor firms effectively. Without effective monitoring, the favored firms can simply enjoy the state's bounty without enhancing their performance in return. The firms are given *ex ante* rewards for technological upgrading without any demand for *ex post* results of the hoped-for technological endeavor. I will present evidence of how procurement undermines the incentives to upgrade in domestic firms in the empirical chapters. Indicative of this problem, a number of non-state firms covered in this study (including those exceptional few foreign firms that have been able to link up with the Chinese state) have gone from upgrading champs to procurement chumps. As soon as these firms started feeding at the state trough, they stopped upgrading. This problem can affect state and non-state favored firms alike though the state firms already suffer from both problems of bureaucratic goals and firm incapacitation so the lack of incentives is the least of their problems.

Just as the state has showered financial favor on some firms, it has neglected many other firms. This neglect creates a two-tiered structure of firms in China (Huang 2003; Gregory *et al* 2000). For the domestic firms that are not favored by the state, financial sources are as limited as they are abundant for the favored firms. These firms have difficulty acquiring loans from the state banking system (Huang 2003; K. Tsai 2002;

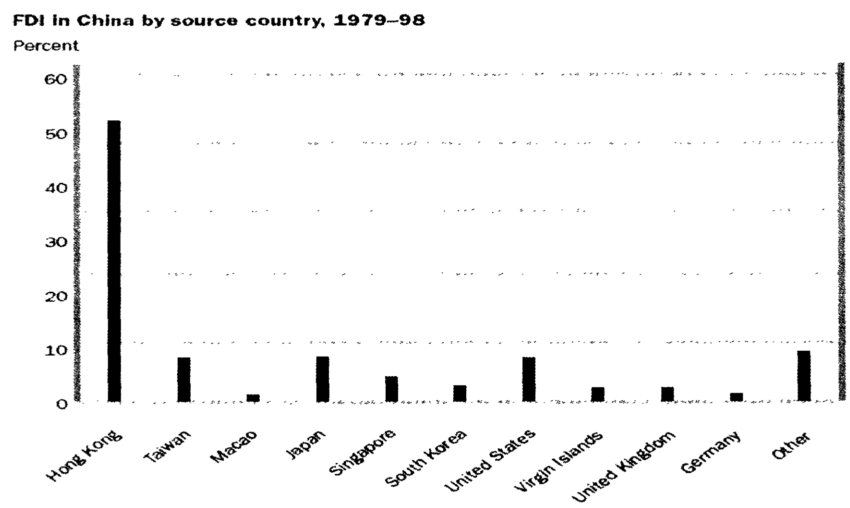
Gregory *et al* 2000). This scarcity of capital prevents these firms from embarking on technological upgrading as these firms do not have the means to do so despite whatever *ex post* rewards for technological advancement they might enjoy. In short, the neglected firms have too few financial resources to risk attempts at technological upgrading. Huang presents data on the general barriers to growth faced by neglected firms. This dissertation will provide evidence from neglected firms that the lack of financing has stymied their attempts to upgrade.

2.1.2 The State and FIEs

The Chinese state has structured the entry of FIEs into China by denying them easy access to the Chinese financial system while simultaneously allowing them access to foreign finance. The state's gradual expansion of the scope of sanctioned activities for foreign firms has been documented by a number of scholars (D. Zweig 2002; D. Yang 1997; Rosen 1999). This expansion eventually led to foreign firms operating in China with very little influence and interference from China's financial system. Consequently, the FIEs have avoided the pitfall of the favored domestic firms being undermined by the easy credit from the state, and they have avoided the pitfall of neglected domestic firms, the problem of credit scarcity.

The FIEs primarily borrow from the financial institutions of the advanced capitalist nations, including the ECEs (ethnic Chinese economies of Hong Kong, Macao and Taiwan). China does have some FDI from other developing countries, but the vast majority is from the ECEs and the OECD (see chart below), the rich nations' club (Y. Huang 2003). The financial institutions of advanced capitalism provide the FIEs with finance on terms quite different from those of either type of domestic firm. These institutions, while by no means perfectly efficient in allocating credit, offer far harder budget constraints for foreign firms than the Chinese state gives to favored domestic firms. At the same time, foreign finance does not starve firms of capital as the Chinese state does the neglected domestic firms. The claim here is simply that the foreign finance that the FIEs access is harder than the credit offered by the Chinese state banking system to the favored domestic firms. No claims are made that the foreign finance offers anything approaching perfect distribution of credit that eliminates the possibilities of bad loans or unfinanced creditworthy projects.

Figure 4
Source: *China and the Knowledge Economy* (Washington, DC: World Bank, 2001), p.143.



With access to credit, FIEs can feasibly undertake technological activities in China. Under relatively hard-budget constraints, the FIEs' performance will not be undermined by the problems of incapacitation and disincentives to upgrade that affect the favored domestic firms. More efficient monitoring and allocation of credit alone does not however separate the technology strategies of the two types of FIEs. Efficient capital allocation would only dictate that firms attempt to make the best use of the capital it has borrowed. Technology firms compete at least in part on their ability to generate and upgrade their technologies. Hard-budget constraints would push technology firms to pursue technological activities somewhere in the world, but would not necessarily push the firms to pursue those activities in China. Thus, the financing of the FIEs explains why they pursue upgrading, but does not explain why they upgrade in China.

2.1.2.1 The Process of Opening China to FIEs

For the foreign firms, the state has created openness by accident as much as by design. Central-location relations determined the movement towards openness. Once the central state began to open certain locations to international trade, the central state opened the floodgates to every locale's demands to be one of the lucky ones enjoying preferential policies. The policy of openness started with the creation of just four small SEZ (Special Economic Zones) in 1979, but the opportunities for wealth generation proved too great a temptation and unleashed a spiral of demands for similar privileges and the granting of such privileges (see Table 5). The preferential policies offered economic growth through increased foreign and domestic investment, freedom from control from higher levels of administration and funds for infrastructure to the lucky locales that managed to obtain them.

Zweig (2002) argues that the opening to trade made all local officials realize that they had an interest in openness as they saw the benefits the SEZs received. D. Yang (1997) stresses the role of organized regional interests in lobbying for greater liberalization. Zweig, however, points out that expression of these regional interests was limited to sponsoring conferences and articles arguing their case. The real pressure for liberalization arose from each individual locale looking out for its own interest (D. Zweig 2002: 82). As the incentives all pointed in the same direction, the individual localities responding to these initiatives effectively exercised uncoordinated collective action demanding liberalization in the form preferential policies for foreign firms, export-processing firms and high-technology firms. High politics played a role in determining the pace to which the state granted these privileges, but after 1996, there were no serious calls to rollback the preferential policies (D. Zweig 2002).

The many government officials running various types of zones whom I interviewed during 2001-2003 admitted that in terms of investment policies China's regions have become quite similar. No particular zone or region could claim to stand out on the basis of policy alone. The interior and the coastal areas all had the same tax incentives granted by Beijing. In selling their zones, local officials stressed the ability of their zones to implement the given policies and other geographic or infrastructural advantages rather than the now quite widespread privileges granted by the central government.

The competition between locales did not end with the spread of preferential policies. As the central state placed greater and greater emphasis on the economic performance of officials, they unwittingly provided incentives for the local officials to collude with firms, foreign and domestic, by giving them unauthorized tax breaks and other illegal benefits, such as free land (NFZM, November 3 2003; D. Zweig, Chp. 2 and 3). One central government official from one of the key economic ministries (prior to the

2003 reorganization) discussed this issue at length and his assessment was that this problem was very serious but insoluble (Interview 223).

Table 5 China's Preferential Policies

Source: David Zweig, *Internationalizing China: Domestic Interests and Global Linkages* (Ithaca, NY: Cornell University Press, 2002), p. 54 Table 2.1.

Date	Policy
January 1979	4 SEZs
May 1980	Opening of Guangdong and Fujian Provinces
May 1984	14 OCCs with ETDZs
February 1985	Opening 3 river deltas
March 1988	Expanding open coastal economic area
April 1988	Hainan established as fifth SEZ
Fall 1988	Establishment of Haidian high-tech development zone as an experimental zone in Beijing
June 1990	Opening of Pudong (deepened in July 1992)
March 1991	Establishment of 21 SSTC new high-tech development zones
1992	Additional 18 State Council ETDZs established
June 1992	Opening of 28 harbor cities on Yangzi River
June 1992	Opening of 14 border cities
June 1992	11 State Council tourist vacation zones established
1992–1993	Opening of 13 bonded warehouses
March 1993	Establishment of another 27 SSTC NHTDZs
1994–1996	Inland regions receive greater authority in approving FDI
March 2000	Investors in Western China get special tax breaks under the Western China Development Strategy

The spread of preferential policies across China and the continued desire for foreign investment by all levels of government resulted in lowered requirements for entry in terms of access to foreign finance. Allowing foreign direct investment opened the door for foreign financial institutions entering China as the FIEs borrowed from them, and did not have much access to state banking system. However, foreigners as late as the early 1990s generally regarded JVs as the only reliable way to invest in China. With greater competition for FDI, barriers to operating WFOEs (wholly foreign owned enterprises) fell by the wayside and WFOEs became the norm by the late 1990s (D. Fuller 2003: 2; Sutter 2000: 2). Majority-owned JVs had already given firms the necessary corporate control to source capital from abroad without undue interference, but due to the Chinese minority ownership, these operations came with a hidden tax as the Chinese minority partners often required the JV to employ some of their workers or requisitioned funds as payoffs for the continued operation of the JV or what some Taiwanese businessmen referred to as "eating the capital" *(chi ziben)* (D. Fuller 2003). With the move to WFOEs, FIEs were freed from this hidden taxation. Without a legal framework for WFOEs, some of the FIEs would have been deterred from setting up shop or expanding their operations in China given the extra hidden costs. Furthermore, FIEs would be reluctant to upgrade the technological level of a JV due to inability to control leakage of proprietary technology.

Liberalization still had its limits. The central state's interest in starting the preferential policies was for economic development rather than an ideological attachment to free trade. Pearson (1999: 162) differentiates full integration from partial integration with the international economy. She views the Chinese government as seeking partial integration in which the Chinese state obtains the practical economic benefits of integration, but is still able to regulate the degree of integration. The central state restricts foreign firms from investing and setting up sales networks in certain sectors. For example, telecommunications services are limited to Chinese firms. A limited number of licenses for mobile phone vendors have prevented smaller foreign vendors from being able to sell their brands in China. In these areas, the local governments do not have as much leeway to find loopholes in the regulations. However, given the problems of control within the vertical ministries, loopholes can sometimes be found within the central bureaucracy itself.

The process of liberalization fueled by the demands of local governments did not make China into a regulatory free-for-all for MNCs, but it did give foreigners incentives to invest and the right to establish WFOEs, which allowed the firms complete freedom to use foreign financial sources without payoffs to cooperative JV partners. Without incentives to lure the foreigners to come in the first place and the freedom to source capital from abroad, the foreign firms with operations in China would not have foreign sources of capital that differentiate their behavior from the domestic firms.

2.2 Second Independent Variable: Operational Strategy

Operational strategy explains the difference in technological upgrading between the hybrids and regular FIEs. Firms either have China-based strategies or foreign-based ones. Firms with China-based operational strategies regard their Chinese operations as vital to the firm's core competencies. The hybrids, possessing China-based operational strategies, essentially see developing core activities in China as critical to their overall success. The hybrid's operational strategy is to treat China as the core base of its operations so the firm is intent on developing the core activities, which in the case of IT firms are primarily technological activities, in China. Thus, these hybrids have a greater incentive to upgrade their Chinese technological resources as these are the firm's core resources. The regular FIEs do not see developing activities in China as critical to their overall strategy. They do not base their choice of locating these activities in China on the belief that it is a strategic imperative to foster their core competencies, including technology, in China. Without such a belief, they, unlike the hybrids, have no preference for conducting key activities in China.

The regular FIEs, with their foreign-based operational strategies, have variable incentives to upgrading in China ranging from low to moderate while they have the same competitive pressures to enhance their competencies, including technological competencies, somewhere in the world. Their incentives to upgrade in China could be affected by a wide range of factors, such as their perception of the opportunities for cost cutting through moving non-critical technology activities to China. One firm could see lots of potential for certain activities in China and move such activities to China that contribute to China's technological upgrading. Another firm might feel that moving activities to China is not the solution and thus contribute little to China's technological upgrading. In either case, such firms fall short of the strategic commitment of the hybrid firms to develop their core activities, including technological activities, in China. The regular FIEs have at best moderate incentives to upgrade in China that lead *ceteris paribus* to at most only a moderate level of technological upgrading in China.

2.2.1 Explaining the Origins of the Hybrids' China-based Operational Strategy

The hybrid FIEs all have ethnic Chinese management.[18] This is an empirical finding of my research rather than an assumption of this project. Some concepts about firm behavior borrowed from the nationality of multinationals literature help to explain the propensity for firms with ethnic Chinese management to adopt a China-based OS.

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[18] I use management because part of the ownership of these firms is from foreign financial institutions, which may or may not be ethnic Chinese. Nevertheless, even in the case of start-ups where the majority of shareholders (the venture capitalists) are often not ethnic Chinese, the teams of managers in charge of running these firms are ethnic Chinese and have a significant equity stake. The managers sold investment stakes of their firm on the basis of their China-based strategy so there is no reason to think that the non-ethnic Chinese foreign finance will try to change the strategic orientation toward China of these hybrids. I uncovered no instances of this and I heard reports of just the opposite, foreign venture firms attracted to invest in hybrid firms precisely because these firms were "China plays." See A. Grimes (2004: B1).

The nationality of multinationals literature argues that firms concentrate core resources in their home bases. The nationality of multinationals literature grew out of empirical observations of MNCs' behavior. Empirical research has shown that firms tend to place and nurture more core activities in the firm's home base giving lie to the idea of the truly multinational enterprise (Doremus *et al* 1998; Wade 1996; Hu 1992; Hirst and Thompson 2001). Even research that bemoans the demise of national systems of innovation due to the offshoring of R&D shows that more than 87% of all corporate R&D among a large sample of the 500 largest MNCs is conducted within the home borders. This research also shows that more than 70% of overseas R&D was concentrated in three countries, Britain, Germany and the US (Patel and Pavitt 1998). [19]

The explanations for this continued nationality of the firm vary. Some argue that firms have developed competitive strengths that rely on the specific institutions of the home economy (Hall and Soskice 2001). One could also make an alternative interest-based argument on the limited information available to firms about foreign economies. Firms generally have accumulated more knowledge about how to operate in their original home base so they need to invest less time and energy in making sure these home operations run smoothly than they do in foreign operations. An ideational argument for the nationality of the firm could be centered simply on patriotism. Push come to shove,

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[19] It should also be noted that Patel and Pavitt's work was concerned about the integrity of national systems of innovation, but their main example of the strains on national systems came from Europe. Europe is exceptional in that the EU itself is arguably becoming the home market. Thus, one would expect individual European countries to have large R&D bases outside their national borders, such as Belgium with two thirds of its R&D outside of its national borders. In contrast to European countries, the US and Japan had well over 90% of the R&D in the home economy and the change from the early 1980s was not dramatic. The US has increased foreign R&D by 2.2% and the Japanese has actually decreased global R&D by .7 %. It should be noted that the main measure Patel and Pavitt used was the origin of US utility patents by the Global 500. When the actual R&D budget is examined, the US had slightly more than the average for MNCs at 11.9% and Japan had much lower than average at 2.1%. However, it is unclear if the R&D budget is a better measure than the patents. In any case, under neither metric, are the two largest national economies in the world very global in their core R&D functions.

firms are run by managers of the same nationality and they do not simply make firm decisions based on cold profit-maximizing principles if the decisions adversely affect the home economy. Another ideational argument is that firms believe that their competitive advantages are linked to distinct features of the home economy even if that belief is not necessarily correct. A third could be that they have certain ideas about the just distribution of resources within their home economy that dictate what activities should be kept at home. Doremus *et al* (1998: 16-17) combine ideational and interest aspects in their arguments of nationality of MNCs.

The connection between these ideas about the nationality of firms and the hybrids' China-based OS is not a simple assertion that ethnic Chinese firms will act as national Chinese firms. Indeed, there is evidence that some ethnic Chinese firms forcefully reject a China-based OS. Taiwan's TSMC has been quite hostile to China (see Chapter Five) and is not any less of an ethnic Chinese firm because of this anti-China sentiment. Instead of assuming all ethnic Chinese will embrace a China-based OS, what we can learn from the nationality of MNCs literature are the ways socio-cultural knowledge and ideas possessed by ethnic Chinese are conducive to adopting a China-based OS.

By drawing on their socio-cultural knowledge, ethnic Chinese firms have some of the same informational advantages in China that MNCs have in their home markets. They have lower information barriers vis-à-vis non-ethnic Chinese in understanding and operating in China. Using the language of economists, they have advantageous information asymmetries compared to non-ethnic Chinese foreigners when operating in China. The ethnic Chinese firms do not just favor Chinese operations because of socio-cultural information. Socio-culturally informed ideas influence their behavior as well. There is a nationalist/parochial component informing the decision to adopt a China-based OS for some ethnic Chinese, just as there are nationalist/parochial motivations that encourage MNCs to favor their home base.[20] Finally, there is an element of ideas influencing interest. These ethnic Chinese (perhaps due to ethno-nationalist pride) may believe there are benefits to being China-based even when these advantages do not actually exist.[21] MNCs exhibit the same attitude when they insist that certain activities must be done in the home country even when these supposed advantages are not realizable. For the purpose of this work's argument, it is not necessary to decide whether it is raw interest or ideas shaping interest that lead some ethnic Chinese firms to adopt a China-based OS. It is sufficient that either motive points in the direction of encouraging them to adopt this strategy.

There are important insights from the nationality of MNCs literature that are not applicable to the China-based OS. The institutional comparative advantages of the nationality of MNCs literature do not carry over well to the China-based OS. German firms may know how to use the German social corporatist system to generate value better than anti-union American firms do, but the knowledge residing in German firms has accumulated over time and through practice. Hall and Soskice do not argue that there is any socio-cultural element having to do with being German. Instead, these German firms

[20] For some countries, one could argue that immigrants also adopt a nationalist bias toward their adopted country, but China is not an immigrant country so the chance of this happening among non-ethnic Chinese foreigners is quite low. For ethnic Chinese, it is a different matter. There is an ideology in China regarding ethnic Chinese foreigners, so-called Overseas Chinese (*Huaqiao*), as fellow Chinese rather than as foreigners. Sun Yat-sen, the founding father of modern China revered on both sides of the Taiwan Straits, was a US citizen who learned about the Chinese revolution he supposedly started while taking a train in the middle of the US.

[21] One of the most interesting examples of imagination of economic interest as crucial to explaining social behavior, even in the face of countervailing objective economic interests, is Yoshiko Herrera's (2005). *Imagined Economies: The Sources of Russian Regionalism.*

have co-evolved with German social corporatist institutions to allow the firms to create competencies that generate value from social corporatist labor arrangements in Germany. The hybrid firms in China simply have not had the time to develop such institutional advantages. They have been in China for at most the same two decades (most of them have been in China for substantially less time) as the foreign firms—hardly enough time to co-evolve comparative advantages with local institutions. During these two decades, the local institutions themselves have changed with great rapidity because China has been in transition from a planned to a market economy. With rapid change, it would be hard to conceive firms being able to build enduring and hard-to-replicate competitive advantages based upon China's institutions.

Even if one does not accept the argument of the nationality of MNCs that firms have a preference or bias towards their home base of operation generally, the evidence in the dissertation will show that the hybrids in strategy and practice utilize China as the main base of operations and the regular FIEs do not. The evidence shows the regular FIEs to be less intensively utilizing China as a base of operations than the hybrids. As for the hybrids, their OS has several characteristics (detailed in a later section) that differentiate them from the OS of regular FIEs. None of these characteristics is simply an assertion of their supposed Chinese identity, but all the hybrids are ethnic Chinese firms.

Another way to conceive of the China-based operational strategy is to view it simply as a choice firms make to adopt a certain type of strategy that becomes in effect part of the firm's practice and embedded in the firm's organization. Rather than hybrids being basically Chinese firms with foreign finance, this conception views them as FIEs that have chosen the China-based operational strategy. Jaeyong Song (1998) argues that firms of the same nationality can have quite different strategies toward upgrading operations overseas due to their internal corporate strategies. These strategies are ones that firms maintain over time. Song documented such long-term strategies in upgrading behavior of Japanese firms in Asia. Song found that certain Japanese firms over time had a consistent international-oriented strategy that resulted in a much stronger propensity to upgrade overseas operations than co-national counterparts that did not have this international-oriented strategy.

Like the nationality of the MNCs argument, the cause might lie in either ideas or interests or some combination of the two. Firms might believe that these strategies are in the interest of the firm or pursue such strategies because of past firm practice. Alternatively, the strategies could be profit-maximizing strategies because they make best use of the internal firm competencies. Song does not explain the cause of these strategies.

The problem with Song's argument is its lack of an explanation for what is behind the adoption of a certain strategy. Empirically, not just any FIE adopted a China-based OS, only ethnic Chinese firms did. This empirical finding strongly suggests that Chinese ethnicity confers some incentive for ethnic Chinese firms to adopt such a strategy. The nationality of MNCs literature provides us with some ideas about what these motivations are whereas Song's concept of the importance of strategy does not explain the origins of these strategies.

2.2.1 Measuring Operational Strategy

That domestic Chinese firms have China-oriented operational strategies is not surprising given the empirical evidence from elsewhere in the globe that suggests the home base bias of even large MNCs (Hu 1992; Wade 1996; Hirst and Thompson 2001). Unless evidence shows otherwise (the research conducted for this thesis did not), it is safe to assume that domestic Chinese firms treat China as the home base. Determining the operational strategy of FIEs is a much more complicated task. Measuring the proportion of a firm's technology activities in China conflates the operational strategy and the variable it affects, the technology strategy. It would be tantamount to saying that firms that have more technological activities in China are more likely to upgrade, which is true but begs the question of why they have more technological activities in China.

To assess the operational strategy of the firm, a wider net must be cast. Three criteria will be used. Firms have to meet two of the three criteria to have a China-based strategy. First, the firm must have a self-described China-based strategy. Second, the firm's functional headquarters must be in China. By functional headquarters, I mean the senior management and their support staff reside in China. Finally, the ethnicity of the management/owners is a criterion. Firms with ethnic Chinese management/ownership are more likely to overcome cultural barriers to maximize the potential of China and ideologically are more inclined to create China-based firms than foreigners would be.[22] Thus, Chinese ethnicity of the management/owners is the third criterion.

I should stress that the operational strategy argument does not privilege the ideological reasons for a China-based strategy over the instrumental ones. The firms that adopt China-based operational strategies attempt to maximize their utilization of China's

[22] See the discussion in A. Segal (2003) about the entrepreneurs' motivations. They stressed that their motivation was not simply to make money but to help China.

resources because they believe utilization of these resources provides competitive advantage. The hybrid firms do not maximize the Chinese resources directly and solely out of a desire to help China. However, a China-based strategy makes more sense for those attuned to the local culture. Furthermore, it would be foolish to ignore nationalism as part of the motivation to embark on a China-based strategy because many ethnic Chinese have stated that they returned to help build a prosperous and strong China.[23] Empirically, ethnicity is a good indicator of a propensity to adopt a China-based strategy as none of the firms that met the other two criteria were non-ethnic Chinese firms.

There are in fact two distinct subcategories of FIEs that often have China-based operational strategies i.e. are often hybrid FIEs. The standards used to evaluate their operational strategy differ slightly. One type is the returnee start-up. These small-scale technology enterprises have been founded by mainland Chinese returning from abroad, sometimes in conjunction with other ethnic Chinese. These firms usually have all of their operational resources in China except perhaps for one or two high-level engineers based abroad, usually in the US. They also all share a clear publicly articulated strategy to use China's resources to create their core competencies.

The other type of hybrid is the ECE (ethnic Chinese economy i.e. Taiwan, Hong Kong and Macao) hybrid. These firms are already established in one of the ECEs and then move some operations to China. Thus, there is a bias if the returnee start-ups and

[23] I did not bring up the nationalist motivation in interviews due to the sensitive nature of talking about such topics with a foreigner, but still some of the interview subjects confided that this factor was part of the motivation. On the other hand, it is equally obvious that not all ethnic Chinese feel such strong desire to help the People's Republic of China. 38% of ethnic Chinese in Taiwan supported the anti-China candidate in the 2000 presidential election in Taiwan and just over 50% supported the same candidate in 2004. Taiwanese businessmen I encountered in China often were strongly anti-China Taiwanese nationalists. Still, for Hong Kongese and Taiwanese, the cultural barriers in China are obviously lower than they are for non-ethnic Chinese foreigners regardless of which conception of nationality these ethnic Chinese from outside of the mainland may ascribe to.

the ECE firms are measured by the same standard. As the new returnee firms have been founded at least with the idea of concentrating operations in China, these firms do not have large operations already built up outside of China when they create their China strategy. In contrast, given that these ECE firms already have established mature headquarters functions in their original home economy, it stands to reason that their headquarters are in one of the ECEs rather than China. Thus, ECE firms are not required to have their headquarters in China to be considered to have a China-based OS.

There is also a difference between measuring the self-described China-based strategies of returnee and ECE firms. Whereas the returnee start-ups must embrace a self-described China-based strategy, I only require the ECE firms to embrace a Greater China strategy i.e. they want to utilize intensely the resources of their original ECE home and mainland China. While there are examples from Hong Kong of firms simply abandoning their ECE home for China (see Chapter Four), most firms embark on a strategy to create "twin towers" (to borrow the phrase of Taiwan's Inventec) with one in China and one in the home economy. ECE firms that describe their strategies as such will be considered to have met the standard of a self-described China-based strategy.

Yet another factor is the regulatory barriers faced by ECE firms from Taiwan. The Taiwanese government forbids the transfer of certain technologies to China. This regulation often prevents hybrid ECE firms from making public their China-based strategy. For example, the Taiwanese government has forbidden IC design houses from investment in China. Although this regulation has failed to stem the flow of IC design houses to China, IC design houses from Taiwan tend to keep a very low profile. Most of them in fact change their Chinese names. For firms that are operating in China in violation of Taiwanese law, their self-described strategy may only appear in interviews with China-based management rather than a public self-proclaimed China strategy. In these cases, I will count self-described China-based strategies from interviews as sufficient.

I should stress that non-ethnic Chinese firms were held to the same criteria. However, they were not required to meet the standard of Chinese ethnicity. For established MNCs, they only had to meet the standards that established ECE firms were required to meet. For foreign start-ups, they had to meet the more stringent requirements of the returnee start-ups.

Using these requirements, one could conceivably find a non-ethnic Chinese firm that had a China-based strategy. Such a firm would simply have to have a functional headquarters in China (if a start-up) and a self-described China-based OS. My research uncovered no such firms. I did not even find a FIE with a self-described China-based strategy. The dearth of such firms gives me greater confidence that possession of a China-based strategy hinges upon the ethnic Chinese background of the firms that adopt it.

3. Technological Upgrading: Defining the Dependent Variable

How does the concept of technological upgrading used here relate to the literature on technological upgrading? Technological upgrading is a term widely used in the business press and has just as wide variation in meaning.[24] The general idea in the media

[24] A Lexis-Nexis search on January 22, 2004 revealed that the top 25 citations for technological upgrading were non-academic press reports. The academic journal citations that appeared were not in the top 25, and the academic citations contained upgrading and technological, but they did not contain the phrase

is some sort of technological improvement. Academics have used such terms as innovation, learning, leapfrogging, upgrading and catch up (often attaching the words technical or technological to these terms) to convey aspects of the term as used here. This dissertation tries to capture a number of these concepts under the term technological upgrading.

This dissertation defines upgrading as moving into either technically more difficult parts of the production (technological upgrading) or moving into higher value-added activities of the production process (economic upgrading). Production is used here in the broadest sense of all the activities that make up an industry from definition of a product to after-sales service. Technological upgrading encompasses two analytically distinct types of upgrading, learning and innovation. Technological learning means advancing into more technically difficult production activities without yet reaching the technology frontier. Technological innovation means advancing into more technically difficult activities that advance the technological frontier. The technological frontier is the most advanced technical knowledge in the world for one particular activity. For example, 90 nanometers (the lower the number of nanometers the more advanced the technology in this case) is the current technological frontier of manufacturing-ready semiconductor process technology. Firms that advance from 500-nanometer process technology to 180-nanometer technology are conducting technological learning. The firms that will reach 60 nanometers soon are conducting technological innovation as they are pushing forward the technological frontier.

"technological upgrading." The top six citations were all from Asian publications reporting events in greater China.

By conceiving technological upgrading broadly as encompassing both learning and innovation, I ensure that firms undertaking one of these activities will be counted in the contributions to technological upgrading in China. Terms such as learning, catch up and fast followership generally refer to what is defined here as technological learning. Innovation generally refers to what is defined here technological innovation. Leapfrogging often means one or the other, but conveys the sense of skipping phases of past industrializers. Upgrading as used in a recent work on economic development (Amsden and Chu 2003: 1) refers specifically to the catch up phase where countries transition from middle-income to advanced economy status as they simultaneously move from mid-tech to high-tech sectors. Technological upgrading incorporates both learning and innovation. We do not assume that one or the other is the sole key to economic development. Nor does the dissertation argue for a particular path or strategy of technological learning. Leapfrogging implicitly connotes skipping phases. Fast followership suggests building competencies by following closely behind the leading firms. In developing countries, technical learning does in fact play a larger role than innovation, which raises doubts about the utility of recent searches for innovation in China.[25] This dissertation remains open to the possibility of discovering innovation as well as learning in China. The research uncovers some cases of technological innovation though technological learning comprises most of the technological upgrading found.

[25] Two recent works, G. Gilboy (2002) and A. Segal (2003), claim to be looking for innovation in China. This research agenda is problematic because not finding innovation in a developing country does not mean that the country's development prospects are bleak (Gilboy). On the contrary, the country may be learning very quickly despite the lack of innovation. The research agenda is also problematic because innovation is often used to mean learning, which simply leads to confusion when comparing China's activities to both analytically distinct innovation and learning activities going on elsewhere in the world (Segal 2003).

Thus far technological upgrading has been described at the level of the nation, but technological activities are usually done within individual firms, universities and research laboratories. Technology activities are ones requiring technical knowledge whether that be process knowledge, knowledge necessary to carry out production, or product knowledge, knowledge necessary to design or re-design products. The research uncovered differences in the quality of technology activities at the level of the individual firm. Along with firms, I examine technology activities in research institutes as well.

I use four steps to determining if a firm contributes to technological upgrading:

1) A comparison of the firm's technology to China's general level of technology
2) A comparison of the firm's technology to the international technology frontier and to other LDCs
3) A check for the commercial viability of the firm's technology
4) A check for the embeddedness of the firm's technology.

Turning to the first step, the dissertation wants to understand in what ways China as a country has succeeded in technological upgrading, but the research gathered data from firms. How to square this circle to generalize from the firm to the nation? The dissertation measures technological activities within the firm against the standard of technology widely available in China regardless of whether or not the technology is new to the firm. Thus, I do not count as upgrading domestic firms that only manage to upgrade their technology to the Chinese average in their particular technology. The dissertation does consider foreign firms bringing technology that is more advanced than

China's general level as upgrading even if the technology is not the most advanced the firm possesses.

To give an example, if a firm moves from making shoelaces to making shoes, one could interpret this movement as technological upgrading for the firm. However, given that China has thousands of firms capable of making shoes, this intra-firm upgrading would not constitute technological upgrading for China as the technology of shoemaking is widespread. On the other hand, if an electronics firm brings to China the technological know-how to design notebook computers, this would be considered upgrading given that China has few design capabilities in this area. It would be judged as upgrading even if the firm had only brought the technology for mature generations of notebooks to China i.e. from the firm's own perspective, it was not engaging in upgrading its overall technical capabilities.

Another qualification is that the general level of technology is the general level outside of the firm. Some firms are so large relative to the size of their sector in China that expansion of their technological activities (e.g. training more workers in the same technical skills) would not be an increase in the general skill level in the relevant technology for China as a whole, but would count as an increase in skill level outside of the firm. To control for large firms, the general level of technology used to measure upgrading is the level of technology outside the firm under examination.

A nation could very well upgrade its level of technical skill, but not reduce the number of possible competitors because many other nations also were able to improve their technical skill level. One way to examine whether or not a nation has improved its technology relative to the global community is to measure if firms in that nation have narrowed the gap between their own level of technology and the international technological frontier, the most advanced technical knowledge in the world for one particular activity.

As a second step to measuring technological upgrading, this dissertation measures the gap with the international frontier for China while also attempting to make rough comparisons with other developing nations that are attempting to develop an IT industry. In this way, one can capture China's relative technological gains or losses both vis-à-vis the developed world and the developing world in order to gain a sense of where China has moved up the technological hierarchy of nations[26]. When I discover that the firm is actually lagging further behind the frontier than in the recent past, then I discount the upgrading. The reason to discount this upgrading is that this upgrading may simply part of the general diffusion of technology globally (e.g.100 years ago, few places had electricity and now it is widespread even in the developing world) and suggests China has not actually moved up the technological hierarchy of nations. I also compare the upgrading in China against the technologies of other LDCs with any significant IT industry presence to see if those countries have experienced a similar level of upgrading. My general findings are that in those areas where China has narrowed the gap with the technological frontier it has far outdistanced most of its LDC rivals. To research China's LDC rivals, I primarily used on secondary sources though some interviews offered direct evidence of the activities of LDC rivals.

[26] Moving up the technological hierarchy of nations means moving from those simple technologies that every country possesses to more sophisticated technical knowledge that are dominated by smaller and smaller oligopolies of nations and perhaps eventually to the apex of technological hierarchy where one nation monopolizes a particular technology e.g. the US monopoly in CPUs via AMD and Intel.

The third step is to determine if a firm's upgrading is commercially viable. The dissertation only counts technological upgrading that might be commercially viable as technological upgrading. By commercially viable, a firm or organization, such as a research lab, has to be able to sell a service or good embodying the technology upgrading in the marketplace and have a reasonable chance of earning a profit. This standard is lower than showing that the product or service is already enjoying a positive return because this dissertation accepts that markets are not always efficient in the short-term. With these short-term market inefficiencies, a firm with a competitive product still may struggle in the near term and firms hone their competencies over time through marketplace competition. In a developing country with many firms struggling to learn new skills, immediate profitability would be too high a bar that would cut out many potential winners from the purview of this study.

How to discern which firms' technological upgrading might plausibly become commercially viable? The method used here is a process of elimination. Those firms that have not sold a good or service in the competitive marketplace or have sold goods and services in the marketplace only at a loss over time are not considered to be commercially viable. I also eliminate those firms that have a commercial presence only through the support of state subsidies i.e. firms that without state subsidies would have had to sell at a loss in order to remain in the commercial marketplace over time. Information about subsidies is often hard to come by (especially in China), but the rule of thumb used here is that those firms that consistently sell more than fifty percent of their output to the Chinese state over time are considered to be subsidizing their commercial presence through government procurement.[27] Such firms are not considered to be competing in the commercial marketplace. This process of elimination does not discount the potential of new firms, but eliminates the obvious commercially unviable. I exclude those firms that are under one-year old and do not have any products (commercial or otherwise) from consideration because it is too hard to tell whether their failure to create products is due to their newness or incompetence.

By restricting technological upgrading to potentially commercially viable projects, I narrow the focus to technological upgrading that has at least the potential to have a positive impact on economic development. The basic assumption in the accounts on technological upgrading as a critical component of economic development in the developing world (Westphal and Pack 1986; Kim and Ma 1997) is that the technological upgrading is done on under conditions of economic efficiency. The standard of economic efficiency used may be longer-term dynamic efficiency, the net social benefits (firm profits plus positive externalities) discounted over time are greater than the net social costs (firm losses plus negative externalities) discounted over time (M. Khan 2000:50), rather than short-term static efficiency in which markets clear (price of a good and costs of production of the good are in balance) almost immediately. Thus, these accounts focus on organizations, usually firms, working to commercialize technology under the assumption that non-commercial technological upgrading, such as R&D for national

[27] Using only procurement to control for subsidies actually is setting the bar low for state favored firms because many of these firms have subsidization through loans. Unfortunately, exact information about how much state finance subsidizes the commercial losses of state favored firms is hard to find. Furthermore, the bar of procurement itself is quite low because globally few IT firms of any size sell 50% of their products to the domestic state. There are two reasons for this. First, many IT products have global scale i.e. one or two plants per firm can meet worldwide market demand (Erica Fuchs, forthcoming). Second, most IT products are direct and intermediate inputs for consumer products where the state usually is not a major customer. The major exemption is telecommunications infrastructure equipment although most countries with large telecommunications markets now have private firms competing in service provision rather than a state monopoly or state oligopoly that China has.

defense systems conducted in military research institutes, could very easily be economically inefficient.

In the context of China's great asset destroying machine of state-run banking, commercially unviable technological upgrading is even more likely to be economically inefficient. Wu Jing-lian (2002: 7) a prominent Chinese economist, recognizes the dangers of pursuing technological upgrading without concerns for efficiency in China's own state-led technology efforts when he warns:

> [A] commonly seen mistake is to consider that only high amount of R&D investment and the construction of enough large scale enterprises is enough to push speedy development of high-technology. This is the kind of mistaken concept created under the centrally planned economy. As soon as one says develop high-technology, the first thing that one thinks of is rolling out the welcome mat [of policy], creation of projects and expanding of research organizations and industrial firms. In fact, this [method] does not grasp the root of the matter. The result is that the investment is high, the efficiency is low, there is tremendous waste of precious resources, but one cannot see any big [positive] results. [Author's translation]

A firm may appear to be contributing to China's technological upgrading because its technology activities in China are closer to the technological frontier than typical for China, but this dissertation argues that this evidence alone is insufficient to prove that a firm is actually contributing to China's technological development. A firm could conceivably have operations in a developing country, but have the technology remain in control of foreign expatriates. If such a firm withdraws from its host developing country, the firm's technology goes as well. Jomo and Felker (1999) argue that Malaysia's development lags because foreign firms have not allowed technology to flow to locals. To resolve this predicament, Jomo and Felker see indigenization, the control of technology by local firms, as the only way a nation can ensure continued development.

Amsden (2000) and Chu (with Amsden, 2003) make similar arguments for other past and present developing nations. China is not immune to this problem of FIEs restricting the flow of technology. I have seen foreign firms that operate in China with very shallow technical links to the host economy.

To measure the ability of the host economy to capture technology, this thesis uses the concept of embeddedness. Embeddedness has essentially two dimensions: the channels by which a firm's technology flows to the host economy and the institutions that work to ensure that the technology once inside the host economy will continue to thrive. To measure the first feature, I look at how individual firms transfer knowledge to the Chinese economy. As for the second, the institutional feature has nothing to do with individual firms' behavior. Instead, it is a question of the larger economy having institutions that encourage continued utilization of the technical knowledge contributed to the economy by firms. I will present evidence of the existence and workings of such institutions in China in the empirical chapters. As the test for institutional embeddedness deals with the economy rather than individual firms, I consider firms that have technology channels to the host economy as having contributed to technological upgrading. In other words, there is no need to test for institutional embeddedness at each individual firm because the wider institutions in the economy determine institutional embeddedness.

Examining the first feature of embeddedness, the two main channels embedding firms' technology in a host economy are utilization of local technical personnel and local suppliers to carry out the technology tasks. Firms embed their technology only when they increase the technical knowledge of its employees or suppliers in the host country and, consequently, come to rely on the local employees or suppliers for some technology activities. Non-embedded upgrading consists of firms bringing in knowledge necessary for technology activities that are more advanced than the current domestic level, but making no effort to train local employees or suppliers to be able to take part in the technology activities.

I draw these two main technology mechanisms from the findings of the large empirical literature on technology transfer in developing countries[28] and from my empirical research in China. There may be alternative mechanisms, but I have not found any in China. In fact, I also have found little evidence of foreign firms upgrading local suppliers.

To give some examples from the research, young women from the countryside taught how to pick and place parts into a printed circuit board are not considered as being technically trained as the knowledge passed to them is very limited (they are simply taught how to put one particular component into the board or other equally simple tasks) and such knowledge is easily taught and widely available among the millions of women who have worked in electronics factories across China. Training an electrical engineer how to use EDA (electronic design automation) tools to take part in the design of manufacturing- and product-ready computer chips is considered the transfer of technical knowledge to the locals and upgrading because such skills are not common even among engineers in China. Thus, EDA training meets the standards of being upgrading and being embedded.

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[28] The literature is too large to do full justice to, but the following works detail these mechanisms: Kawakami (1996), Ritchie (2002), McKendrick *et al* (2000); Lindsey (1986); Fosfuri *et al* (2001) and Markusen (1991).

Technological upgrading has to be embedded institutionally as well. The training of local workers and local suppliers to do progressively more sophisticated technical activities alone does not guarantee that the activities will stick in the domestic economy if the firms training them leave or die. What guarantees the continued use of these accumulated technical resources in China is an institutional framework that encourages foreign investment and new firm creation. In other nations, foreign investment would not be necessary because domestic investment could finance the technology activities, but in China, domestic investment is skewed to inefficient firms with political connections. Thus, foreign investment becomes critical to investment in technological activities and new firm creation. Surprisingly, China has such a set of institutions despite the failures of China's strategic or targeted industrial policies. The Chinese central government opened up the space for local governments to attract foreign investment, and the local governments have responded with alacrity. Local governments compete vigorously for foreign investment, and shrinking the space for foreign investors would kill any chance a locale has for success. In addition to wooing foreign capital, the central and local governments in China are increasingly aware of the importance of fostering new firm creation (A. Segal 2003). In fact, local governments have come to view foreign capital as essential to the generation of new firms. Consequently, local governments have sought foreign venture capital and foreign incubators to aid in this endeavor. Finally, the central and local governments in China all want to boost exports and have opened hundreds of export-processing zones to promote this endeavor. The zones in and of themselves may be problematic for fiscal reasons (Po and Pun 2003), but they have helped to create international institutional support for continued generation of technology enterprises and activities in China by linking the firms in China with the global IT industry. The global IT industry outside of China now has set up the supply chains and concomitant infrastructure to source from China that will help to ensure that firms in China have outlets to the large global marketplace. The final chapter, Chapter Six, will provide a detailed assessment of the institutions embedding technology activities in China.

4. Returnees: The Mechanism for Upgrading

Politically structured financial arrangements and operational strategy explain which types of firms are likely to upgrade, but they do not show the precise mechanism by which firms in China upgrade. The mechanism is returnees bringing knowledge back from centers of innovation. This mechanism has been well documented in the literature on transnational technological communities. In this section, I will first discuss how returnees help firms upgrade in China.

4.1 The Role of Returnees in Upgrading

Technological upgrading occurs when firms acquire new technical skills. Several inputs play a role in this acquisition of new skills. Firms need capital to pay for the process of skill acquisition[29] and they need inputs of codified (or explicit) and tacit knowledge. Cook and Brown (1999: 381) nicely frame the distinction between explicit and tacit knowledge in their review of the literature on tacit knowledge, "[E]xplicit knowledge is treated as knowledge that can be spelled out or formalized, and tacit knowledge as that associated with skills and 'know-how.'" Codified or explicit

[29] Some may argue that a firm can receive technology for free by learning from another firm. However, even in such situations when a lead firm transfers technology to a supplier, the supplier incurs costs to learn the technology in terms of man-hours spent and machinery acquired.

knowledge is embodied in blue prints, manuals and capital equipment, but codified knowledge by its very nature is generally available to those with the money to buy it, so relying on codified knowledge alone does not separates one's firm from the multitude of would-be competitors.

In the IT industry in particular, a number of authors (Bresnahan, Gambardella and Saxenian 2001 hereafter referred to as BGS; Saxenian 2002; Saxenian and Hsu 2002; Ernst 2004ab; Saxenian and Li 2003) emphasize that tacit knowledge is the critical knowledge needed to thrive in the sector. BGS view the common key to the success of Ireland, Israel, India and Taiwan in the IT industry as a process of knowledge acquisition in which educated local workers acquired tacit knowledge. According to BGS, these societies originally had electrical engineers and computer scientists, but these engineers needed to acquire the tacit knowledge beyond the electrical engineering textbooks. The engineers gained tacit knowledge from training within the local branches of MNCs and from returnees from established clusters of the IT industry, such as Silicon Valley.

The precise mechanism of technological upgrading in this dissertation is the transfer of knowledge carried out by ethnic Chinese technical personnel (the returnees) and other technical personnel from abroad (though in both numbers and importance the ethnic Chinese predominate). This transfer of knowledge can be carried out in conjunction with other important inputs, such as importation of the necessary capital equipment for a given task, but it is the transfer of the knowledge that is the critical factor to achieve the process of technological upgrading. Capital equipment can be imported and let sit idle because of insufficient knowledge of how to operate it. The technical personnel from abroad transfer those tacit skills that cannot be easily transferred other than by the means of practice of the skill under the supervision of those who possess the skill. If such skills were easily codified, then bringing in skilled technologists to train workers would not be necessary for the transfer of these skills. Without cookbooks of codified knowledge, real people honed in the given tacit skills are necessary to guide along the green recruits into the mysteries of the particular skill as Teece, Pisano and Shuen (1997: 277-78) have observed:

> Only in those settings where all the relevant knowledge is fully codified and understood can replication be collapsed into a simple problem of transfer...Indeed [,] replication and transfer are often minimized if investments are made to convert tacit knowledge into codified knowledge. Often, however, this is simply impossible to do.

The returnee scholars (BGS2001; Saxenian and Hsu 2002; Saxenian 2002; Saxenian and Li 2003) emphasize that the knowledge provided by returnees from centers of innovation is not simply technical knowledge. They emphasize knowledge of the relevant marketing skills, contacts, capital, and information on new opportunities and new markets (Saxenian 2002: 189; BGS 2001). Returnees do not just provide a single lump sum contribution of knowledge to the local economy. They also create transnational technological communities that serve as conduits of tacit knowledge from centers of innovation in the developed world. These communities are networks of technologists connecting the returnees to technologists in industrial clusters abroad. These networks serve to renew and refresh the knowledge of the returnees and pull local technologists into these networks. Without continual contact with those involved in industry abroad, the returnees' knowledge of technology, markets and contacts might become obsolete. The returnees do not monopolize these connections, but share them with locals in their network of associates, partners and employees to realize mutual benefit. Improving the knowledge of their local business network helps the returnees as much as it does the local technologists.

I build on the conception of the returnee networks bringing a whole array of information and skills to the local economy, but I emphasize the centrality of one bundle of assets, the technical and quasi-technical managerial skills brought to China by technical experts (primarily returnees), to the process of technological upgrading. This emphasis emerges as a finding of the research rather than a prior assumption of centrality of technical knowledge to technological upgrading.

If returnees are the key to the mechanism of technological upgrading, what explains their interaction with the different types of firms found in China? I did not attempt to conduct a comprehensive survey of returnees' motivations, but the interview data revealed that very few returnees chose to go to neglected domestic firms. Also, many returnees interviewed offered their views on why they and other returnees would choose one firm over another. Inductively inferring from the interview data showing a lack of returnees in neglected domestic, I found two factors critical in determining which firms returnees join. These inferences were bolstered by interview subjects' own evaluations of their own and fellow returnee's choice.

The relationship of the different types of firms to the state explains both which firms returnees go to and which firms can effectively utilize the returnees. Returnees face the choice of which firm to enter to when they return to China. Their decision is influenced by two factors: ability to retrieve their wealth if the firm becomes successful and the initial prospects of the firm. Simply put, returnees want to join firms from which they can receive some of the revenue they helped to generate, and they want to join firms they believe will have a chance to be successful. Neglected firms are cut off from access to capital so their prospects are not good, and it is hard for these firms to list on the stock market so the chance of the returnee being able to retrieve his wealth is not high. The state controls both access to finance through the state banking system and access to the stock market through its approval mechanism. Thus, the state has structured the system to neglect these firms and thereby makes them unattractive to returnees. The other three types of firms (domestic favored, hybrid FIE and regular FIE) offer better prospects because they have access to capital, and they offer a way to retrieve capital through share distributions and stock listings.[30]

An earlier study of the choices of returnees over the course of the 1990s (based on surveys done in 1992, 1995 and 1998) actually found slightly more returnees returned to domestic enterprises than foreign ones (X. Liu 2001: 204-206).[31] This study does not differentiate between types of domestic enterprises. Given the low status of private and even collective enterprises in China throughout much of the 1990s, it is unlikely that the returnees were going to domestic enterprises that were not state-owned i.e. favored domestic enterprises in my typology. My findings differ somewhat from this early study. I uncovered a significant number of returnees across the hybrids, regular FIEs and

[30] Until this year, both FIEs and Chinese domestic firms were restricted in their ability to grant employees stock. They were prohibited from giving employees equity in firms listed abroad (including Chinese SOEs listed abroad) though this restriction was easily circumvented. SOEs could issue stock from domestic listings to employees, but the stock could not be sold outside the firm. Even this seemingly onerous restriction could be circumvented by setting up companies in Hong Kong without approval for listings by the Chinese state (the so-called red chips) and then granting employees (usually only upper management) stock from these firms.

[31] The data presented in Liu Xielin's work for returnees in 1998 actually shows most returnees returning to non-commercial organizations, such as universities (44.1%) and research centers (14.1%). Slightly less than a third went to commercial enterprises in all three surveys (1992, 1995 and 1998).

domestic favored firms though the FIEs generally attracted more returnees than the state firms. The difference may be a time lag effect. During the 1990s, there were not many foreign or hybrid firms pursuing technology activities in China, so the realistic alternative for returning technologists was state enterprises. In any case, my research found that favored domestic firms attracted enough returnees to make technological upgrading a possibility.[32]

One can overlay this typology of inputs (capital, codified and tacit knowledge) necessary for technological upgrading onto the typology of firm types (Table 5) in China. The neglected domestic firms are starved of capital and thus cannot acquire even much of the codified knowledge such as capital equipment let alone attract or buy offers of cooperation with MNCs or entice returnees to join their firm. The three other types of firms have capital so they can presumably attract or buy inputs of tacit and codified knowledge.

If the returnees from abroad are the key mechanism of upgrading, then what differentiates these three types of firms is their utilization of returnees. In turn, their relationship to the Chinese state affects their ability to use returnees effectively. The favored domestic enterprises suffer from bureaucratic management, general inefficiencies and disincentives to upgrade that prevent them from effectively utilizing the returnees.

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[32] There are two reasons that domestic favored firms have had reasonable appeal beyond a simple economic calculus for returnees. The patriotic appeal of working for what some returnees regard as the truly Chinese firms was mentioned by several returnees who spurned FIEs to go to work for domestic firms (Interviews 147, 267). The other appeal is the appeal of working for a member of the *guojia dui* (national team) of firms promoted by the Chinese state. This appeal contains a more complex political calculus that the Chinese state will regulate the market to ensure that these firms win out over foreign competitors in the end so it is an economic calculus but one that incorporates a belief about the importance of political connections for success in China.

The dissertation presents many examples of how returnees or other technical personnel from abroad have been underutilized by firms suffering from the curse of state favor.

Table 5 Access to Inputs of Upgrading by Firm Type

Inputs \ Firm	Favored Domestic	Neglected Domestic	Hybrid FIE	Regular FIE
Finance	Yes	No	Yes	Yes
Codified Knowledge: capital equipment, blueprints, manuals	Yes	No	Yes	Yes
Tacit knowledge: training from returnees or in MNCs	Yes	No	Yes	Yes

The FIEs operate under harder budget constraints and thus escape the inefficiencies engendered by state favor. Thus, they are better able to utilize the returnees that come their way.

5. The Dog That Didn't Bark: Strategic Industrial Policy in China

Strategic industrial policies are those policies to shift resources to a particular sector in order to achieve outcomes that are economically efficient for the economy as a whole (H. Chang 1994: 60).[33] Efficiency can include dynamic efficiency in which the net social benefits outweigh the net social costs over time in addition to static efficiency where the immediate benefits outweigh the immediate costs (M. Khan 2000: 50). The revisionist political economists of development, including some economists[34], expect or

[33] This definition paraphrases Ha-joon Chang's (1994: 60) definition while omitting the perception of the state from the definition, as the state could perceive something as efficient that is in fact not efficient.
[34] H. Chang (1994), M. Khan (2000), Aoki *et al* (1997) and Stiglitz (1998) are some of the economists who argue that such policies are feasible and helpful for development.

advocate such policies as part and parcel of the process of successful economic development. The fact that China has been able to upgrade technologically in the IT industry without successful strategic targeting policies is even more surprising. One would expect developing countries to pursue industrial policy in the IT industry as part of an effort to move out of low-technology sectors and into technology intensive ones. Mathews and Cho (2000) examined successful cases of developing IT in East Asia and found similarity in state strategic industrial policies to foster the industry despite differences in the precise mechanisms used. Where then is the strategic industrial policy in China's IT industry?

If China does not have successful strategic industrial policy, it is not for the lack of trying. Many cases of failure will be addressed in the body of the dissertation. In this section, I will present an overview of the failure of China's strategic industrial policy. From a broad policy perspective, as early as the 1960s, foreign scholars (F. Schurmann 1968) identified what the Chinese called the *tiao tioa kuai kuai* jurisdictional conflict between the vertical lines of the authorities descending from the central ministries (*tiao tiao)* and the horizontal lines of authority emanating from the regional or local governments (*kuai kuai*). The central Chinese state has a very hard time establishing priorities (Lieberthal and Lampton 1992) and the horizontal authority versus vertical authority conflicts undermine any priorities established. On top of these already severe control problems is what Lu and Tang (1997) call the soft authority constraint meaning that Chinese officials interpret and stretch the laws any which way to suit their desires.

As for the regulation of economic activity in China, the general picture is a grim one of a China in which state actors collude with private ones for rent-seeking rather than wealth creation. Gilboy's (2002) China is one in which particularistic networks vie for spoils from the state. Yi-min Lin (2001) tends to agree with Gilboy. He depicts the Chinese economy as full of state agents and private actors engaged in a horse-trading state favor for personal gain. Although, these detail rich narratives do depict the malfeasance in the system, Huang (2003) and Whiting (2001) both convincingly show through more aggregate level data that the state does not eventually favor all firms equally (the outcome of Yi-min Lin's account) nor intermittently favor firms, the presumed outcome of particularistic networks continually vying against each other for state resources in Gilboy's account. Instead, Huang and Whiting show the state consistently steering resources toward a favored set of firms while ignoring most of the private sector. Collusion exists, but the collusion takes place between a relatively defined and stable set of participants. Particularism exists, but it is consistent particularism. This prevents the state from disciplining firms that do not meet the expectations of the industrial policy by cutting off their credit. Even if Lin and Gilboy are correct, the outlook for conducting industrial policy is bleak. The incentives meant to encourage certain behavior will be given to the highest bidder rather than to the firm with best performance.

In the area of strategic industrial policy, the consensus is even stronger. Recent accounts of strategic industrial policy (T. Moore 2002; Huang 2003; D. Zweig 2002; D. Perkins 2002) in China describe the Chinese state's deficiencies in carrying out such policies. Huang (2003:138-140) points out two severe problems with the state's management of industrial policy as regards the favored firms, which in his account consist solely of SOEs. Harkening back to the problem of priorities, Huang finds the state has many goals and maximizing firm profits is not the exclusive goal. Compounding this problem of multiple goals, the state does not have an accounting mechanism to reconcile the different and conflicting goals. Chinese SOEs also violate the efficiency condition that the owner of the rights of control also be the owner of the rights of revenue. The rights of revenue do not belong to the officials controlling the firm or managing the state-owned banks and the officials bear none of the financial consequences if the revenue streams disappear or turn negative. In short, the state officials have no incentive to monitor the firms' properly, and do not have the incentives to discipline firms to achieve static efficiency let alone the greater capabilities needed to monitor firms to ensure dynamic efficiency.[35] A consequence of these dynamics is a tendency to regard heavy capital investment and investment in physical technology in and of themselves as the solution to firm problems and a corresponding de-emphasis on developing better business strategies and the knowledge and training needed to utilize the technology (Huang 2003: 224-225).[36] Steinfeld reported finding a similar phenomenon where SOE mangers repeatedly complained about the severe lack of capital (*ziben ji bu zu*) as their core problem despite the fact that they were in precisely the type of firm that had access to capital.[37]

Zweig's analysis of the policies of economic openness for rural TVEs exemplifies the problem of local governments undermining central government industrial policies. In this particular case, the local governments undercut the central government's efforts to

[35] M. Khan (2000: 50-53) points out that developing countries need to award subsidies for learning before firms will take up that task so the capabilities needed to monitor the firms over time are that much greater as the rewards are given out prior to firm performance.
[36] Gilboy (2002) found exactly the same type of mentality among Chinese mangers he interviewed.
[37] Epoch-IPC Globalization Conference, July 2000, Taipei, Taiwan.

limit foreign access to Chinese markets as part of an infant industry strategy. In reference to a county in Suzhou, Zweig (2002: 153) states, "...officials in Zhangjiagang sold out the national interest and became a transnational linkage point through which foreigners accessed China's domestic market on more favorable terms than the central state preferred." Zweig presents another example involving the state's foreign trade corporations. Rural industries worked with horizontal state organizations, the foreign trade corporations, to approve JVs that circumvented state controls on trade, controls designed to protect domestic industry (Zweig 2002: 160).[38]

Moore's (2002) *China in the World Market* analyzes the deficiencies of the China's industrial policy capabilities more comprehensively. There are two main problems that prevent China from following the path of state-interventionism of the East Asian Trio (Taiwan, Korea and Japan). He argues that the nature of government-industry relations (he purposely avoids government-business to emphasize the public ownership of many of the business in China) and the organizational structure of the state are powerful restraints to implementing strategic industrial policy successfully.[39] Moore (2002: 285-286) suggests that Chinese government-industry relations are marked by industrial paternalism in which state agents take care of the firms under their purview rather than

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[38] This outcome was negative in the sense of the state being unable to pursue an effective infant industrialization strategy and the inability to have continued leverage over local firms once they allied with foreign business. Zweig (2002: 157-158) quotes P. Evans (1995: 16) approvingly on this point of the local firms selling out state-generated rents for rents in terms of technology and global market from their foreign partners. Evans' judgment is that this arrangement will lead to a developmental dead-end. On the other hand, Zweig also finds that the circumventing of the foreign trade corporations' control over exports was economically efficient though the control of exports is not good strategic industrial policy in any case. Rather, this policy of restricting exports during the 1980s shows the problems of trying to conduct strategic industrial policy while dealing with the legacies of the socialist planned economy, in this case the legacy of the idea that international trade on open markets was inherently exploitative and to be avoided.

[39] Moore calls strategic industrial policy administrative guidance as he borrows from C. Johnson 1982. He emphasizes the same key concept of policy shifting credit towards promoting competitive industries (Moore 2002: 286-87).

exercising discipline over them. With soft budget constraints, there is dual dependency with the state agents exercising paternalistic tendencies toward the firms and the firms demanding such paternalism. Borrowing from Kornai, he argues such paternalism can only be broken by instituting hard budget constraints. Without bureaucrats subscribing to the more universalistic principles of developmental discipline, coherence and discipline of policy cannot be maintained in the face of the desire to protect one's network in China. In terms of state structure (Moore 2002: 279-281), fragmented authoritarianism prevents China from pursuing policies requiring coordination across the relevant bureaucracy. Central control over a single vertical hierarchy of a ministry is difficult enough let alone coordinating control across ministries and localities.

Moore's review of a range of major state initiatives targeting specific industries concludes that the results have been poor across the board (Moore 2002: 302-305). The basic problem is the inability to "impose strict performance requirements and other disciplinary measures as a condition of government support (Moore: 305)." Moore ventures the hypothesis that the industries that lag furthest behind are precisely those previously targeted by the government though he concedes he may be overstating the case. He suggests that perhaps the government endangers successful industries by co-opting them, but he subsequently backtracks to talk about the danger of the state showering favor on specific firms, the good firms gone bad scenario mentioned in Section 2.1 of this chapter.

Reviewing the potential for industrial policy in China and Vietnam, Dwight Perkins reaches similar conclusions. Perkins points out the obvious but overlooked fact that China's immense size creates difficulties in managing industrial policy. Contrasting it with Park's Korea in the 1960s, Perkins notes that negotiating with enterprises in China would involve thousands not dozens of participants as it has in Korea. He sees three other general reasons why neither China nor Vietnam could successfully implement strategic industrial policy. The tradition of central planning means the bureaucracy in these countries is geared towards commandism (orders backed up by direct control of inputs) rather than strategic guidance that makes use of the market forces and the private sector as well as the state. Political interference in economic decision-making prevents industrial policy from being implemented as planned. Finally, corruption is rife in both countries at levels not seen during the heyday of Japan's MITI or Park's Blue House in the 1960s and 1970s.

Thun's forthcoming work examines the results of Chinese industrial policy in the auto sector. He is principally interested in explaining regional variation across China. Thun argues that Shanghai has been able to become the dominant source for auto parts for foreign assemblers in China. He believes that the key to Shanghai's success lies in local state policy. However, Thun does not view this cultivation of Shanghai's auto parts base as an industrial policy success story if the standards used to judge it are those of embedded technology upgrading. Shanghai's principal suppliers are all JVs with foreign partners and the generation of technology remains in foreign hands abroad. The JVs themselves are capable of making the requisite current parts models but they are not able to generate the next models themselves. Simply put, the critical technologies have not been captured by local firms or local personnel in foreign firms.[40]

[40] This paragraph is based on a discussion with Professor Eric Thun concerning his forthcoming book from Cambridge University Press.

Are there major challenges to these arguments about the Chinese state's incapacity to conduct strategic industrial policy? There is only one recent academic work[41] that broadly champions the use of strategic industrial policy in China, Peter Nolan's *China and the Global Business Revolution.* Nolan does argue persuasively that many domestic Chinese firms are weak compared to the global lead firms across a wide set of industries. He argues less persuasively that the source of some of this weakness is neglect from the Chinese state. This neglect is common among private firms, but Nolan mostly concentrates on large firms that are regarded as members of the national team (*guojia dui)* of supposed industry champions. These are precisely the firms that are at the top of the political pecking order of firms. However, in calling for strategic industrial policy to rectify this situation, Nolan does not offer hard evidence that such a policy has worked. He offers the case of an aerospace firm as a potential winner that the government abandoned and he argues that one SOE steel conglomerate has exhibited a lot of potential through state support. In Steinfeld's *Forging Reform in China,* state support for these SOEs is precisely the path to perdition, as continued lavish support undermines any incentives to continue to improve firm performance. Nolan agrees with the pessimist revisionist arguments that development is well nigh impossible if one does

[41] There is a growing literature on the economic policies of Chinese localities and some of this literature makes broad claims about local state capacity. However, none of these claims really constitutes strategic industrial policy as we have defined it. Belcher and Shue (2001) go so far as to say that there is a local developmental state in China, but their example really consists of state provision of public goods and does not include state-led upgrading of the industrial structure of the locality from lower technology to higher technology industries. Similarly, the local state corporatism literature exemplified by Jean Oi (1999) primarily focuses on localities that originally owned as well as managed their local firms. These localities did not pursue strategic industrial policy in the sense of getting the prices wrong to upgrade industry. Rather, the TVEs (township and village enterprises) of these locales conformed to the market signals sent by the wider economy. Finally, these works focus on such a low level of government, county level and below, that it is unrealistic to expect these governments to muster the necessary resources to upgrade the industrial structure of the local economy in a significant manner. The fact that no serious IT industrial projects have been undertaken by the local governments at the county level and below suggests that they are indeed too financially strapped to do so.

not pursue strategic industrial policy, but he disregards the notion that such industrial policies require state capacities for coordination and monitoring that are not widely available to all developing nations (Haggard 1990; M. Khan 2000; P. Evans 1995). While presenting a passionate description of the odds stacked against developing firms in international competition and containing rich narratives derived from Nolan's deep knowledge of Chinese firms, Nolan's work does not analyze the problem of China's capacity to conduct industrial policy. Fortunately for China, the choices are not as stark as Nolan presents. This thesis provides accounts of development without successful state industrial policy.

6. Industry Selection: The IT Industry as the Case

There are several reasons for selecting the IT industry as a case. The IT industry is both a representative case and a critical case. By representative case, we mean a case that potentially represents a wider number of similar cases. A critical case is one that has broad implications despite not being representative. A critical case can be one in which the previous theories predict the polar opposite outcome from the actual one. Or a critical case can be one in which the case itself is of such great import that its singularity by no means diminishes its importance.

The IT industry is a representative case of a growing number of industries that are modular (the production chain is segmented into narrow functions) and have rapid technical change. As I will examine in Chapter Three, there is growing evidence that firms in the developing world can take advantage of these industry attributes to become important players in the modularized industrial production chains of these industries.

These opportunities to become major firms within the industrial production chains, in turn, offer developing countries opportunities for economic development (Sturgeon and Lester 2003; Ernst and Kim 2002). Thus, if China can develop the IT industry in this manner, perhaps China and other developing countries can develop a number of other industries in the same way.

The IT industry is also a critical case for two reasons. First, the IT industry is considered one of the critical technologies or general-purpose technologies of the current era (Dahlman and Aubert 2001; Yusuf and Evenett 2002; M. Trajtenberg 2002; Steil *et al* 2002) and important for the development of future technology areas based in part on IT technology (Miranda-da Cruz 2002; Anton *et al* 2001; M. Trajtenberg 2002). It is also a critical case because China experienced upgrading without successful state industrial policy, which is contrary to most theories of development, such as those of the GPN School and the revisionist political economists. State neglect of this sector is highly unlikely to be the cause of the failed industrial policy. The IT industry is one of the Chinese state's pillar industries, industries the state considers most important to develop, and an industry that the Asian neighbors China usually looks to emulate (Korea, Taiwan and Japan) (Moore 2002: 303)[42] have developed successfully. Examining this area may reveal much about how Chinese state policy affects industry.

7. Domestic Firms and Foreign Firms

The division between foreign and domestic firms is not as absolute as I have presented it. A more appropriate terminology might be foreign-linked and domestic-

[42] Moore claims that China usually publicly does not want to emulate Taiwan, but that simply is not true in the IT industry.

linked firms because in the course of research I discovered a few cases of foreign registered firms linking up with the Chinese state and one case of a domestic firm that was in the process of receiving venture capital which would turn it into a FIE. In the cases of FIEs linking up with the Chinese state's capital, these firms suffered the same ill effects of the state's favor as domestic firms. In the case of the one neglected domestic firm discovered by the foreign venture capitalists, the firm acted like and eventually became a hybrid.[43] The firm had a China-based strategy, but the venture capitalist wanted foreign registry and a future foreign IPO in order to be assured of being able to exert control over its investment. As these cases are exceptions to the general population of firms, I will refer to foreign-linked and domestic-linked firms as foreign and domestic firms.

8. Alternative Explanations

Other than the explanation offered here, what other explanations could exist for the differences in upgrading performance among firms in China? The literature does not address my argument directly because my typology of firms is different than any in the literature, but some scholars offer plausible counterarguments.

8.1 Tax Favoritism for FIEs

This dissertation accepts the general premise of Huang (2003) that many private firms are kept down by the state and the ones favored by the state are not performing well

[43] The actual story behind this firm is more complex. The VC appears to have only gained interest in the firm when foreign-based technologists were willing to provide the firm with technology inputs and when the VC realized it could take the firm's human capital and place it in a new foreign-registered firm. Without the access to a foreign technology firm, the VC would not have been interested in investing in this local firm.

due to this favoritism. Others (J. Fu 2000) would go so far as to argue that foreign firms have received excessively beneficial treatment by the Chinese state, particularly in the area of taxation. Simply put, the domestic firms are being taxed to death or at least to innovative inertia while the foreign firms receive all sorts of tax breaks. Huang (2003: 87-89) acknowledges that the FIEs have received more generous treatment than local firms historically though he also notes that reforms in the tax treatment of domestic enterprises have decreased this bias.

The main counterargument is that is simply not true. FIEs may on paper still have slightly favorable terms of taxation but the reality of effective taxation (the percentage of profits actually paid in taxes) is actually in favor of domestic firms. Domestic firms have a lower effective tax rate than foreign firms (Eun Choi, forthcoming). The second problem with this argument is that the nationality of firms in the technology sector does not seem to matter. The technology firms examined in this dissertation more often than not have benefited from a variety of preferential tax treatment regardless of their nationality. My visits to more than thirty different industrial zones, parks and incubators in China indicate that the foreign firms and domestic firms both enjoy low rates of taxation. In none of these zones were the preferential policies limited to foreign firms. In some of the zones, local firms actually predominated. Third, as Huang (2003: 89) has pointed out, the enterprises favored by the state have received preferential financial treatment far outweighing tax disadvantages. Finally, the few foreign firms that have become state favorites have exhibited the same poor upgrading performance as the favored domestic firms. Their tax status does not account for their poor performance.

8.2 Technological Level of the Firm: The FIEs' Higher Level of Technology Determines Their Higher Contribution to Upgrading

One could plausibly argue that foreign firms contribute more simply because these firms generally have more technology than local firms. However, many of the hybrids, the very firms at the forefront of upgrading in China, are brand new firms. These firms do not have an archive of technology. The only technology they have is the tacit knowledge brought by the employees and codified knowledge that they buy. Thus, they are not at an advantage over state favored firms that lure those with tacit industry knowledge and have the means to buy codified knowledge. Nor are the newly founded hybrids at an advantage against large regular FIEs in the same industry segment. If it were simply the technology embodied in the firm, one would predict that the large regular FIEs in the same industry segment would contribute far more to technological upgrading than the hybrid newcomers. In reality, hybrid start-ups generally contribute more to upgrading than the regular large FIEs in terms of the level of technology and often even in terms of local technical staff trained despite the much smaller size of most hybrids.

8.3 Ethnic Network Argument

A third counterargument is that ethnic networks determine which firms upgrade in China. One could imagine such an argument as an extension of Hsing's (1998) magisterial work on the importance of ethnic connections for the operations of Taiwanese firms operating in southern China.[44] This dissertation recognizes the role of ethnicity in recognizing the role of returnees and firms from ethnic Chinese economies, but ethnicity alone does not determine the upgrading outcomes. If Chinese ethnic connections were all that was required for upgrading, then the domestic firms would be on an equal footing with the returnees and the ethnic Chinese from abroad. Finally, there would be no differentiation between those ethnic Chinese firms that were simply regular FIEs and those hybrids that adopt a China-based operational strategy.

8.4 The Sheer Weight of the Foreign Sector

Another plausible counterargument is the relative weight of foreign firms. The FIEs dominate the Chinese IT industry sector in aggregate value of production so it would be natural that they would contribute more to China's upgrading. The problem with this argument is that it ignores the fact that the majority of production value of the IT sector in China is in low technology manufacturing in both foreign- and domestic-owned plants.[45] If one looks to the areas where significant upgrading has taken place, such as ICs (integrated circuits), only in the last five years has there been significant foreign firm participation after years of local firm dominance. Thus, in the truly technology-intensive segments, the playing field is much more level than the aggregate statistics on production value would lead one to assume.

[44] For a more popularized account of the importance of Chinese networks, see Weidenbaum and Hughes (1996).

[45] One indicative fact of the low technology, assembly-intensive nature of most of Chinese IT production is the low value-added of consumer electronics production in China, which is estimated to be as low as 15 percent (FT, May 24, 2005: 17).

8.5 The Returnees as the Only Determining Factor

One could argue that the only factor that really matters in determining contribution to upgrading is the number of returnees flocking to firms of a certain type. The FIEs have been able to attract more returnees than the domestic firms and this attraction determines their success. There are several problems with this argument. First, the returnees regularly went to domestic enterprises more often than domestic ones throughout the 1990s based on survey evidence for returnees in 1992, 1995 and 1998 (X. Liu 2001: 204). If returnees alone were the key, then one would expect better performance from domestic firms than from FIEs during the course of the 1990s. The research for this dissertation was primarily from post-1998, but one would expect some of the better performance due to greater numbers of returnees in domestic firms to continue, especially since the critical role of returnees is to train local engineers within the firms they enter. Moreover, to explain the lack of upgrading by domestic firms despite the fact that returnees initially preferred them, the argument would have to assume some sort of tipping point. The explanation would be that returnees went to local firms, but they simply did not go to these firms in sufficient numbers to create technological upgrading. Many of the successful contributors to China's upgrading were in fact small firms with only a handful of returnees so the tipping point argument is implausible. Even for firms of a larger scale, such as IC foundries, evidence from the development of Taiwan's foundry industry suggests that the level of returnees needed is not large. Taiwan simply recruited a few technical people over to Taiwan each time it needed to move to the next generation of wafer processing (D. Fuller 2005).

Other evidence also suggests that something beyond recruiting the returnees is critical. Some returnees interviewed, who had worked for very unsuccessful local firms and achieved little, then went on to contribute greatly to China's technological future. For example, one of Lucent's consultants charged with the task of transferring both IC design know-how and management skills to Huajing, an unsuccessful state firm, then went on to train engineers in IC design and product design skills in two FIEs, one of them one of the few major IC firms with design activities in China and the other his own startup. In each case, he operated with only a handful of other returnees. In the two foreign cases he succeeded whereas in the state favored firm he failed to achieve much.

Finally, there is the problem that this returnee-only explanation fails to differentiate between the performance of the hybrids and the regular FIEs. Both sets of firms were able to attract returnees in large quantities, but as this dissertation will demonstrate, one type of firm contributed more to technological upgrading.

9. The Structure of the Thesis

Chapter Two will review the literature on development under globalization. Chapter Three will present a study of the implications of the IT industry's structure for development. This chapter will argue that the modularity and rapid pace of technical change in this industry offer real possibilities for development and these possibilities may emerge across a widening span of industries. Chapter Four will examine the Chinese IT hardware end product segment, primarily telecommunication and computer equipment. This chapter will offer evidence for the greater contribution of FIEs, particularly hybrids, to technological upgrading. Chapter Five will look at the Chinese integrated circuit (IC) industry, as ICs are one of the core technologies of the IT industry. Contrary to expectations, this core technology area is the one where the most upgrading has occurred in China. The upgrading in ICs has occurred almost entirely in hybrid FIEs. This chapter provides more robust evidence of the superior upgrading performance of hybrids over regular FIEs than offered by the hardware end product segment covered in Chapter Four. Chapter Six will consider both the sustainability of the differential behavior (will hybrids continue to outperform other FIEs and will FIEs continue to outperform domestic firms) and the sustainability of the institutions that help embed the technological upgrading in China.

<u>Chapter Two</u>

The Three Worldviews of Globalization and Development

1. Introduction

John Williamson, an economist in the Institute of International Economics, coined the term Washington Consensus in 1989 in the wake of the policy discussions of how to deal with the Latin American debt crisis of the 1980s. Yet, the neoliberal ideas of free trade, private enterprises and fiscal discipline (which in practice means smaller government) encapsulated in the Washington Consensus were already gaining adherents in the international financial institutions (IFIs), such as the IMF, during the 1970s. The rise of neoliberalism led by Reagan and Thatcher in the 1980s resulted in the triumph of Washington Consensus ideology before it had even acquired this name (A. Escobar 1995: 93; Stiglitz 2002: 13).[46] Williamson simply created a new name for the already coherent neoliberal ideology of development embraced by the IFIs.

The Washington Consensus was not just a direct reflection of the demise of Keynesianism and the rise of neoliberalism in the West (A. Escobar 1995). The Washington Consensus was also a critique of a set of import-substitution industrialization (ISI) policies adopted by a large part of the developing world in the post-war period. Developing countries from Latin America to South Asia were all concerned about the problem of economic dependency, the unfair terms of trade for non-industrialized goods and perpetual lack of industrialization that they thought inevitably went hand-in-hand with free trade. Neoclassical economists pointed out that ISI policies actually

[46] Escobar argues the clear turn toward the Washington Consensus should be dated from Reagan's "magic of the market" speech at the North-South conference in Cancun in 1981.

exacerbated the very terms of trade problems that concerned developing countries (Fishlow 1985). Economist also pointed out that ISI policies routinely failed to encourage the superior rates of growth that they were supposed to achieve even as they created enormous and enormously inefficient rents captured by local business groups (Balassa 1981: Krueger 1974; Krueger 1990; Bhagwati and Desai 1970). In spite of the rise of neoliberalism, the dependency theorists, who trace their intellectual roots to the thinking of Prebisch and Baran among others[47], continued to argue that the problems of the developing world were still due to dependency on the industrialized core of advanced economies. Whatever industrialization had taken place in the developing world, it had been in conjunction with and dependent upon international capital so the result was still dependency (Cardoso and Faletto 1979; Amin 1976; Evans 1979).

Despite the growing intellectual and political power of neoliberalism, a different set of ideas concerning development were gaining prominence at the same time. Rejecting both the pessimism of dependency theory and the free market prescriptions of neoliberalism, these revisionist ideas favored state involvement in managing and guiding economic development. The revisionists, drawing upon earlier work by List (1885) and Gerschenkron (1962), believed that the state could intervene to shape the very industrial structure of the nation and even individual firm strategies. Using country case studies, Chalmers Johnson (1982), Alice Amsden (1989) and Robert Wade (1990) demonstrated that Japan, Korea and Taiwan, respectively, were practicing state-led development during their economic miracles rather than following the neoliberal proscriptions of the IFIs.

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[47] The intellectual roots of dependency are contested. Escobar (1995:81-82) suggests that Baran contributed more and CEPAL (Economic Commission for Latin America) under Prebisch contributed less to dependency theory whereas Evans (1979: 26-27) suggests that Prebisch, Baran and many others were the intellectual progenitors of dependency theory.

In the following decades, revisionist scholars added nuance to this state-led explanation. Starting with Thomas Gold's *State and Society in the Taiwan Miracle* (1986), scholars began to recognize that the state-centric explanations of development overstated the state's role vis-à-vis various societal forces. Along with this recognition, there came a critique of the politics of the statist or development state explanation. Scholars of Japanese politics[48] began to point out that the state did not operate without checks in the domestic political economy. Among others, Daniel Okimoto (1989) and Richard Samuels (1987) suggested that the state had to negotiate with other key actors, such as big business, rather than roughshod over everyone in the creation of national economic policy.

Building on this political critique, a number of scholars began to make an argument for state-societal alliances for development. Dubbed alternatively the neo-developmental state (V. Chibber 2003) or embedded development (P. Evans 1995), these scholars argued that the true effectiveness of these efforts was due to the ability of the state to work with and cooperate with societal agents, primarily the capitalist class. While they conceded that the state still operated from a relatively powerful position in cooperating with society, they also argued that without societal involvement the state policies would have failed. The two primary grounds for failure have been the state's lack of information about firm activities and the investment veto of the capitalist class. Lack of information undermines state efforts to reward and punish firms based on their economic performance and cuts off the state from receiving new information about new markets to exploit and private evaluation of the effectiveness of state policies. The

[48] There were economists who critiqued Johnson's claims on economic grounds. See Patrick (1986) and Saxonhouse (1982).

investment veto undermines the whole developmentalist project because without corporate investment the plan of channeling massive resources to new sectors with greater economic returns would be starved of the capital to succeed.

Another stream of revisionist scholarship emphasized the role of international systems of production in the rise of East Asia. Whereas world systems theory had originally argued that the countries on the periphery faced a near impossible task of upgrading[49], in the face of East Asian development, a group of sociologists sympathetic to the world systems approach proposed that global commodity chains offered both opportunities and constraints on development in East Asia. They argued that one had to look at which global commodity chains countries interacted with to understand their development trajectories and not simply focus on domestic policies (Gary Gereffi 1996ab; Gereffi and Wyman 1990). The revisionist optimists of the global production networks (GPN) school are the direct descendants of this line of scholarly inquiry. The revisionist optimists of the transnational technology communities (TTC) school also build upon the global commodity chain literature for the idea of informal transnational institutions structuring development.

This chapter will examine three main current theoretical viewpoints on the prospects for the developing world under globalization: the Washington Consensus, the pessimist revisionists and the optimist revisionists. First, the strengths and weaknesses of each will be assessed. Then, the chapter will compare the three frameworks to the global hybrid development framework.

[49] See for example, Peter Evan's (1979) *Dependent Development* where he argued that the even the lucky few industrializers on the periphery were essentially stuck in a dependent relationship with the industrialized West, "For all the TV sets it may import from Taiwan, the United States remains firmly in the center of the international system and Taiwan remains on the periphery (Evans 1979: 15)."

2. Three Perspectives on Development under Globalization

What fundamentally differentiate the three worldviews on development are the perceived scope of market failure and the solutions for such market failures. The Washington Consensus views market failures as limited in scope whereas the revisionists view market failures as widespread. The revisionists split over what solutions to market failure are viable under globalization.

There are two broad types of market failures: failure to achieve static efficiency and failure to achieve dynamic efficiency. Conventional neoclassical thinking on market failure focuses on the failure to achieve statically efficient outcomes. Static efficiency is the state of market clearance i.e. the cost of producing the last unit is exactly equal to its price. In this equilibrium state, the net social benefit (the profits and positive externalities over the costs and negative externalities) is maximized. Static efficiency is measured at a given point in time rather than over time. Thus, market failure in the static context is when this market clearance is not achieved. The net social benefit is not maximized because the costs and benefits of a given economic activity are not accurately priced in the marketplace. Dynamic market efficiency is the maximization of net social benefit over time. In other words, dynamic market efficiency recognizes that some activities judged at a given point in time may not appear to maximize net social benefit. Over a longer period of time, these activities do maximize net social benefit because over time these activities create additional value not realized at the initial investment stage or shortly thereafter. Failure of dynamic market efficiency is simply the failure to realize this additional value. This failure could be due to the pursuit of static market efficiency because dynamic efficient activities often entail more short-term social costs than benefits i.e. they are often statically inefficient.[50]

To give a concrete example of static market failure, a developing country may have all the proper factor endowments to enter garment making (lots of manual labor, a little capital and basic knowledge of garment making), but fail to produce the quantity of garments that its factor base should allow. This failure to maximize the net social benefit of making the amount of garments expected, in turn, could be the result of the price of capital being too high relative to actual supply and demand. This higher than market-clearing price of capital would result in fewer investments in sewing machines than ideally would be the case given the country's potential in garment-making. Actual developing countries are plagued by such incorrectly priced capital (Sanchez 2003) and even the inability to turn hard assets into liquid capital (de Soto 2000) among many other market failures.

Statically efficiency outcomes may be inefficient when viewed over the long term. For example, with their given present resource set, the static efficient outcome for many developing countries would be to concentrate on low value-added textiles and apparel as they are labor-intensive, capital poor economies. However, with state intervention, these countries may successfully enter more capital-intensive, higher value-added sectors, such as petrochemicals or steel. In a short-term sense, the net social costs may outweigh the net social benefits as the subsidies to encourage entry may cost more than is justified by the short-term value of the steel or petrochemical output. From a longer-term point of view, this intervention could be dynamically efficient because the

[50] The discussion of static and dynamic efficiency draws heavily form Mushtaq Khan (2000:21-70) and Ha-joon Chang (1994: 70-79).

accumulated profits and positive externalities (the social benefits over time) outweigh the cost of investment and negative externalities. This is not simply a theoretical example because Korea, Japan and Taiwan intervened in precisely this manner to shift their industrial production from light, labor-intensive manufacturing to heavy, capital-intensive manufacturing.

2.1 The Washington Consensus

The Washington Consensus believes that developing countries can achieve development by adhering to sound fiscal and monetary policies coupled with free markets. A critical component of these free markets is free trade with other nations. Free trade increases growth opportunities because the free traders simultaneously have access to goods at the best possible price and eliminate inefficient rents that appear under protection or other interference in free markets. Some Washington Consensus economists have even claimed that there are equitable gains for all under economic openness (Dollar and Kraay 2000).

Acting as the great apostate of the Washington Consensus faith, former World Bank chief economist, Joseph Stiglitz, has offered a series of trenchant critiques of the neoliberal policies imposed on the developing world by the World Bank and IMF. Reading such critiques as Stiglitz's (2002) *Globalization and its Discontents*, one would wonder whether the Washington Consensus had any merit at all. In fact, the Washington Consensus does provide some important insights into the problems of development even if one accepts the critiques of it as a flawed blueprint fro development.

First and foremost, the Washington Consensus encapsulates cogent arguments for the negative effects of government intervention in the economy, the government failure argument. Going back to Adam Smith, there have been arguments about the stifling effects on wealth creation of government interference in the operation of markets. What the economists who contributed to building the Washington Consensus offered beyond the original defense of laissez-faire policies are counterarguments to those advocates of protection and industrial policy to foster industrialization. These arguments center on the tremendous costs of these policies irrespective if they actually create gains through increased scale economies or positive externalities. Essentially, these economists point to the fact that interference in markets creates rents and concomitant opportunities for rent-seeking. Buchanan (1980: 3) defines rents as "that part of the payment to an owner of resources over and above that which those resources could command in any alternative use." Buchanan (1980) and Krueger (1974) convincingly argue that the existence of these rents can be welfare reducing because resources are misallocated from productive activities to rent capture.[51] The activity of rent-seeking undermines the legitimacy of the market and invites further state intervention and thus further rent-seeking (Krueger 1974: 302). Thus, any benefits of ISI industrialization or other state intervention may be overwhelmed by the negative consequences of the rent-seeking generated. To be fair to the Washington Consensus economists, there is enough evidence of these problems in various parts of world, such as Turkey, India and Latin America, to lend empirical credence to these arguments (see Bhagwati 1993; Ahluwalia 1985; Krueger 1974;

[51] This does not apply to all rents as monopoly rents acquired by technological innovation are welfare enhancing because the resources are spent to create knowledge embodied in the monopoly rent (Khan 2000: 41-50) or because competition exists which quickly drives down the monopoly rents at the same time that new knowledge has been created (Ha-joon Chang 1994: 28).

Balassa 1984). Stigler's (1975) theory of regulatory capture contributes another reason to fear rent-seeking by firms. In his view, current market players lobby for regulations to suppress competition and create rents.

Another set of arguments related to the Washington Consensus also pointed to problems of state capabilities. State intervention was supposed to solve problems of market failure in the developing world. As the ISI and developmental state advocates both viewed the problem, allowing the market to allocate capital in developing countries would lead to underinvestment in those sectors that promised higher long-term returns. The Washington Consensus economists pointed out that there were legitimate reasons to think that the state would not be able to resolve these problems due to information asymmetries between the state and individual firms. A good example offered of these problems is the persistence of firms receiving infant industry protection for the long haul despite the fact that firms are supposed to grow out of their need for such protection (Bell et al 1984).

The main problem with the Washington Consensus prescriptions is that their assumption that market failures are not widespread appears untenable in the light of evidence from the very countries, principally Latin American ones, that have implemented their prescriptions (O. Sanchez 2003). The most damning critique is that the very embrace of economic globalization entailed in the Washington Consensus actually undermines the very market institutions and supposedly superior market-driven economic performance that the Washington Consensus envisions. As Sanchez points out for Latin America, the very economic openness the IMF and World Bank demand seems to undermine the institutions for encouraging and channeling domestic savings to productive uses. Sanchez cleverly shows that both dependency theorists and the Washington Consensus thinkers overemphasize the role of the external environment. The dependency theorists told Latin Americans that trade with the First World kept them down and the Washington Consensus similarly exaggerates trade integration as a panacea for the developing world. The political outcome is governing elites in the developing world overlook the critical domestic institution-building that is necessary for good long-term performance of markets (Sanchez 2003).

In conjunction with this problem is the evidence that at least some states have been able to intervene in their economies to create dynamically efficient outcomes (long-run net social benefits outweigh net social costs) despite fears of incapable states and rent-seeking. This finding in combination with the evidence about widespread market failures suggests that states should intervene more often to rectify market failures than the Washington Consensus prescribes. What the Washington Consensus has missed is that development involves active institution building to solve market failure in addition to efficient usage of inputs of labor and capital. Thus, the Washington Consensus provides good warnings about possible dangers of non-market solutions and a cogent defense of market mechanisms, but it falls far short of offering a good blueprint for development.

What about the Washington Consensus in light of globalization? The performance of countries adopting Washington Consensus neoliberal policies under globalization has not been encouraging (Stiglitz 2002; Sanchez 2003). While the enormous international flows of capital under economic globalization, the rules of the WTO and the dictates of the IFIs may constrain state actions in the current era, the reliance on economic openness (i.e. globalization) has not worked well either, as the experiences of many developing nations that embraced globalization demonstrate. What the revisionists and dependency theorists both realized is that foreign capital by itself will have insufficient motivation to foster local development. To place it in the language of static and dynamic efficiency, foreign capital when investing in developing host economies more often than not settles on the static efficiency equilibrium (how to realize the maximum rates of return today) and foregoes the dynamic efficiency equilibrium (how to realize maximum rate of return in the mid-to-long-term).[52] To rely on foreign capital and financial institutions alone remains a less than satisfactory solution under globalization.

2.2 The Pessimist Revisionists: The Difficulties of State Intervention under Globalization

Scholars in the revisionist political economy of development like Johnson (1982), Wade (1990), Amsden (1989; 2000; 2003 with Chu), Woo-Cummings (1991, 1999) and Evans (1995) see the state or state-society partnerships as the most effective or even essential[53] political force to achieve economic development. While these authors have created a variety of counter-claims to mainstream economics, their claims all rest on the basic claim that markets in developing countries fail to work effectively enough to spur

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[52] While revisionists often talk about static and dynamic efficiency in terms of the net social benefits over social costs rather than the rate of profitability of firms today or over time, the same authors would be the first to point out that profitability of firms have to be enhanced to gain the long-term dynamic efficiency. If such increases in profitability were not available, then the firms simply would not cooperate to realize the outcome (Ha-joon Chang 1994; Khan 2000; V. Chibber 2003).

[53] Some of the revisionists may have argued that the state's involvement was merely conducive to development or very effective in the case of particular countries, but did not go as far as to say that the state or a state and local capitalist alliance was absolutely necessary for developing nations. Later revisionists have been willing to make or at least imply broader claims of the necessity of such political structures for economic development (Wade 1990; Evans 1995; Amsden 2000; Amsden and Chu 2003). Some economists, notably Joseph Stiglitz, have embraced this concept and Stiglitz (1998: 7) goes so far as to claim that all the most successful developers (those nations that have achieved the status of advanced economies), including the US, have had governments play a significant role in their development success.

development. There are two basic perspectives on this claim of widespread market failure. One perspective sees market failure as rife so a state or state-societal alliance to rectify this failure is necessary to realize growth (Amsden 2000, 2003; Stiglitz 1998, 2002; de Soto 2000[54]). The other sees market failure as a long-term problem in so far as markets alone will achieve short-term static efficiency but fall short of achieving long-term dynamic efficiencies (Ha-joon Chang 1994; M. Khan 2000; Rodrik 1996: Ferris and Gawande 2003; Sauer, Gawande and Li 2003; Murphy, Shleifer and Vishny 1989). For these scholars, developing countries could grow without state intervention, but they would miss many opportunities to grow faster over the long-term without state or state-societal intervention in static market outcomes.

What the revisionists have contributed to the debate on development are empirical examples of (Johnson 1982; Gold 1984; Amsden 1989; Wade 1990; Haggard 1990; Evans 1995) and theoretical justification (Ha-joon Chang 1994; M. Khan 2000; Rodrik 1996: Ferris and Gawande 2003; Sauer, Gawande and Li 2003; Murphy, Shleifer and Vishny 1989) for state or state-societal involvement in development to correct the widespread problem of market failure. These twin contributions provide the most compelling counterargument to the Washington Consensus' celebration of the market. The revisionists' critique points out how irrelevant the ideal of the efficiently functioning market is for the project of development in the real world. The empirical cases also show

[54] De Soto's (2000) *The Mystery of Capital* is interesting in so far as he embraces much of the Washington Consensus belief in markets in conjunction with adequate property rights, but believes that the main challenge is a social and political one of creating a property rights regimes that encompasses the existing informal rights practices of the majority of the people in the developing world. Thus, he buys the Washington Consensus market-based growth arguments, but points out that without political and social change in the property rights regimes market-based growth will not be realized.

that effective state interference is possible despite the theoretical arguments for seemingly inevitable government failure made by neoliberal economists.

There are also several flaws and limitations in the revisionist view of development. The most critical limitation is the amount of state capacity necessary for coordinating, monitoring and disciplining economic agents to intervene successfully to rectify market failures and capture dynamic efficiencies. While several revisionists have argued that these interventionist development projects can be widely adapted with success (Amsden 2000; Woo-Cumings 1999; Ha-joon Chang 1994), others recognize that the precise political arrangements needed to successfully implement such policies are rarely found (M. Khan 2000; Haggard 1990, 2003). The bare minimal requirements for conducting such policies are government control of the conditionality of rents (i.e. the government can credibly take away policy benefits from firms) through the government's ability to monitor firm performance and reward firms accordingly (Haggard 2003; World Bank 1993; Khan 2000; T. Moore 2002; Amsden 1989; K. Fields 1997; Schneider 1998; V. Chibber 2003; Wade 1990; H. Chang 1994). Others add additional requirements such as internal bureaucratic coherence based on meritocratic recruitment and advancement (Evans 1995; Evans and Rauch 2000; Johnson 1982; Wade 1990) and a coherent shared developmentalist ideology within at least the governing elite and perhaps the nation as a whole (Johnson 1982; Wade 1990; Woo-Cumings 1991, 1999). Some also see the need for broad representation of business through peak or sector-based business organizations (Campos and Root 1996; Kang 2002; V. Chibber 2003).

Leaving aside the additional requirements, few countries appear to be able to monitor and reward firms according to their performance i.e. maintain conditionality in the face of firm demands for benefits. This empirical finding is not limited to neoliberal economists, such as Krueger and Buchanan, who are ideologically opposed to state intervention. Mushtaq Khan (2000), who finds merit in the revisionist approach for certain countries, such as Korea, still critiques state intervention as inappropriate for most countries because they do not have the domestic political configurations to monitor and reward firms effectively. He and others (Jomo 2000; Gomez 1991; Jomo and Gomez 1997; Jomo and Gomez 2000) argue that even Malaysia, commonly seen as the most developmentalist of the Southeast Asian countries excluding Singapore, lost its ability to distribute rents in an efficient, market-enhancing manner over time. As Haggard (2003) has observed, the debate over industrial policy has devolved into a debate over what unique institutional or political configurations in East Asia prevented the type of government failure that occurred nearly everywhere else state intervention was attempted. If a policy appears to have worked only in a few countries, then its utility for the wider developing world is in doubt.

The revisionist model also overestimates the scope of static market failure just as the Washington Consensus underestimates the scope of market failure. This overestimation of market failure in turn allows for a relative underestimation of the problem of government failure. Using cases in South and Southeast Asia, Khan argues countries that fail to develop industrial policies, such as Thailand, are better off than countries that pursue industrial policymaking without the state capacity to monitor and control the rents generated, such as all of South Asia. This argument embraces the idea that developing countries like Thailand have developed through pursuit of static efficiency. Obviously, if Thailand could have successfully realized dynamic efficiencies, it would have been preferable, but it still did okay without achieving these (Khan 2000; Doner and Ramsay 2000). In contrast, South Asia suffered from widespread government failure (Khan 2000; Bhagwati 1993; Ahluwalia 1985). In other words, market failure is not as widespread and complete as some of the revisionists would presume so countries should be concerned about avoiding government failure. Countries can at least achieve static market efficiency without much effective state intervention.

There is another tack on the same problem. Rather than an overestimation of market failure leading to an underestimation of government failure, government failure itself may be hard to avoid over time. Countries that have witnessed brief or more sustained periods of successful government intervention can through their very policies create opportunities for government failure. Malaysia is an example of a country that enjoyed only brief success (Jomo 2000; Gomez 1991; Jomo and Gomez 1997; Jomo and Gomez 2000) before government failures caught up with its industrial policymaking ambitions. Korea has a much longer track record of successful state intervention, but its recent history suggests that the state-society partnership began to create as many net social losses as benefits in the 1990s.

A final problem in the revisionist view is the lack of consideration of alternatives to state or state-societal intervention in the economy. Even under conditions of domestic market failure, there plausibly could be international alternative to state intervention to correct market failure. Starting with Gereffi's global commodity chains framework, scholars began to recognize the opportunities that the international organization of production offered local firms. This dissertation offers a different alternative, the importing of market institutions from abroad via FDI.

The revisionists have a convincing critique of FDI-driven development. Foreign firms only contribute to development when they are forced to do so by effective state intervention (Mani 2004; Jomo and Felker 1999; Fosfuri 1999). Singapore is the sole case where FDI played a central role in technological development and Singapore's policies were geared toward leveraging technology from these FIEs (Mani 2004). However, the revisionists do not consider the possibility that there could be an alternative manner to discipline MNCs to contribute to host country development. Drawing on the transnational technology community scholarship, I have uncovered co-ethnic entrepreneurship as an alternative mechanism to provide the motivation needed to foster local development.

The state-oriented revisionists become pessimists because they doubt the feasibility of this interventionist approach in the current era of globalization. Even those who hold out hope for the continued efficacy of the state or state-society partnerships in pursuing development are discouraged by the inability or reluctance of the developing world to confront the forces of globalization. The most pessimistic are those who believe that the developing world is doomed because the domestic state cannot resist the forces of economic globalization (Milanovic 2003; S. Strange 1996; Vernon 1998; Evans 1997[55]). Others add a political twist to the argument of the state's diminishing capacity under globalization. They argue that there are domestic and transnational political forces, such as Al Qaeda, that deem the nation state as antiquated and ill equipped to meet their demands (Clapham 2002; Stiglitz 2003). Another group of pessimists believes that the developing economies can reject globalization but the states more often than not accept

[55] Evans argues that the current globalization keeps the state down because of the current globalization's neoliberal ideology. With a change of ideology in the institutions of globalization, there could be a resurgence of state power.

economic openness as inevitable. These pessimists see this acceptance as one of the chief culprits keeping the developing world mired in poverty (Stiglitz 2002[56]; Sanchez 2003; Nolan 2001). Others see the persistence of the North-South divide despite the industrialization of the South, but they also see possibilities for the destabilization of the current inequitable global hierarchy (Arrighi et al 2003).

Some of the state-oriented revisionists are not at all pessimistic and believe that the state or state-societal alliances can continue to foster development. Alice Amsden (2003) in a recent critique of the pessimists declared their stance to be a return to dependency theory thinking and claimed that developing countries could still develop through state-sponsored industrialization. Others have found that the capacities of states in the domestic arena simply have not diminished very much under globalization (Gilpin 2000; L. Weiss 1998).

There are two reasons that we will discount this argument for continued state-led development under globalization. In the case at hand, China, the state clearly is not effective at conducting industrial policy (see Chapter One Section 5). Thus, the general case of the state's capacity under globalization is irrelevant to the Chinese situation. The second reason is the problem of the scope of state-led development. If state-led development requires levels of state capacity that only a few developing countries possess, then we should consider alternative policies for the rest of the developing world. This need for policy alternatives is true even without the advent of globalization. In any case, the majority opinion among the state-led growth school is that globalization seriously compromises this route to development.

[56] Stiglitz believes that acceptance of neoliberalism is a problem, but he also recognizes that it is hard for developing countries to throw off given the support of the Washington Consensus by the West.

2.3 Revisionist Optimists: The Transnational Networks for Development

The optimists recognize that development does not simply happen because of lower barriers to trade and financial flows.[57] Networks of production provide information, market opportunities and capital that can facilitate development. While the optimists do not talk in terms of resolving market failures, the networks provide the information and knowledge to solve many of the market malfunctions discussed in the development literature. The networks lower the knowledge barriers to entry for firms from the developing world because much knowledge is available within the networks. The networks also free firms from domestic coordination requirements where firms in different sub-sectors or even different sectors must co-invest to realize the full benefits of their investments. Ensconced in international networks, firms can draw on the international industrial infrastructure and markets instead of reliance on the industrial infrastructure and markets of their home economy. Engaging in networks allows firms and countries from the developing world to move from the static efficiency equilibrium to the high growth dynamic efficiency equilibrium.

There are two main streams of the transnational networks of production. The global production network (GPN) theorists that argue MNC-organized networks of production offer opportunities for learning and growth for the developing world. The scholars of transnational technology communities (TTCs) view co-ethnic transnational networks of technologists as driving much of the learning and technological development

[57] Here we only deal with those optimists that accept some social or political conditionality on the opportunities for globalization, and dismiss those optimists who accept a borderless world as *a priori* the best of all possible worlds (K. Ohmae 1999; W. Lewis 2004). In the case of China, Guthrie's (1999) *Dragon in a Three-Piece Suit* comes closest to this latter type of optimism concerning globalization with his argument that corporate practice of Chinese firms is seamlessly converging with those best practices of the developed capitalist world.

in the developing world. These two streams are not completely separate as each acknowledges the existence of the other (Ernst 2004b; Saxenian 2002), but the emphasis of each remains distinct.

Turning to the TTC literature, Saxenian (2002) and others (J. Hsu 1997; Hsu and Saxenian 2000, 2001; Bresnahan, Gambardella and Saxenian 2001; Saxenian and Li 2003) discuss the critical role of transnational networks of co-ethnic technologists who serve as bridges to channel the flow of technology from the developed world to their ethnic homelands. The implicit theoretical underpinning of the TTC scholarship is the sociological literature on networks, which portrays networks as an alternative form of economic organization fundamentally different from the traditional ones of markets and firms (Powell 1990; Castells 1996).[58]

The TTC scholarship conceives of the returnees to the developing world tapping transnational networks that ease the flow of information. The returnees are individual cogs in the wheel of larger networks of technical, managerial and market information as well as capital. Through iterative interaction, the co-ethnic technologists create these networks. Saxenian's work (2002) comparing India, China and Taiwan also implicitly assumes that there is a tipping point requiring a certain number of returnees for networks to flourish. The game of network development is a conceptually simple one. Countries must attract enough returnees back from the centers of innovation in the developed world while at the same time encouraging these returnees to maintain contacts with those advanced industrial clusters. If not enough returnees come home, then the links to

[58] In the four returnees pieces cited, there is only one citation to back up their claims that co-ethnic networks facilitate knowledge transfer and create transnational technology communities. The citation is Portes (1996), which documents co-ethnic transnational networks, but is not a theoretical piece concerning network forms of organization.

transnational networks will be weak or nonexistence and the flow of information will be a mere trickle.

No specific sociological or cultural norms are necessary to have these networks up and running. Saxenian and Hsu (2000) make this clear by rejecting the cultural norms case for ethnic Chinese networks. There is a large literature (Hsing 1998; Hamilton 1996; Yeung 1998; Kao 1993) explaining Chinese networks as functioning according to the reciprocal and fluid norms of *guanxi* (the approximate translation for this term is relations/relationship). Capitalism in ethnic Chinese economies and transnational connections between ethnic Chinese have often been referred to as *guanxi* capitalism. In the case of ethnic Chinese transnational technology communities, Saxenian and Hsu claim that *guanxi* is not the main driver. People are not allowed into the networks solely on the basis of whom they know, the main means of networking under the rules of *guanxi*. They must bring some industrial skills to the network or they do not gain admittance. Furthermore, without technical skills, they cannot upgrade their firm's capabilities within these networks. Given that the transnational technology communities are based on shared ethnicity, some shared cultural understanding may be necessary for a network to work effectively. Beyond the claim for common cultural identity, there are no common norms required for these networks. Indians and Irish can create these networks as effectively as Taiwanese and Chinese just as long as technologists return to the home country (Saxenian 2002: 200).

What brings the returnees home are business opportunities fostered by public policies. Saxenian (2002) recognizes that developing countries' policies towards recruitment of co-ethnics to return home are critical to building these bridges to the developed world. She argues that the relative success of Taiwan and China compared to India in building these transnational networks is due in part to more active state recruitment policies of Taiwan and China. In particular, she cites the pool of potential returnees created by the previous brain drain to the advanced world, programs to support technical and business exchanges, projects to encourage returnee entrepreneurship and active government recruitment as the means to bring returnees home. She also mentions rapid economic development in the home economy, which arguably is partially the result of state policies. Through public policies, the state lures returnees home and the transnational technological community emerges.

The scholars (Ernst 2004ab; Ernst and Kim 2002; Rugman and D'Cruz 2000; Borrus *et al* 2000;) of the Global Production Networks (GPN) also draw on the literature on networks. They argue that the reach of global production networks have grown to displace the individual firm as the way to organize industry and have served to diffuse international knowledge to the developing world by bringing local suppliers from disparate parts of the developing world into their networks. Globalization is what in large part caused these networks to arise. The driving forces have been liberalization, increasing competition and the spread of IT (Ernst and Kim 2002: 1419). The first two are usually considered aspects of economic globalization and the latter is often seen as a facilitator of globalization (M. Guillen 2001). Thus, for the GPN scholars like the Washington Consensus scholars, globalization has facilitated rather than retarded economic development.

Where the Washington Consensus and GPN theory part ways is the problem of development. The GPN scholars are clearly intellectual descendants of the original revisionist political economists of the 1980s in their recognition that markets alone will not adequately foster development. Given their heavy focus on networks of production in relatively technologically intensive goods, the GPN theorists emphasize the old problem of underinvestment in R&D that Arrow (1962) delineated. Essentially, since R&D creates positive externalities, firms on their own will underinvest in R&D. This problem is true even in the developed world, but is magnified in the developing world (Mani 2004; Ernst 2004b). In addition, the developing world does not have the complete set of science and technology infrastructure fostering thought necessary to create cognitively and organizationally complex knowledge. Without an institutional mechanism to acquire knowledge outside the domestic systems, the domestic economy would be incapable of generating sufficient new knowledge to catch up. The GPNs provide the knowledge and markets to allow developing countries to grasp the dynamic efficiencies of innovation (Ernst 2004b: 9-10).

The key contribution made by the GPN and TTC optimists is to demonstrate the continued role of transnational informal institutions (i.e. not IFIs) in shaping the global economic landscape. Even under globalization, the debate should not be solely between the vanishing state and the triumphant market. Markets themselves are shaped and constrained by the organization of production including the production of diffusion of knowledge. Both the Washington Consensus and the state-oriented revisionist pessimists miss the vital role TTCs and GPNs can play in the critical spread of knowledge.

The main problem with the optimists is that they do not go far enough in recognizing the domestic environment's importance in its interaction with transnational structures in determining the possibilities for development. Saxenian and Bresnahan *et al* recognize the policies to encourage the return of co-ethnics as critical and Ernst and Linsu Kim mention a plethora of policies as important in fostering the competencies that the GPNs demand. Unfortunately, there is no strong empirical analysis of which policies are effective. Their analysis contains the *post hoc ergo propter hoc* fallacy of assuming any good outcome with policy support is a result of that policy support.[59] What follows from this uncritical examination of local policies is a lack of recognition of how the contours of domestic political economy shape the outcomes. Local conditions underpin the possibility of creating a transnational community or successful local participants in GPNs.

In the case of China, neither set of theories anticipates the domestic factors of financing and firm operational strategy as having an impact on the operations of the GPNs or transnational technology communities. In the empirical chapters, I will demonstrate that the finance and operational strategies of firms in China mediate the effects of the GPNs and transnational technology networks on technological upgrading.

The TTC literature is especially problematic in not anticipating the effects of the domestic environment. The TTC literature expects a transnational community to emerge regardless of the characteristics of the domestic firms.[60] If firm type is critical, then we need to look beyond the predictions of the TTC literature to understand technological upgrading. I will present evidence of returnees with extensive contacts with other technologists at home and abroad that could not upgrade their firms because their firms' close relationship with the state made it extremely difficult to pursue upgrading. These

[59] This is a common problem in analysis of industrial policymaking as Haggard has demonstrated (Haggard 2003).
[60] The one partial exception to this observation is the finding in Saxenian and Li's (2003) article that certain Taiwanese VCs invest differently given their local partners.

returnees were as much members of the transnational technological community as anyone, but their links to these networks had no effect on their local firms. Rather than a ubiquitous positive effect of transnational communities, the process of returnee-supported upgrading is better conceived as one in which the local state-imposed constraints on firms determine how effectively returnees can draw upon their network of contacts to upgrade the firm's technological capabilities. The TTC school would also predict that transnational communities are created as soon as enough returnees come home. Although the exact number of returnees necessary is unspecified in the TTC literature, a significant number of returnees returned earlier in the 1990s (X. Liu 2001: 204; dissertation interviews), but no vibrant firms with returnees emerged before 2000. Even after the turn of the new millennium, what differentiated firms that upgraded from firms that did not was the different relationships to the Chinese state. In short, networks of technologists are only as effective as local circumstance allows.

3. The Global Hybrid Model and the Three Worlds of Globalization

The global hybrid path to development combines the institutional advantages of global capital with the strategic commitment of quasi-domestic firms. Through reliance on foreign finance, the hybrid firms benefit from operating under the relatively efficient (measured in terms of credit allocation) institutions of global capital. The hybrid firms combine this institutional advantage with co-ethnic ties to the host economy that lead them to make a commitment to developing their strategic assets within the host country. This strategic commitment to the host country drives these firms to contribute to local development even without a capable state to monitor and discipline them.

What does the global hybrid model borrow from the Washington Consensus, the revisionist pessimists and the transnational network theorists? From the Washington Consensus, the hybrid model borrows a respect for market efficiency and recognition that government failure may be as common in the developing world as dynamic market failure. The global hybrid model makes explicit what the Washington Consensus leaves implicit. Openness to foreign trade and capital is not simply a mechanism to access goods and finance more cheaply, but a means to import institutions to enhance market efficiency. In the case of China, openness to FDI has given certain China-based firms the opportunity to access better functioning financial institutions than the domestic economy offers. Where the global hybrid-model differs from the Washington Consensus is in a recognition that markets alone, particularly reliance on accessing market discipline through economic openness (the prime Washington Consensus prescription), can lead to at best statically efficient outcomes. As for the pessimist revisionists, the global hybrid model builds on their ideas of wide scope of market failure in the developing world and the lack of commitment of FIEs to host countries. The global hybrid model diverges from the revisionist pessimists by recognizing that there are other ways to solve market failures and lack of FIE commitment other than state or state-societal intervention in the marketplace. From the transnational networks literature, the hybrid model takes the concepts that these transnational networks help to diffuse knowledge and that this diffusion can help overcome barriers to realizing dynamic efficiency. However, the hybrid model takes issue with their assumption that these transnational networks operate with relatively similar efficacy across different firms within and nations. The table below shows the difference across the four paths of development.

Table 2.1 The Four Paths of Development

Paths of Development	Problems of Development	Solutions	Prospects under Globalization
Washington Consensus	Government failure looms large Market failures are not widespread	Government failure solved by keeping government's role in the economy to a minimum Free markets flourish without much help from the state	Bright prospects under globalization because the lower barriers to trade and capital flows lead to a greater role for free markets in the developing world.
Revisionist Pessimist	Static market failure is a problem Dynamic market failure is rampant Government failure is less costly and less likely than market failure	State or state-societal alliances create the institutions to align incentives properly in the face of failed markets.	To the extent that globalization weakens the capabilities of states and societal forces to create these institutions to solve market failure, globalization limits the development potential of the South.
Revisionist Optimist	Dynamic market failure is rampant because Developing countries do not have the institutional infrastructure to create technology The standard Arrow problem of private underinvestment in technology due to inability of complete rent capture	Transnational networks solve the problem of dynamic market failure by providing the technological resources upon which local firms can build their own technical capabilities. States can play a limited role in encouraging local firms to engage transnational networks.	To the extent that globalization plays a role in broadening the scope for the operation of these networks in the developing world, globalization is a boon to the developing world.
Global Hybrid	Government failure can be a problem (serious problem in China) Both types of market failure can be a problem	Importing foreign institutions of finance solves static market failure The host-based operational strategy of the hybrids solves dynamic market failure Solving market failures through hybrids and foreign institutions avoids the problem of government failure	Bright development prospects for those countries without the state capacity to intervene to correct market failure without inducing equally or more costly government failures. However, solving dynamic market failure through FDI in the absence of effective state monitoring is only open to those countries with the potential to develop transnational technology communities.

Chapter Three

Digitization and the Rise of the Modular Model in the Global IT Industry: Increasing Opportunities for Developing Nations

1. Introduction

This chapter[61] discusses the IT industry effects that help structure the opportunities available to IT firms in the world and how this opportunity structure affects IT firms in both developed countries and developing countries such as China. The chapter argues that technical changes and increased standardization have reorganized the IT industry into a modular organization in which firms can focus on quite narrow competencies while drawing on outsiders from around the globe to supply. This modularity (defined below) has opened up great opportunities for small, de-verticalized and spatially dispersed firms to compete in the global IT industry. These effects are not limited to the IT sector, however. The chapter concludes by arguing that the modularization found in IT has spread to other industries.

The chapter has four sections. First, there is an introduction to the literature on the IT industry and modularization. Then, I explain how modularization has fostered reorganization and re-location in the IT industry. A third section offers a variety of cases of these two phenomena mainly focusing on non-Chinese cases because the rest of the dissertation will provide examine Chinese IT firms in detail. Finally, the fourth section looks at the opportunities for firms from the developing world and places the IT industry in comparative industrial context.

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[61] This chapter is based in part on a paper written by the author and Professors Akintunde I. Akinwande and Charles G. Sodini of MIT's Department of Electrical Engineering and Computer Science. The author has received permission of his co-authors to incorporate material from that paper into this chapter and would like to take the opportunity to thank Professors Akinwande and Sodini for their generosity and encouragement.

Over the last decade, the electronics industry has undergone immense change through twin processes of reorganization and relocation. While these processes started in the 1980s, they accelerated rapidly during the course of the 1990s. Academics during the 1990s began to recognize the massive changes in the electronics industry. Langlois and Robertson (1995) recognized de-centralization, but their scope confined such de-centralization to recognition of component suppliers that exist outside of the organizational hierarchy of the lead firms. Sturgeon (2002) expanded the scope of this de-centralization to include the use of external manufacturers. Some studies concentrated on particular industry segments, such as PCs (Dedrick and Kraemer 1998) or hard disk drives (HDD) (McKendrick *et al* 2000). Others in management studies advocated outsourcing, but did not take a specific industry angle (Fine 1998). Many confined their research to such processes in the US (Best 2001), which is understandable as the US has been the driver of such networks, or to the influence of American modularity on Asia (Borrus 2000; Lester and Sturgeon 2003).

While all of these studies contributed immensely to scholarly understanding of the changes taking place within the electronics industry, more recent studies have expanded the explanatory scope about how the standardization and codification of knowledge have led to the disintegration and modularization of the electronics production chain. Sturgeon (2002) presents evidence of the disintegration of production process as the manufacturing module was increasingly outsourced to contract manufacturers in the US. Sturgeon and Lee (forthcoming) extend this analysis of the modularization of manufacturing to a comparison of the US contract manufacturers and the Taiwanese ODMs (original design manufacturers). Langlois (2003) sees this modularization of production becoming widespread in the post-Chandlerian new economy resulting in increasing marketization of production relations or buffering through markets as opposed to buffering through integration and management.

This study aims to extend the research on the transformation of the electronics industry to demonstrate the extension of modularity over virtually the entire value chain and the consequent impact on the organization of production for both products and components. This chapter will also examine the geographic reach of these changes and demonstrate that modularization is a global trend that both reorganizes national industries and opens up new geographic spaces in which electronics industry activities may take root. In short, this chapter argues that modularization has driven twin processes of reorganization and relocation affecting the entire global electronics industry, not simply one country or simply one particular segment.

The modularity described here is the modularity of production in the broad sense. The term module is used to denote entire functions (design or manufacturing) in the production process that can easily be connected informationally to other functions to allow the flow of production. This modularization should not be confused with the modularization of design in which firms acting independently of each other design parts of a system following the same set of design rules (Baldwin and Clark 2000). Indeed, Baldwin and Clark (2000: 12) acknowledge that modularity in design differs from modularity in production.

Over the past decade, the digitization[62] of information needed to produce electronic industry goods has driven a profound re-organization of the value chain of

[62] Digitization of information is the ability to transmit information electronically.

electronics. Digitization has enabled the modularization of electronics value chain.[63] The basic idea of modularity is that value chains can be broken down into parts (modules) with clearly defined (a) functions and (b) interfaces between the different functions. These clearly defined interfaces simply hand-over processes from one function to the next. This modularization has in turn led to segmentation of the value chain because modularity allowed for clearly defined functions and the accompanying codification of the necessary information needed to establish an information interface between functions in the value chain.

The re-organization of the industry has interacted with new influences, such as the rise of new sources of human capital, and old ones, such as the lure of low-cost locations and jumping trade barriers, to cause a re-location of many of the electronics industry's activities. Scholars of GPN (global production networks) (Ernst and Kim 2002) have correctly pointed out that liberalization and deregulation of trade and investment have facilitated relocation of industrial activities, but these factors alone would not allow the possibilities of relocating specific activities without the reorganization of production e.g. before the separation of design from fabrication in ICs, one could not expect the rise of fabless suppliers in new locations around the globe. Furthermore, liberalization and deregulation have been followed by re-regulation and other policies that are often beyond the bounds of international agreements. For example, a variety of NTBs have been used to keep markets protected despite entry into the WTO.

This chapter has two main points. First, digitization combined with competitive pressure derived from utilizing this digitization to enhance the core competence of the

[63] Modularization could technically be made without digitization, but there would not be clean clearly defined interfaces so the costs of modularizing production would probably outweigh gains from focus on core competency (see footnote two).

firm have driven firms around the globe to re-organize along modular lines in order to survive.[64] Secondly, modularization also allows for new de-verticalized type of re-location of the electronics industry. Modularity in conjunction with better communications technology has allowed for spatially dispersed, de-verticalized activities whereas in the past spatially dispersed activities could only be managed by the vertically integrated firm. With the possibility of dispersed and de-verticalized activities, barriers to entry have come down dramatically. New entrants from parts of the world previously neglected by the global electronics industry have pushed re-location of certain industry functions. When placed in a comparative industrial context, modularization combines with rapid technical change to cause this opening of opportunities for spatially dispersed, de-verticalized activities, but, given that the IT industry itself had a high rate of technical change before modularization, this factor of pace of technical change is not obvious from examining the IT industry in isolation. The final section will develop this comparison in greater detail.

2. Processes of Reorganization and Relocation

2.1 Reorganization

The causal chain from digitization of information to segmentation of the electronics value chain works as follows. Digitization has enabled modularization of electronics products, which in turn has led to segmentation and codification (well-defined interfaces or hand-offs between modules) of the value chain. Others (Sturgeon 2002) have argued that digitization and standardization were equally necessary to create the opportunities for modularity in the electronics industry, but digitization accelerated and

[64] For core competence, see Prahalad and Hamel (1990).

enabled much of the standardization. Simply put, without digitization, standardization would not have gone very far. Thus, to the extent that standardization can be differentiated as something other than an outcome of digitization, standardization is a necessary but not sufficient factor.

The technical innovation of digitization makes modularization feasible, but technical innovation alone is rarely the determining factor for industrial re-organization. Firms adopted modularization because it enabled them to hone their core competency. In areas where there is little value to be generated by modularization, modularization is unlikely to be pursued.[65] As Steil *et al* (2002) and Fine (1998) among others have pointed out, industries with faster paces of technological change are more likely to be de-verticalized both due to lower returns to scale (Utterback and Suarez 1993), including negative returns to scale (C. Christensen 1997), and fewer opportunities to add much value by concentrating on particular segments.

Modularization has allowed for whole new models of organization, such as the rise of contract manufacturers (Sturgeon 2002), which have re-defined the scope of core competency in the electronics value chain. Firms re-defined their core competency in the context of the opportunities and competitive pressures offered by the evolving new organizations of the electronics industry. For example, IDMs (integrated device manufacturers i.e. vertically integrated firms) in the IC (integrated circuit) industry have

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[65] This prediction assumes vertical integration prior to the digitization that affords easy modularity. Thus, in those areas, such as the Third Italy, where social norms and historical institutional trajectory made de-verticalized industry the norm before digitization, one would not expect modularity to have much effect on industrial structure although it would still have the profound effect of opening up the opportunity of sourcing or supplying certain functions from suppliers or to customers geographically distant from the industrial district. The digitization hypothesis makes no prediction about firms that for social normative reasons want to be modular. The areas with the most modularized industry before digitization, the Italian and German industrial districts, are not centers of electronics so their experiences are outside the scope of this study, see Sabel and Piore (1984).

begun to dramatically re-define their core competency towards design plus some manufacturing in light of the maturity and cost pressures of the leading pureplay foundries. Similarly, branded PC firms have begun to shed manufacturing while re-focusing on marketing, distribution and after-sales service. Firms or even whole societies that have resisted the new re-organization have suffered from a loss of competitive advantage as the new organization has taken away their core competence. The Japanese electronics industry has been the most reluctant to embrace this model, but the costs of this reluctance have forced even Japanese firms to begin to adopt the new segmented approach to organization.

Modularization has created new industry structures that have allowed for new firm entry as firms take advantage of the lower cost of entry in narrowly defined niches in the reorganized industrial structures. One example is IC design. Design firms arose well before the modularization was complete, but they faced difficult barriers to coordinating production and technological barriers. IC design houses can access an array of services that have arisen with re-organization. Reorganization may even cause a virtuous cycle of new firm creation as firms think of new ways to focus on a segment or functions of the value chain, and look for partners to help them to facilitate this strategy. For example, the rise of the pureplay foundries helped to drive the rise of the ASIC (application specific integrated circuits) vendors, firms that offer design services for the backend chip design, as foundries looked to partner with ASIC vendors to enhance the services offered to their design house customers. Critically, the facilitation of entry of new firms goes hand-in-hand with re-location as many new firms filling new niches appeared in parts of the world with previous little experience in those activities, such as the rise of foundry fabrication in Taiwan and Singapore.

Intellectual property (IP) protection is critical for the process of reorganization to work. Moving to segmentation is not a seamless and riskless transition. Focusing on a narrow segment is itself fraught with risks. Dependence on those outside the firm hierarchy is increased dramatically. Obviously, the transaction costs in terms of information flows have decreased dramatically with digitization, but there are risks inherent in sharing this information. The vulnerability of one's IP increases even as the digitization makes the information flows less costly. Thus, IP protection is critical to the functioning of this new system because without adequate protection the costs of the new organization of the electronics industry vastly outweigh the gains reaped from focusing on the firm's core competency. The ability to protect a customer's IP has become one way to create a competitive edge over one's competitors in the electronics industry as will be discussed below in the pureplay foundry example.

2.2 Relocation

Modularity combined with better communication at lower costs opens up opportunities for de-verticalized, spatially dispersed activities. In the past, only large vertically integrated enterprises had the ability to spatially disperse their activities because hierarchy was needed to overcome the coordination and communication problems (Saxenian 2000: 259). Small firms at the very least needed to be in the vicinity of other firms to make use of the external economies of scale and scope, the industrial district model, because they did not have the capabilities to do everything in house and they could not control outsourced activities at a distance. Today, fabless design houses around the world make use of the foundries of Taiwan and Singapore. Likewise, the branded electronics firms from the advanced economies make use of CEMs (contract electronics manufacturers), brandless firms that offer manufacturing services, and ODMs (original design manufacturers), brandless firms which offer both manufacturing and product design services. The CEMs and ODMs are headquartered primarily in the US and Taiwan, respectively, but they have manufacturing facilities around the globe. However, the plants of the Taiwanese ODMs are much more concentrated in developing East Asia than the plants of the more global CEMs operating from the US (Sturgeon and Lee, forthcoming). The production facilities do not need to be near the contract manufacturer's headquarters nor near the branded firm.

What is different about the new relocation of the global electronics industry is the role of small and new technology enterprises. New entrants seizing the opportunities afforded by the reorganization of the global electronics industry have pushed the geographic boundaries of the industry to encompass more and more of the world. Generally, occupying relatively high value-added functions along the value chain, these new entrants have placed their home location on the global electronics map rather than waiting for MNCs to take advantage of the opportunities of reorganization to promote new locations in the developing world. MNCs tend to be first movers in those areas where they are looking to unload lower value-added functions just as they were in past relocations. For example, domestic entrants in Taiwan created the whole ODM model and thereby drove the relocation of electronics manufacturing and, more importantly, design to the new site of Taiwan in the 1980s and 1990s. When electronics hardware manufacturing became relatively commoditized in the late 1990s, the Taiwanese ODM and US CEM firms moved low-end box manufacturing to China, but the Taiwanese ODMs retained most of the value-added design and service functions at home. However, the Taiwanese have begun to move some design functions to China.

Along with modularity and better communications, the other new critical factor in determining location is human capital. Human capital has always been necessary to develop sophisticated technology-intensive products. The interaction between the increasing demands for skilled personnel and the ability to utilize such personnel over great distances without necessarily paying the cost of setting up operations in the distant locale is new. This interaction gives rise to a pressing incentive to relocate and has given rise to new industries in new locations, such as the software industry in Bangalore, and to the concentration of certain functions in old locations, such as innovative IC design clusters in the US.

Other old factors still play a role in shaping locational decisions in the new global electronics industry. States still subsidize various activities in order to encourage those activities within their borders. Lower labor costs still attract firms making location decisions. Even with the WTO and ITA, trade barriers and regional trade pacts influence locational decisions. Managing geographic risk has always been a concern and has become even more of one now that activities are often located so far from the home base. The classic new electronics industry example of this concern was the call for Taiwanese foundries to set up more operations outside of Taiwan in wake of the Taiwanese earthquake in 1999 despite the fact that the Taiwanese foundries were able to resume production within a few days. More recently, firms have begun to reassess the concentration of manufacturing in China in the wake of SARS.

3. The Segmentation of the Component and Product Value Chains

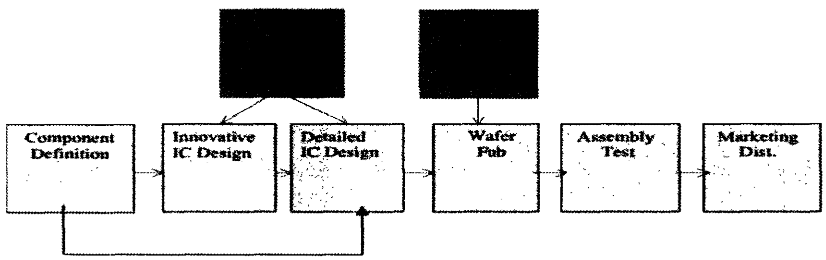

Figure 3.1 Electronic Component Value Chain Model

The Electronic Component Value Chain depicted in Figure 3.1 shows the specific functions that have emerged through the reorganization of the electronics components chain. We will explain the component value chain using the integrated circuit (IC) as an example since the IC is clearly the dominant key component in most electronic products. I will discuss each segment and give an example from the IC industry. Before designing a component, firms often attempt to define the component to meet or create a new market demand. This component definition could be considered a form of proactive marketing. Some IC firms interact closely with product houses to determine what types of new ICs they need and then design to these specifications. For example, engineers at ST Micro spend significant amounts of time interacting with product engineers at Nokia to create the ICs that meet Nokia's specifications for new generations of cellular phones. The component definition function is the link between the electronic products and the key components it requires. Component definition is performed by both electronics products companies and by component companies.

The component definition is rarely done in isolation as the single function undertaken by a company. While both product companies and component companies do this function, this function differs from others in that the digitized interface does not flow in both directions. The component definition module has a clean, digitized interface with component design, but lacks such an interface with the product definition or design, the functions in the product value chain (see below), with which component definition interacts. Thus, product companies that outsource for non-standardized components must work with the component providers closely during the process of component definition as in the ST Micro and Nokia example above. Another way to overcome this digital divide between the product and component value chains is for the component definer to provide all necessary information to aid the product producer to design and manufacture to the component specifications. In this case, the component definer has already designed the component before the close interaction with the component customers occurs. Intel's large support staff that aids firms that design and manufacture PCs to design and manufacture for Intel's CPUs is a prominent example of this type of interaction.

The design function contains both Innovative and Detailed Design. The innovative design function captures the higher value design skills where the design engineers must have a deep understanding and experience in silicon circuit and system design to translate the component definition into custom analog or digital circuits.

Designers capable of performing this function require significant training and mentoring and usually have at least a MS degree in electrical engineering. Therefore it has been difficult to find engineers with these skills in emerging economies. This function is highly valued and can often provide a high barrier to entry. Detailed design consists of the relatively less complex tasks of translating the component definition or the innovative IC design into data that is ready to be sent to wafer fabrication. This data is called "mask data" referring to the detailed digitized drawings that will appear as layers in the silicon fabrication process. IP vendors, such as Artisan and ARM, and EDA tool providers, such as Cadence and Synopsys, provide much of the technology for both Innovative and Detailed IC design. Some fabless design houses, such as Broadcom and Silicon Labs, concentrate on the higher valued innovative design function, but generally perform detailed design as well. Others, such as ALI, are taking advantage of this design segmentation by performing the detailed designs in lower skilled/lower cost locations, such as China, while retaining innovative design in Taiwan and the US.

There is significant know-how at the interface of the design functions and the wafer fab functions. The IC fabrication process and resulting device specifications are captured in a sophisticated set of models that are provided by the wafer foundries. These models capture the detailed physics of the transistors so that the designers can simulate the operation of the circuit before fabrication. The successful wafer foundries have considerable expertise in making this interface user friendly with the aid of web-based tools for easy information transfer. Wafer fabrication takes the IC design and creates actual circuitry on a silicon wafer. Process tools, the capital equipment used by wafer fabs, embody most of the process technology. Thus, the process technology R&D is carried out by the process technology firms, such as Applied Materials, Nikon and ASML. In terms of process R&D, the IDMs and foundries carry out the process integration from machine to machine and the interface back to design. The assembly and test function adds the packaging that allows the chip to interface with other electronic components and then tests the packaged IC. Some firms do both processes, but many firms do solely assembly or testing. Marketing and distribution of ICs is an important function of the component value chain as these components have in some cases become brand names, such as Intel's CPUs. Specialized distributors also do the marketing and distribution function.

IDMs perform all 5 functions though they often outsource assembly and test. They attempt to do value-added processes in wafer fabs and capture systems design of products in silicon. Many IDMs are following a fab-light strategy that follows in line with the progressive abandonment of in-house assembly and test operations.

Foundries perform only the fabrication function. While much of the technology is captured in fab tools, foundries do have large and growing R&D departments for process technology and also capture value by being more efficient in fabrication due to their focus and flexibility. Competing with flexibility, multiple processes and multiple products share the same fabrication facilities and even the same wafer as in TSMC's MPW (multi-product wafer) production. Foundries also compete on the service elements of fabrication by trying to provide ever more detailed information about the timing and quality of production to their customers via the Internet. At the leading foundries, customers can receive real-time data on their wafers as they are being fabricated. Critically, the need for a design firm to reveal IP to foundries in order for the foundry to be able to fabricate the chips necessitates that foundries strive to protect customer IP in order to keep clients and attract new ones.

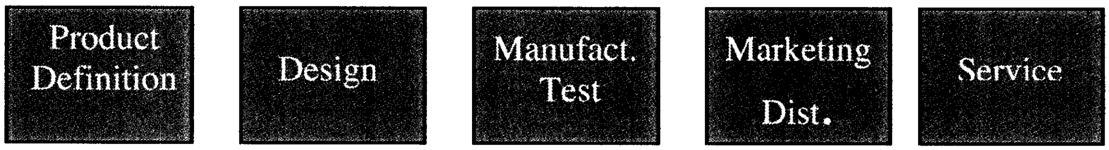

Figure 3.2 Electronics Products Value Chain Model

The Electronics Product Value Chain stretches from defining what the product is to marketing and distributing the product, which includes provision of services to end-users of the product. Product definition consists of trying to create a product concept that will sell in the market. This function requires both sophisticated knowledge of the market demands, extant (Market Pull) and latent (Market Push), coupled with highly valued design engineering to define the product. Design is the creation of a product blueprint that matches the specifications of the product definition. Manufacturing and test turns these designs into the physical products and tests them. Marketing and distribution maintains brand image, identifies and creates consumers for the products and manages the complex logistics of delivering to them. Marketing and distribution has become one of the key value generating functions of the electronics product value chain as manufacturing know-how has spread and become increasingly commoditized. Large retail firms, such as Walmart, within the marketing and distribution function play a significant role by sending feedback to the firms in the product definition and product design functions as the large retailers send volume orders for products with certain specifications. Given that these large retail chains are dealing with products with very large volumes, commoditized products, and lack any R&D capability to generate new products based on new technologies, they are sending signals to the product design function for an evolutionary change. For example, the large retailer sends orders for a 2 MP (mega-pixel) digital camera with removable storage card. This feedback rarely results in a new product definition where the goal is to create new products differentiated from the competitors. The services provided to the end-user as part of the purchase of the product are becoming a critical value generator, which will be highlighted in the case studies.

In the product value chain, large MNCs tend to be strong in product definition, marketing, distribution and service, which constitute the core activities of maintaining a brand. While these MNCs may constitute flagship enterprises (Rugman and D'Cruz 2000: 84; Ernst and Kim 2002:1422) in the sense of having extensive influence over the other activities in the chain, these branded firms do meet their match in terms of suppliers of critical, technology-intensive activities that exercise reciprocal influence with the branded MNC e.g. Qualcomm and cellular phone brands or Intel and PC brands. Vertically integrated firms are now a rarity though some large firms are developing new business models in which they perform multiple functions that are not contiguous in the value chain. For example, there are companies that define products, market them and have a service component. Others attempt to straddle the component and product chains by defining products and then capturing the concept in silicon. Detailed design and manufacturing are often sub-contracted. ODMs do design and manufacturing in an attempt to add value through detailed design, and CEMs do just manufacturing.

The electronics value chain was not always organized into two distinct chains separating components and products. Often, the two chains were integrated within the firm. Macher and hi colleagues note in *US Industry in 2000* that the so-called merchant IC firms, what would later be called IDMs, were a type of firm particular to the US and that IC activities in Europe and Japan tended to take place within the vertically-integrated box manufacturers (Macher *et al.* 1999). Even in the US, a number of firms, such as IBM, were integrated in this fashion. A number of firms still contain many or all of the functions of these two chains within the firm even if they do not necessarily rely on their in-house activities. For example, IBM has a significant IC components group and a computing systems group, but the computing systems group does not necessarily procure its ICs from the IC group. Given these historical roots, a significant number of firms try to straddle these two chains even as they react to pressures to focus.

4. Case Studies

4.1 Component Chain

4.1.1 TSMC: The Rise of the Pureplay Foundry and the Reorganization of the Global IC Components Value Chain

When the Taiwanese first started to create private IC firms in the early 1980s, integrated device manufacturers (IDMs) dominated the global IC industry. IDMs vertically integrated the production of ICs from the design segment to fabrication through to the test and assembly stages. Led by a returnee from the US, Morris Chang, TSMC experimented with a new type of firm organization for the IC industry that took advantage of several emerging technological opportunities. Chang conceived of a firm that would focus on fabrication of the ICs leaving the design and the test and assembly stages to other firms. While many IDMs had served as foundries for chip designers as a sideline to their own business, this new model was called the pureplay foundry model because it would focus solely on being a fabrication foundry for its customers and undertake no other activities. This decoupling of the IC design and fabrication functions was demonstrated initially by some university and DARPA projects in the US, and led to the formation of MOSIS, which essentially provided technical proof of the concept of a digital interface of design and fabrication. However, no one had proven that this concept would work in actual IC production. The decoupling of the IC design and fabrication stages was made possible by the ability to codify knowledge of device characteristics in computer models using CAD (computer aided design) technology. TSMC actually may have over-anticipated this trend by trying to use this model in the late 1980s while sufficient computer modeling of the interaction was not possible until about 1993-1994. Nevertheless, TSMC definitely reaped the advantages of being the first mover in this field as the technological trends justified this new type of fabrication-only firm, the pureplay foundry, and TSMC outstripped its Taiwanese rivals to become the largest IC producer in Taiwan in 1993. TSMC's sales revenues were 475 million USD in 1993 and grew to roughly 5.3 billion USD in 2000, an increase of over 1100 percent (TENS 2001). From the beginning of TSMC's invention of the pureplay foundry model, TSMC was the largest pureplay foundry and remains so today.

One example of how difficult it was to manage a fabless design house before the emergence of TSMC and its pureplay foundry model is the operational tight-rope act that Crystal Semiconductor, one of the early American fabless design houses, had to carry out to ensure the fabrication of its chips. Crystal had to coordinate production done in the fabs of seven different IDMs in order to have access to the best foundry service for a particular product and to ensure that the fabless firm was not too dependent on a single IDM firm. The logistical nightmare that Crystal had to endure in a world without pureplay foundries points to the great opportunity for those firms that eventually figured out how to be pure providers of foundry services.

The pureplay foundry model succeeded not only because the trend of de-coupling led to the emergence of a large number of fabless design houses in search of fabrication services, but also due to the ability of pureplay foundries to capitalize on the benefits of focus. Pureplay foundries devoted their energies to increasing the sophistication of their wafer production rather than having their energies and R&D budgets split between product innovation and fabrication process innovation. The pureplay foundry model was also ideal for firms that were technologically behind because they could learn from their customers primarily through customer feedback. While this type of learning through customer feedback continues to this day, the feedback mechanism and more direct demands and technology transfers were critical in the early stages to be able to catch up to the process technology of advanced firms. For example, VLSI Technology transferred specifications for 1.2 micron technology to help TSMC upgrade to that level of process technology (Mathews and Cho 2000: 172).

The Taiwanese foundries with TSMC in the lead soon became world leaders in being able to produce multiple products with multiple processes within a single fab and in achieving extremely high production yields. Today, there are credible reports that the leading Taiwanese foundries are among the industry leaders in process technology (Cataldo 2001). The yearly benchmarking done by the quasi-governmental ITRI saw

Taiwan, represented by Taiwan's foundries, at the technological frontier along with the US and Japan in CMOS logic fabrication at .13-micron process technology (TSIA 2001). Not taking a back seat to other leading firms in creating the generation beyond .13-micron, TSMC has been cooperating with other leading IC firms including members of the Crolles-2 alliance and NEC to align their next generation of process technology, .90-micron technology (Lapedus 2002). However, it must be acknowledged that the Taiwanese foundries recently have also been able to take advantage of the trend towards embodying greater amounts of process technology in the capital equipment to keep up with the technological frontier.[66]

The foundry model started by the Taiwanese and buttressed by the increasing modularization of the electronics value chain has begun to spread (see Table 3.1). The top five foundry firms come not only from Taiwan, but also from other countries, such as the China and Korea, in which there were existing wafer fabs but no major pure foundries until the last several years. IBM's foundry services are also beginning to give the Taiwanese foundries competitive pressure in high-end manufacturing as a number of loyal customers of Taiwan's foundries, such as Nvidia, have begun to employ IBM as well. Thus, modularization can even give rise to new industrial models in old centers of industry. New entrants in the developing world are becoming numerous.

[66] This account of TSMC and the rise of the foundry model is based on Fuller, Akinwande and Sodini 2003.

Table 3.1 Top 15 Pureplay Foundries in 2003

Source: IC Insights.

2003	Company	2003 revenue (USD millions)	Location
1	TSMC	5855	Taiwan
2	UMC	2740	Taiwan
3	Chartered	725	Singapore
4	SMIC	365	China
5	Dongbu Anam	330	Korea
6	Jazz	185	US
7	HHNEC	170	China
8	SSMC	155	Singapore
9	X Fab	127	Germany
10	ASMC	125	China
11	CSMC-HJ	120	China
12	Silterra	87	Malaysia
13	Polar Fab	85	US
14	1st Silicon	83	Malaysia
15	Tower	65	Israel

4.1.2 AMLCDs: The Integrated Model Continues in Some Components

Not all the component production has become as de-verticalized as the ICs with the rise pureplay foundries.[67] AMLCDs (active matrix liquid crystal displays) thus far continue to be assembled in vertically organized firms containing design, manufacturing, assembly and marketing in house. One should note that a major difference between AMLCDs and ICs is that AMLCDs are comparatively design-light components with most of the design activities taking place at the system level rather than at the level of the AMLCD glass. Thus, there is very little value except in the highest performance displays to capture by solely doing design of AMLCD in contrast to IC design so one would expect continued vertical integration. The new Taiwanese and Korean entrants usually have received technology from the Japanese and the Taiwanese in particular do not have

[67] For further differentiation between components, see Fuller *et al* (2003). Their paper breaks down ICs into separate categories, and compares logic and DRAM (dynamic random access memory) ICs to AMLCDs.

much design capability. The Japanese tried to pursue a fab-light strategy of outsourcing production to the Taiwanese AMLCD fabs while the Koreans and, secondarily, the Taiwanese, are trying to do more of the design themselves. Due to the design-light nature of AMLCDs, the Japanese could not capture much value with only design so many are in the process of retreating from the AMLCD market with Sharp the only significant remaining producer investing in the new generation of production equipment in Japan. Similar to ICs, much of the process technology is embodied in the tools, easing the technological barriers to entry for new entrants somewhat. Thus, both the new entrants and the old dominant player, Japan, are trying to do all the functions in the chain at least partially in-house though many of the Japanese players are in the process of exit from the AMLCD industry altogether.

4.1.3 Twelve-inch Fabs and Further De-verticalization of the IC Component Value Chain

With the rise of the foundries and the advent of expensive but efficient twelve-inch wafer fabs (estimated to cost between 2.5 and 3.5 billion USD according to Taiwan's Market Intelligence Center), the question arises about the viability of any IDMs or firms attempting to do both design and manufacturing. The 12-inch fabs do not possess any inherent technological difference from 8-inch fabs, but they are much more expensive and much more efficient than 8-inch fabs with cost savings of 30-40% over 8-inch fabs assuming 80% utilization (Asia Tech Strategy Team 2002: 11). Thus, to remain competitive, firms must move to 12-inch fabs, but not all IDMs can actually afford to do so. The answer according to the detailed analysis of one investment bank is that IDMs with large revenue streams and high profitability can meet the challenge of keeping 12-inch production in-house where as small and unprofitable producers should outsource. Furthermore, leading IDMs may be wary to pass on leading process technologies to foundries that help their competitors. For example, the investment bank's analysis of Intel notes:

> Additionally by owning 12-inch fabs, Intel does not pass leading-edge technology know-how to foundries, which produce chips for rivals such as AMD, VIA and Transmeta. Traditionally, Intel migrates CPU production to the newest processes and wafer-size fabs in order to drive down die cost, while leaving previous processes and wafer-size fabs for production of its other devices, such as flash, chipsets, Ethernet ICs, which rely less on the most advanced manufacturing technologies (Asia Tech Strategy Team 2002: 15).

The strategies to deal with the high cost of 12-inch fabs go beyond the stark in-house or outsource dichotomy. Other strategies are partial ownership of fabs in conjunction with foundries or IDMS, guaranteed access to fab capacity by investment in foundries or swapping technology for fab space. TI, like Intel, is an IDM with high margin, large volume products, such as TI's DSPs, but in order "to mitigate risks in leading-edge technology, TI plans to outsource select products using .13 micron copper interconnect to TSMC and UMC." (Asia Tech Strategy Team 2002: 15) Mitigating risks refers to mitigating the risks of independently implementing leading-edge process technologies. ST Micro is taking a very similar approach to TI as they are outsourcing some production to TSMC due to the same interest in mitigating risk even while they are keeping much of the production in-house due to the ability to create a wide array of high margin products. ST Micro is currently investing in a joint 12-inch fabrication facility with Philips in Crolles, France.

One of the leading IDMs (IPC Interviews)[68] intent on keeping manufacturing in-house identified three key reasons. First, to keep the knowledge of manufacturing because once you stop you lose it irretrievably. Secondly, the IDM wants to optimize the supply chain by achieving faster time to volume. The close interaction of design and wafer fabrication has the potential to improve this critical metric. Thirdly, the cost of the component to the IDM could be lower since the IDMs do not have to pay the overhead costs and profit margins to the foundry. I find the first and third reasons rather weak. I believe that one can re-attain manufacturing, but it is expensive. It may not be possible for a company to re-learn IC manufacturing without some help from government. For the third reason to hold, the differential cost between the IDM and the foundry has to be lower than the profit margins charged by the foundry, and this is often the case. Other IDMs, such as Motorola, will adopt what Motorola describes as an "asset-light" strategy in which most of the production is outsourced but some production is kept in-house to have some guaranteed production capacity. Significantly, even the foundries are trying to jointly invest in fabs with IDMs to lower their capital burden. For example, Infineon and UMC are building a joint 12-inch fab in Singapore.

4.1.4 ARM: IP Provider and Fabless Design Firm

To give an idea about the newness of the new modularized chain of the electronics components industry, one need only look at ARM, one of the largest IP providers in the IC industry. ARM's products are generally IP cores though they also sell

[68] IPC Interviews were interviews conducted with electronics firms by Professors Akinwande, Sodini and myself as part of the Industrial Performance Center of MIT's research project on the globalization of the electronics sector. The interviews were done under the condition that firms' names would not be released to the public.

fully designed chips. IP cores are blocks of design that firms can buy from the IP providers. ARM was spun out of Acorn Computer in 1990 with a charter to create a new microprocessor standard. It started shipping IP cores in 1991. The firm listed five years ago. Firms need IP providers like ARM because the IC industry faces a simple fact of widening gap between complexity of design and design productivity (Linden and Somaya 2003). In the 1989-1991 period, an advanced IC design took 100 man-years to design circuit by circuit. In the near future, 8500 man-years will be required. Thus, IP cores are a necessary part of both innovative and detailed IC design to bring products quickly to market (East 2003). ARM is most famous for providing processor IP cores to be placed in others design, but the firm also does full-fledged IC design itself (East 2003). ARM's rise has been part of the growth of a cluster of IC design innovation around Cambridge, UK, demonstrating how the modularized structure of the IC industry has given rise to new clusters in new areas. These new clusters are not necessarily only in developing or recently developed economies, such as Bangalore, India or Hsinchu, Taiwan, but can also arise in mature industrial economies such as the UK.

4.1.5 Innovative IC Design: Broadcom

One of the most successful fabless design firms is Broadcom Corporation based in southern California. This company founded in 1991 has produced revenues in 2003 over $1.5 billion or over 75% of the revenue of the CPU-heavy IDM, AMD (iSuppli data for AMD and IC Insights data for Broadcom). Broadcom was one of the first companies to focus on fully integrated broadband communication components. Their core technological expertise includes communications systems, algorithms and protocols coupled with advanced digital signal processing hardware architectures. In addition, their integrated circuit design expertise includes high performance RF, analog and mixed signal circuits, such that their final integrated circuit contains most of the functionality needed by the systems integrator.

Within the electronic component value chain model, Broadcom clearly has significant strength in component definition and innovative integrated circuit design. The component definition expertise is a large set of key broadband markets including wireless networks, cable/satellite set top boxes, cable modems, digital subscriber lines (DSL) and a number of others. Their innovative IC design expertise includes the innovation of radio frequency, analog and mixed signal circuit design placed on the same integrated circuit as the digital signal processing hardware which implements the communication algorithms. Broadcom uses standard CMOS process technologies allowing them to fabricate their designs in a variety of silicon foundries including TSMC, Chartered and NEC in Japan. They have recently also been manufacturing at Semiconductor Manufacturing International Corporation (SMIC) in China. Broadcom's assembly and test is also done at companies in Hong Kong, Singapore and Taiwan.

Broadcom is one of many examples of successful fabless design houses that concentrate on component definition and innovative IC design in specific markets. Other examples of these types of firms are Silicon Labs, CSR (Cambridge Silicon Radio), Mediatek, Zoran and the former S. Parthus (now part of DSP Group) dispersed across the globe in Austin, TX, the UK, Taiwan, Israel[69] and Ireland. There are a large number of

[69] Zoran's CEO and CTO are in the US, but the entire team of technologists for this firm is based in Israel. I learned about Zoran's organization from my colleague, Danny Breznitz.

start-up fabless design houses developing integrated circuits for a variety of markets. The barrier to entry is not financially large, however the skill sets required for world-class component definition in specific markets coupled with innovative IC design capabilities is a scarce resource.

The fabless model is beginning to reach into new emerging economies as Taiwan's VIA and ALI have large design teams in Hangzhou, Shanghai and Beijing in China. IDT has a large design subsidiary in Shanghai called IDT Newave, which was essentially a start-up that IDT bought out for 80 million USD. Over 200 senior (more than ten years of experience in IC design) design engineers have returned to Shanghai alone to start firms in the last several years (Interview #269). While many of these firms will be more oriented toward detailed rather than innovative design, they still represent a vanguard in emerging economies as China has had little IC design activities until the recent push by such returnee firms and the Taiwanese. Chapter Five will discuss China's IC design activities in detail.

4.2 Product Chain

4.2.1 Manufacturing and Manufacturing-plus: Contract Manufacturers versus ODMs

Contract manufacturers arose in the US primarily as a result of branded firms spinning off their manufacturing to focus on core competencies, such as product definition and marketing and distribution. For example, IBM spun off Celestica. These firms were intended as a manufacturing resource and were not intended to do design in competition with their branded customers. Thus, most of these firms have stuck to the model of concentrating solely on manufacturing though Flextronics has begun to move towards a more design-heavy model. The contract manufacturers tend to do a wide range of products and have a large number of plants placed globally to better serve their customers (Sturgeon 2002).

In contrast, the ODMs arose primarily from small enterprises based in Taiwan. The dominant producers in this sector in the initial stage were American producers. The activities of these foreign producers in Taiwan were significant because they were pursuing the core manufacturing activities in the production of PCs whereas they only pursued the backend tasks of assembly and testing in the IC sector. In the late 1970s, foreign manufacturers made up the great bulk of PC-related production in Taiwan.[70] During the 1980s, the share of foreign computers manufactured in Taiwan gradually declined from 57 percent in 1984 to 30 percent in 1990.[71] By 1995, the figure was down to 15 percent.[72] Figures for the foreign manufacturing segment are no longer kept by Taiwan's Market Intelligence Center as this segment is insignificant. However, the state did not make any efforts to drive them out. The decline in production by these American MNCs is attributable to their strategy of increasing outsourcing of production and the rise of the modular value chain.

The large foreign presence was critical in several ways. Kawakami (1996) argues that the firms stimulated the components industry, offered technological assistance to their Taiwanese suppliers, nurtured human resources and served to demonstrate what

[70] Momoko Kawakami (1996: 3), based on the Ministry of Economic Affair's Industrial Development Bureau's *Annual Report 1982-1983*, argues that in 1979 the only PC manufacturers in Taiwan were American ones aside from possible procurement from the small component suppliers implied by Kawakami's data (1996: 16-17). However, at least one Taiwanese firm was involved in minicomputer Chinese language input device production since 1974, IPC Interview.
[71] Kawakami (1996: 6).
[72] Chin-yeong Hwang (1995: 45).

were the new products demanded by the international market.[73] The very fact that these firms were already in Taiwan also made the transition from vertically integrated producers to brand firms outsourcing to Taiwanese OEM firms that much easier. The logic behind the OEM relationship helps to explain how these firms were able to foster technological upgrading outside of ERSO while they were still very small companies. As Lee and Chen (2000) argue, these OEM manufacturing firms can leverage their relationships with outsourcing partners to upgrade.[74] The experience of Mitac, Acer and other firms, such as the PCB (printed circuit board)-manufacturer, Compeq (called Compaq in English until lawyers from the U.S. Compaq caught up with it), confirms this theory of upgrading. The intensive OEM relationships with foreign, particularly U.S. firms, and the ability of relatively small firms to enter into PC production in the early years help to explain why the government R&D center, ITRI, did not play as critical a role in the development and diffusion of technology as it did in the IC industry.

The Taiwanese PC producers have been heralded as shifting from OEM to ODM production.[75] The primary purpose of the out-sourcing firm in an OEM relationship is to reduce production costs so OEM production tends to have low margins. Thus, the logic behind this move to ODM is to increase margins because OEM manufacturing's low margins.[76] The addition of global logistics services seems to be a further bid to enhance or at least preserve value as global customers demand these services from OEM/ODM

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[73] Kawakami (1996: 12-17).

[74] Ji-ren Lee and Jen-Shyang Chen (2000) argue that firms can upgrade from OEM to ODM, but, given Kawakami's evidence from the relationships between outsourcing firms and OEM firms in the early years of Taiwan's PC industry, this argument should also be extended backwards to the initial stage when the outsourcing firms had the incentive to upgrade the manufacturing abilities of local firms to at least a minimum acceptable level.

[75] Chi Schive (2000: 2).

[76] Lee and Chen (2000: 7).

suppliers.[77] However, interviews conducted by the authors with the PC and notebook manufacturers in Taiwan indicate that the move to ODM in just these products has not been a sufficient boost to margins so Taiwanese ODM firms have sought to diversify into a wider range of products. PC and notebook makers such as Quanta, Compal, Acer Group-affiliated BenQ, Wistron, Arima and Inventec have expanded into cellular phone market as these firms anticipate that this will not only be a large market, but wireless communications will be necessary for future products as communications, consumer and computing products converge. Their entrant into this market appears to be quite successful as they have been able to receive orders from major branded firms.

Table 2 Global Mobile Phone ODMs and Their Customers
Source: Arcchart Blueprint, August 21, 2003

ODM	Country of Origin	Models	Customer	Customer Country of Origin
Arima	Taiwan	T100, A3618, T535i	Sony Ericsson, Toshiba	Japan, Sweden
BenQ	Taiwan	T190, T191, C300	Motorola	US
Compal	Taiwan	E360, E365, G60	Motorola, Panasonic	US, Japan
Dbtel	Taiwan	N/A	Siemens	Germany
GVC	Taiwan	R600, T200	Sony Ericsson	Japan, Sweden
HTC	Taiwan	XDA, SPV, SX56	Orange, Siemens	UK, Germany
Microcell (Flextronics)	Finland (US)	T66	Sony Ericsson	Japan, Sweden
Quanta	Taiwan	GD55, G50, CL50	Panasonic, Siemens	Japan, Germany

4.2.2 Branded Firms: Product Definition and Marketing and Distribution as the Core Functions

[77] Schive (2000:2) and IPC Interviews with Taiwanese PC manufacturers.

A number of branded firms have shed other functions to focus on defining products and then creating and managing markets for these products. The epitome of this model is Dell. In 2001, Dell finally displaced long-standing best-selling notebook vendor, Toshiba, as the largest notebook vendor in the world. Dell has surpassed Toshiba to become largest global notebook computer firm after Toshiba had been the largest for seven straight years. Dell had about 14% of the market share in 2001. Dell has surpassed Toshiba because Dell has low cost manufacturing, better service to its end customers and direct sales to the consumer. Dell's typical inventory is 4 days while Toshiba is 20 days. The same notebook model costs 160K Yen for Dell and 260K Yen for Toshiba to produce and deliver to the customer (IPC Interviews).

The reason for these gaps in inventory time and cost is the decision of Dell to outsource everything but product definition and some product design (Christensen 2001: 109). In contrast, Toshiba has been one of the firms most slow and reluctant to outsource with only marginal outsourcing to the Taiwanese ODM notebook manufacturers. Toshiba has emphasized the need to keep production of systems as well as components in-house to be able to do the product definition for innovative, new products. While the ability to create key components may give Toshiba a leg up in defining products (see the discussion of straddling chain below), keeping manufacturing in-house appears to be a losing proposition when up against the modularized outsourcing model used by Dell and increasingly other manufacturers. Obviously, Dell also enjoys a first mover advantage in terms of its use of the Internet compared to other branded PC firms, but the Dell-Toshiba contrast reflects the larger contrast between the US brands and their Japanese rivals. The former have taken advantage of the modularized value chain to dominate the global PC market while their Japanese rivals have been slow to seize the opportunity to outsource and consequently have a much smaller global PC presence.

4.2.3 Product Design Firms

One product area where a number of design firms have emerged around the globe is mobile phone design. These firms design the mobile phones and then sell them to manufacturers for production and branding. The brand firm usually retains the industrial design and sometimes insists on its own user interface. The table below shows the geographic dispersion of these product design houses.

Table 3 Mobile Phone Product Design Firms
Source: Company websites.

Firm Name	Location of Design Operations
Microcell (Flextronics)	Finland
Wavecom	France, US
Elektrobit	Finland, US
Alphacell	Israel, US
Cellon	US, France, Korea, China, Canada

4.2.4 IBM and Philips as Value-added Services in the Product Value Chain

Large vertically integrated companies such as Philips and IBM have been changing the functions they perform. They no longer see the need to keep all functions in house. Rather, they have shed significant fractions of their manufacturing capabilities in the last few years. They are also shedding some of their component manufacturing. For example, IBM no longer is manufacturing DRAM and Philips recently sold its CCD imager manufacturing to DALSA, a Canadian image sensor company.

Large vertically integrated companies are searching to find the right combination of functions to perform for their specific business. One very new development is the recognition of the importance of value-added service to electronics products. For example, Philips wants to create products where it gets in the position of making revenue daily instead of once every 5 years when it sells products such as a television. Brand names of major vertically integrated companies are under attack since service providers have more name recognition than the makers of the products. In mobile phones, service providers can demand to have their name put on a phone rather than the maker of the phone. NTT DoCoMo uses this strategy. The brand name on the phone is that of the service provider not the maker of the phone. Pretty soon that may be the case for a variety of consumer products.

To deal with this new threat major vertically integrated electronics companies are developing products with a value added service component. IBM has placed an enormous investment in its business services group. Although it is an open question as to whether they will tie this service to specific hardware products that they manufacture, it appears that this opportunity is being explored by most large vertically integrated manufacturers in the US and Europe.

4.3 Straddling the Component and Product Supply Chains

A number of companies still link the component and product chains within the firm hierarchy. However, unlike the past, many of these firms pick and choose a few functions from each chain rather than being vertically integrated mammoths. A senior manager from Hitachi is working on incubating a company within Hitachi. The product is based on a very simple silicon chip that is an RFID tag he calls the Mu chip. Unlike other RFID tags, such as those made by TI, this one can only transmit (no receiving capability). Its data is programmed at manufacturing. The interesting part about this product is that it is an entire system. A box to receive signals from a number of tags connects to a computer system with a sophisticated database. The user can program how he wants to use the knowledge of the location of the devices. A description of the entire product was given to us in a set of foils. The interesting point to be learned from this story is that this manger from Hitachi recognized that the service function must be emphasized to generate value. The service function is becoming a new focus of attention in large vertically integrated companies. As mentioned in the Philips and IBM examples above, they are realizing that their brand recognition can only reap rewards if it is their brand name that the customer is ultimately buying. Since service providers are also close to the customer they pose a serious threat to the brand name of vertically integrated companies. This RFID tag system requires all the functions from component design to marketing and distribution. The manager stressed that they need not all be performed in Hitachi after its initial development.

Other firms have pursued similar straddling strategies. For example, HP created ink jet print heads using a proprietary technology developed at HP. These print heads are the key components for the ink jet printer. HP sells own brand printers as well as selling ink jet heads to other printer makers, but the intermediate steps of manufacturing printers are not kept in-house.

Straddling the component and product value chains does not require the firm to be large or even established. SMaL Camera Technologies, a recent start-up in Cambridge, Massachusetts, embarked on a strategy to protect its innovative product definition with key components that were designed in-house. The product is a credit card sized digital camera that has a very thin (6mm) form factor. This unique product is made possible by a custom designed CMOS image sensor with extremely low power dissipation along with a custom ASIC that performs the overall control of the camera. The resulting camera electronics dissipate ten times less power compared with camera electronics made from components available on the open market. The low power dissipation enabled the design of a custom thin lithium polymer battery that was required to maintain the 6mm thickness. In addition to the electronics, custom optics were required to ensure a short focal length and allow for the ultra thin camera design.

SMaL sells the custom designed components along with the image processing software to major brand names that may customize the product with their own industrial design. These brand names perform the marketing and distribution on their own and may use ODMs to perform the detailed product design and manufacturing. In this example, three different entities are participating in the overall value chain for this product. SMaL performs product definition along with innovative component design. The brand name solicits an ODM, in this specific case a Hong Kong ODM to design and manufacture the product. The brand name markets and distributes the product. SMaL has sold over 600,000 of its kits to brand name manufacturers including Fuji Axia and Logitech.

SUN is another example of a company that straddles the product and component value chains. The introduction of Computer Aided Design (CAD) on workstations was championed by SUN. The workstation used the UNIX operation system and SUN adopted a new processor technology based on the Reduced Instruction Set Computer (RISC). SUN defined its own component but had it manufactured at a number of places including TI. TI as an IDM worked closely with SUN and did the Innovative Design, the Detailed Design, Manufacturing and Assembly & Test. The RISC machines were significantly much faster than the CISC machines, which were industry standard, leading to SUN capturing a significant portion of the workstation market.

In the micro-display CMOS backplane industry segment, the cooperation of Tality and eMagin is an example of component definition by a product company and a component design company jointly straddling the two value chains. eMagin, a product company, worked closely with Tality Corporation, a design services company, to design the CMOS backplanes that are used to power the Organic Light Emitting pixels on micro-displays and the component (CMOS backplane) was manufactured by IBM Microelectronics foundry. Part of the innovation came from the product company and part of it came from the design services company. For example, Tality did not know how organic materials behave and it learnt how they work from eMagin. This interaction is an example of mutual learning common in the modular model rather than the unidirectional knowledge transfer from the lead firm to the local supplier as envisioned by the GPN theorists (Ernst and Kim 2002: 1426).

4. Conclusion: Modularity and Opportunities for Firms in Emerging Economies

The rise of the modular model in the global electronics industry has changed the organization and geography of the industry profoundly. Organizationally, the vertically integrated firm continues to exist only in a few niches and many firms concentrate on a narrow band of expertise. This reorganization has lowered entry barriers for new firms by lowering the costs of entry through providing external economies of scale and scope. Advantages of market scale remain due to the fact that firms give preferential treatment to large customers, whether in the transaction between design house and foundry in the IC component value chain or between contract manufacturer and branded firm in the product value chain, but in an industry of fast technical change such market advantages can be very short-lived (Christensen 1997).

Geographically, the modularization has expanded the opportunities for parts of the world previously on the periphery of the global electronics industry. Rather than just the continued movement of mature products to low cost locations, modularity has offered developing economies the opportunity to participate in segments of the industry generating significant value. Here too, though, a word of caution is necessary. Not all developing countries or even developed countries can easily participate in such value-generating activities. As manufacturing itself has become more mature and, consequently, a widely acquired skill, value generation has required greater and greater levels of human capital. Only certain of the emerging economies, such as China, India and Russia, rather than all or most of the developed economies have the necessary skills to carry out the value generating activities within the global electronics industry. Due to the different human assets that various regions offer, one witnesses in technically demanding design skills the same spatial concentration with geographic dispersion observed by the scholars of GPN (Ernst and Kim 2002: 1420). To the extent that design functions have moved from the Triad of Japan, the US and the EU, the design has primarily migrated to greater China, Israel and Korea though India and Russia hold promise.

How does the effect of modularity function across industries? The critical factor is a combination of the feasibility of modularity and rapid technical change, the technical clockspeed of the industry. Feasibility of modularity is the basic capability to modularize, and is driven by the twin forces of ability to codify information digitally and the availability of standards in the industry. As discussed above, codifiability and standardization are not completely distinct from each other, but there are some industries where the codifiability should not be a difficult, such as organic electronics, as they can theoretically use previous generations of CAD (computer-added design equipment) to transmit the information, but the industry is relatively young so standards have not yet evolved. Even for relatively old industries, such as machine tools, the amount of tacit knowledge that has not been transformed into widely available standards is still high.[78]

The IT industry is an industry with a rapid rate of technical change and was even before the rise of digitization and standardization within the IT industry so the effect of the clockspeed (measured in terms of product generation change) is absent when one looks at feasible modularity within this industry alone. It is important to note that

[78] This lack of standardization has both helped nurture and protect machinery districts in high wage countries, such as Germany, and necessitated non-standardized production to remain in such a districts or clusters in order to facilitate communication in the supply chain (Sabel and Piore 1984). Without codification and standardization, a firm can only cluster or become vertically integrated as long distance communication of non-digitized communication becomes too costly as the holders of the tacit knowledge have to travel to the next link in the supply chain to transmit this knowledge. In the case of Germany, to the extent that industry segments have become standardized, the German industrial districts have lost out to Japanese mass producers of machine tools.

clockspeed is NOT a measure of the technological intensity of the industry as some industries with slow clockspeeds, such as commercial aircraft with its product technology generations of 10 to 20 years (Fine 1998: 239), are technologically intensive. A number of authors have noted the propensity of slow clockspeed industries to be more vertically-integrated and oligopolistic (Steil *et al* 2002; Utterback and Suarez 1993; Christensen 1997; Fine 1998), but fast clockspeed industries are not modularized either if there are not ways to enhance the standardization and digitization of the production chain as the pre-digital era IT industry demonstrates. Christensen (1997) argues forcefully for the necessity of vertical integration of non-standardized segments of the value chain.

Firms in developing economies generally face the greatest opportunities (.i.e. the greatest options of being to avail themselves of highly modularized production chains) in sectors where feasible modularization and clockspeed are both high. If one or the other is not high, the scale and scope barriers present difficulties for the firms from developing countries. Indeed, these barriers to entry are the main justification for protecting and promoting infant industries until they grow large enough to compete i.e. have already developed the scale and scope to compete with established firms. What the combination of high feasible modularity and high clockspeed creates is a highly modularized production chain that allows small firms without the internal or external (cluster-provided) economies of scope and scale to enter the industry more easily. The table below presents the opportunities available for firms from the developing world under each scenario.

Table 3.4 Level of Opportunity for Firms in the Developing World

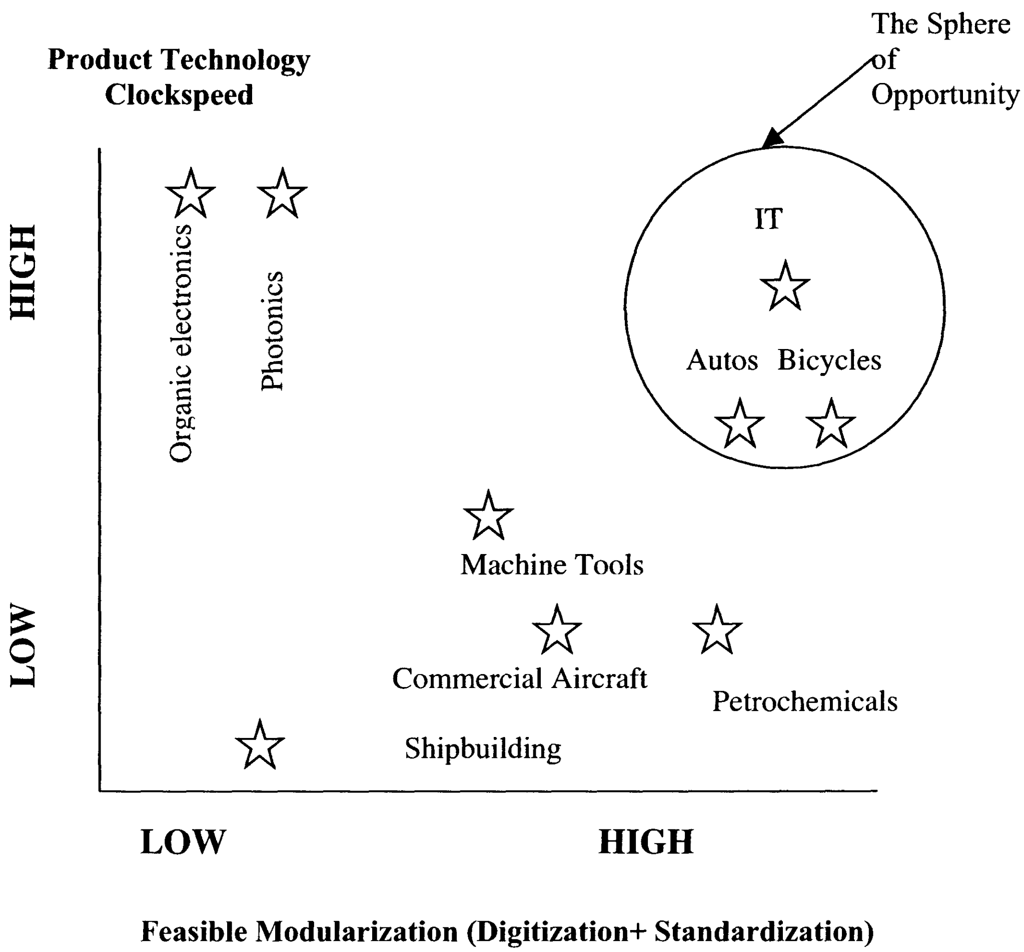
Clockspeed

Feasible Modularization	**Low**	**High**
Low	LOW Vertically-integrated/industrial clustered firms and slow pace of technical change gives incumbents advantage—scale barriers are high	LOW Vertically-integrated/industrial clustered firms. Scale barriers are high.
High	LOW TO MODERATE Modularized but in large blocks so scale barriers are still relatively high.	HIGH Modularization and fast technical change allows niche players to compete. Barriers to entry are low as scale and scope may actually work against incumbents.

The question remains about what industries have high feasible modularity and high clockspeed. The graph below using Fine's clockspeed measures (1998: 239) and stylized facts for the industries shows where different industries fall on these two metrics. The sectors in the circle are sectors where the opportunities are likely to be greatest. With the increasing sophistication of computer-aided design, there should be a rightward shift for most industries just as the IT industry experienced in the past. Also, as newer industries age, the chances of standardization grow. For example, standardization is beginning to emerge for some older photonics products just as it did for electronics products in the past.[79]

[79] Discussion with Erica Fuchs provided me information on photonics industry.

Figure 3.2 Comparing Industries and the Sphere of Opportunity



While the industries above are only a slice of the industrial sectors, the graph does depict a number of large industries where China and other developing countries will not have many opportunities to use modular production chains to develop their own industries. More importantly, it suggests that other sectors are now (autos and bicycles) or may in the near future (organic electronics, photonics) be part of the sphere of opportunity (the part of the industrial landscape with high product technology clockspeeds and high modularity) as digitization increases across the industrial landscape.

Finally, the graph does not depict the other main implication of developing the IT industry. Developing IT presents developing nations the ability to leverage the technological capabilities of this critical technology to gain advantage in other related areas (Yusuf and Evenett 2002; Miranda-da-cruz 2002; M. Tratjenberg 2002; Dahlman and Aubert 2001; Steil *et al* 2002).

<u>Chapter Four</u>

Paper Tigers and Hidden Dragons: Technological Development in China's IT End Products

1. Introduction

Like many developing nations, China has had the dream of domestic technological development. In recent decades, the proclaimed route for many of China's firms has been the *mao gong ji* (trade to manufacturing to technology) road to technology. *Mao gong ji* has been attributed to Liu Chuanzhi, one of the founders of Legend, but has been applied to describe a range of Chinese large companies, particularly in the technology sector. Unfortunately, this strategy appears to have failed. This section will endeavor to explain why domestic firms have proven to be technological paper tigers and it will contrast this failure with the little known and often disregarded contributions of the hidden dragons of China's technological development, the hybrid and regular FIEs.

The technological failure of domestic firms has not escaped the notice of a number of commentators in China. In 2004, twenty years after the founding of a number of a number of the prominent technology companies, including Legend, Stone and Haier, an opinion piece in *Jingji Guancha* (The Economic Observer), an influential economic daily in China, observed that none of these companies were celebrating their 20th birthdays despite the fact that everyone loves birthday celebrations (JJGC, July 12, 2004). The editorial went on to explain that these firms had nothing to celebrate because they (and China's large firms in general) had failed to become firms of international influence and stature. What explained this failure was the inability of these firms to make the transition from *gong* (manufacturing) to *ji* (technology). The author argued that this tragedy was due to the myth of "Made in China." Firms and analysts alike had assumed that manufacturing scale would somehow induce the creation of core technologies. Instead of investing in technology, these firms concentrated on short-term profits and telling baseless "technology tales" (*jishu gushi*) about their products. These technology tales were particularly useful in securing government loans and procurement. The result was a lack of core technology capabilities in Chinese firms. The assessment of the Economic Observer is not alone. The famed Chinese economist, Wu Jinglian, and Liu Xielin, the director of China's Ministry of Science and Technology's policy research center, have both issued book-length critiques of China's firms to develop technology (J. Wu 2002; X. Liu 2001).

What has escaped the notice of many is the increasing contribution of FIEs. With the increased attention on outsourcing, more media attention has been focused on the movement of skilled jobs to the developing world, including China, but less media and scholarly attention has been focused on the positive impact these moves have had for the technological development. Recent studies of MNC R&D in China have looked more at how these institutions relate to their headquarters than their impact on China's technological development (S. Chen 2004; K. Walsh 2003). Chinese commentators have generally viewed the MNCs as being very reluctant to transfer technology or transferring inferior technology that serves to keep China backward and dependent when the MNCs do transfer technology. Even the bureaucratic boosters of foreign investment, the Ministry of Commerce (former MOFTEC-Ministry of Foreign Trace and Economic Cooperation), has criticized the reluctance of MNCs to contribute to China's development and the dangers of MNCs displacing local innovation (Z. Wang 2003: 142-144).

The rest of this chapter will present evidence on the contributions of the FIEs and the failure of domestic firms. I will show how state-determined access to capital and procurement as well as firm operational strategies drive these outcomes in accordance with the causal mechanisms outlined in Chapter One. In IT end products, I will show that the regular FIEs made the greatest contribution in terms of technicians trained whereas the hybrid FIEs made the greatest contribution in terms of skills conferred on the local workforce.

I will focus on the telecommunications equipment and computer-related products because these are the two largest IT product segments in China. The firms in these areas are also increasingly involved in the IT services segment so examining the hardware firms provides some analysis of the IT services sector as well. The traditional consumer electronics[80] segment, such as televisions and other audio-visual equipment, is also quite a large segment in China, but according to both organizations that rank technological intensity of industry segments (OECD 2004) and my own findings, this segment is not generally as technically sophisticated. The sophisticated integrated circuits that go into these traditional consumer products are covered in Chapter Five.

The next section will present a framework to evaluate R&D activities because I will use this framework as a general benchmark to compare the activities of different firms. The third section will examine the major domestic computer and telecommunications equipment firms in China and evaluate their technological activities.

[80] With the so-called 3C (communications, computer and consumer) convergence, one could argue that it is hard to place certain products neatly into a given category. However, in China, computer and communications firms produce most of these new consumer products, such as PDAs. Thus, these new 3C products are included in the scope of the study even though the traditional consumer electronics firms are only tangentially examined.

Table 4.1 Production Shares of IT End Products in China (2002)
Source: Ministry of Information Industry.

Product Categories	Telecommunications Equipment	Computers	Traditional Consumer Electronics	Software	IT Services	Other*
Share of Total Production in China (%)	27.9	30.7	25.8	4.8	3.2	7.6

*This category includes a wide range of products including radar, chemicals used in electronics and electrical machinery. This category is larger than it should be because the data did not allow for the separation of end products from components.

The fourth section will examine the activities of a range of FIEs, both hybrids and FIEs, involved in these product areas. This section will also provide a wider examination of foreign and domestic R&D activity that extends beyond these product categories to encompass the major IT-research activities in China today. However, the vast majority of the R&D activities uncovered in China fall within these two segments so the comparison will generally stay within these two product categories.

2. Evaluating MNC R&D

To evaluate the sophistication of R&D, it is useful to have some standard to compare across products and activities. There are several widely used rankings of R&D sophistication. The most common classification system is the OECD's Frascati manual. The Frascati manual breaks R&D into three categories: basic, applied and experimental development. In the Frascati manual, basic research is defined as experimental or theoretical work to acquire new knowledge. Applied is defined as original investigation with a specific practical aim and experimental development is defined as systematic work drawing on existing knowledge to produce new products or services (Amsden and Tschang 2003: 556). Many US government agencies have used the Office of Management and Budget's modified Frascati classification system breaking the stages into basic, applied and developmental research. The US Department of Defense (USDOD) has created finer distinctions with four categories: basic research, applied research, exploratory research and advanced development. Advanced development is "advanced" in that it advances the research to its final product goal, but it is the least technically demanding of the stages. Thus, more appropriate names for this stage would be final development or end development or design for manufacturing. I will use these names when discussing this stage.

Another classification system is Ronstadt's (1977) system that divides R&D centers into four types: technology transfer units, indigenous technology units, global technology units and corporate technology units. Reddy and Sigurdson (1994) added a fifth category, regional technology units. One problem with this classification is that they do not deal with research and design flow that occurs across different units (see Table 4.2 below). Instead, they assume that these research units are holistic and have little interaction with other units involved in corporate R&D. Another problem is that they do not explain in detail what types of skills and activities each type of site contains to the degree that Amsden and Tschang's framework (Table 4.2) does. This lack of detail and the assumption of rigid boundaries between different types of technology units in the Ronstadt and Reddy-Sigurdson models probably explain why the Frascati framework and its descendants are most commonly used today.

The current state of the art in R&D classification is Amsden and Tschang's modified version of the USDOD classification system. Amsden and Tschang add the category of pure science (I leave out this category for reasons explained below), but this addition is not their critical contribution. They make an important improvement to R&D classification by delineating what exactly makes each stage of research more or less technically sophisticated. They identify eight metrics by which to describe each stage of R&D: search, objective, output, measure of performance, time horizon, techniques, qualifications/skills and size of effort. They define search as, "the purpose of a company and institute in performing R&D," and objective as "the process or set of attendant objectives by which that purpose is achieved (Amsden and Tschang 2003: 557)." They assume output and performance to be somewhat self-evident and only define them through examples in Table 4.2 of the stages of R&D. Time horizon refers to the time frame for a given type of activity. Techniques "refers [sic] to the body of tools and methodologies used by researchers to conduct R&D (Amsden and Tschang 2003: 561)." Amsden and Tschang differentiate scientific and engineering techniques and deem the former to be more sophisticated. Scientific techniques use mathematical and science-based theories to address the more theoretical challenges while engineering uses the same tools in an applied manner to solve specific problems related to a particular product. Research qualifications refer to what level of education is required for the given task. The size of the effort is partially the number of people involved with the corporate research lab of 1500 to 2000 full-time researchers conducting mainly basic research being the apex of R&D in terms of size. However, the size of effort is also the combination and sophistication of the skills involved, what Amsden and Tschang refer to as "skill mass."

Amsden and Tschang view basic research as the most sophisticated activity with the others following in descending order of sophistication. Amsden and Tschang's typology explains why basic research is more sophisticated than the others and offers a benchmark against which other design activities can be judged.

Table 4.2 Amsden-Tschang Typology of R&D Characteristics (modified)

Source: Adapted from Amsden and Tschang 2003, p. 555.

Stages / **Characteristics**	**Basic research (Stage 1)**	**Applied research (Stage 2)**	**Detailed design (Stage 3)**	**Final development (Stage 4)**
Search	New knowledge for radically new marketable product	Differentiated product "on paper"	Prototype in a system	Prototype for manufacture
Research	Uncover scientific principles with applications that are unknown or diffuse	Transform, variegate and reapply known concept for new application	Implement concept as engineered system	Reduce costs or uncertainties of manufacturing/routine final design implementation for non-manufactured goods e.g. software
Output	Product-based IP transfer to stages 2 and 3	Differentiated product for specific market	Detailed product design or prototype	Manufacturable/"implementable" product
Measure of performance	Product-based IP	Differentiated/niche product with IP	Market results (e.g. time to market)	Market results (e.g. number of rejects)
Time horizon	Long-term	Medium-/short term	Short-term	Immediate
Techniques	Scientific experimental and mathematical techniques	Scientific techniques (formulation of equations, algorithms)	Engineering design tools, including simulation	Same as 3 but includes testing and quality control
Qualifications	PhD	BS/MS/PhD	BS/MS	BS/MS
Size of effort	Critical skill mass related to whole product range; specialization and integration	Smaller critical mass appropriate for exploiting niche hand-me-down from stage 1	Scales with size of system	Same as stage 3

To give more concrete examples, Amsden and Tschang also present two cases of R&D for specific products, a communication algorithm for mobile devices and a hard disk drive head (the component within a hard disk drive that retrieves information stored on the disk drive). However, I believe there is a lack of concreteness in their algorithm example. They state that the algorithm is implementation of circuit in production prototype, but it is unclear if the final form of this algorithm is captured in a circuit or in software, even in their example. In my mind, the communication algorithm has to be placed within a box (such as a mobile phone) in order to be used so stages 3 and 4 would be better conceptualized as configuring the software or circuitry to function within the given box and design ("final tweaking") for manufacturing the mobile phone, respectively. I have modified their example accordingly.

Table 4.3 Product Examples in Amsden-Tschang Framework

Source: Amsden and Tschang 2003, p. 560 (modified from original).

Example	Basic research (1)	Applied research (2)	Exploratory research (3)	Final development (4)
Communications algorithm (A)	Conceptual development of (A) for commercial application	Development of multiple variations of A (software)	Configuring software A to function within the system (the mobile handset)	Design for manufacture of the handset
HDD (hard disk drive) head	Integrated and concurrent research on new materials for HDD head	Application of new materials to new head	Development of new head prototype	Development of production prototype

Amsden and Tschang's classification provides a solid method to assess a wide spectrum of R&D activities, but Amsden and Tschang themselves recognize that their framework cannot work in every case.[81] However, when in doubt, this work will fall back on the research qualifications method used by Amsden and Tschang. In cases where the activity does not seem to line up very well with the other metrics, I will use research qualifications to determine the sophistication of the R&D. Where Amsden and Tschang's framework succeeds in breadth, it fails in depth. In other words, specific knowledge of a particular technology gives one a better way to evaluate activities in that technology area than the general Amsden and Tschang method. Precisely because I have knowledge of specific technology metrics in semiconductor technology, I do not use Amsden and Tschang to evaluate that sector in Chapter Five. Where appropriate, I will bring to bear what technical knowledge I have acquired to evaluate the activities of firms in China. I will also evaluate the activities in light of what is happening in the relevant technology in the real world.

As mentioned in Chapter One, I evaluate China's technological progress relative to that of other societies. For technological activities, one should always ask the question of how many firms in how many countries have the capabilities to carry out these R&D activities. If the answer is a mere handful of firms in a handful of countries can carry out the activity, then that activity should be considered to be relatively technologically sophisticated. For example, knowledge of notebook computer design for manufacturing is limited to an oligopoly of firms in North America, Japan, Taiwan and Korea. This activity is clearly more technically demanding than assembly of the average electronic gadget given the limited number of firms with the capabilities to carry it out (Fuller 2005).

[81] Amsden and Tschang in their definitions recognize that not every case will fit perfectly in their classification scheme. Indeed, their advocacy for a more finely delineated scheme relies on the problem of pigeonholing rather than assessing activities under the Frascati three-stage approach.

Another caveat about the Amsden and Tschang framework is the pure science category. Amsden and Tschang themselves recognize that pure science is not effective in fostering research and development activities when bereft of links to corporate research. The critical corporate R&D labs are focused on basic research whereas pure science is mainly university-based (Amsden and Tschang 2003: 556 and 564). Furthermore, Amsden and Tschang (2003: 557) recognize that for most developing countries, the goal is to move final development or exploratory development to "generation of at least a differentiated product through better product design," i.e. applied research. Clearly, they do not regard pure science in local universities as part of the corporate R&D. As laid out in Chapter One, one requirement of technological upgrading is commercial viability. Research conducted in universities with no commercial link to enterprises would not meet the standard of commercial viability. Thus, under neither Amsden and Tschang's framework nor the standards laid out in Chapter One will solely university-based pure science be considered when examining corporate R&D. Furthermore, in China, the pure science-oriented research has been quite weak in creating innovations that can be commercialized through further R&D. Unlike the US, the linkage between firms and universities (to the extent that it exists) has failed to produce many technologies (J. Wu 2002; X. Liu 2001). For these reasons, I have modified the Amsden-Tschang framework to leave out the pure science category when judging corporate activities in China.

3. Paper Tigers: China's Gentle Giants of High Technology

Media sources around the world talk of the rise of China and naturally turn to look for large Chinese companies to illustrate China's increasing economic prowess.

Since China has developed so rapidly, there is an implicit assumption that large firms in China are the prime movers of this development.[82] Careful investigation of these firms reveals them to be the gentle giants of the IT industry. They may be large by domestic and even international standards, but they lack technological capacities commensurate with their size. On the surface, they are fearsome competitors from the fastest growing economy on the planet, but in reality they are paper tigers, all show and no substance.

In this section, I will first examine the technological activities of the major Chinese brands from the vantage point of their Taiwanese design and manufacturing suppliers, particularly in the notebook computer sector. I will then examine specific Chinese firms in the computer and telecommunications sectors. I will describe in which of the three ways outlined in Chapter One (incapacitation, bureaucratic goals; disincentives) the state undermined particular firms.

3.1 The Accounts of Their Suppliers

The major Taiwanese suppliers of IT hardware to the big Chinese brands can provide evidence about which Chinese firms actually have technology. Additionally, these Taiwanese firms also serve major international clients so they have an ideal vantage point to contrast the capabilities of Chinese and foreign MNC customers. Between the interviews I conducted under the auspices of MIT's Industrial Performance Center and my dissertation interviews in China, I interviewed all of the top ten notebook makers, top four desktop makers, the two dominant firms in Taiwan's telecommunications equipment companies and five of Taiwan's top seven cellular phone makers. I also interviewed

[82] One refreshing recent article that runs against the grain of hyping Chinese firms is "The Struggle of the Champions: China Wants to Build World-class Companies. Can It Succeed?" *The Economist*, January 6, 2005.

small mobile phone design companies in China. Other industry participants were also interviewed. The picture from these interviews is clear and consistent. The Chinese firms almost without exception lack any technology and are passive recipients of off-the-shelf parts. With the Chinese, the design firms take over all the design and often even the manufacturing of the products. In contrast, foreign brands, even when ordering from those suppliers with design capabilities, the ODMs (original design manufacturers), still take an active role in technological development and design of new products.

3.1.1 Notebook Design and Manufacturing

One prominent example of this dependency on foreign technology is China's notebook computer segment. The major laptop brands in China (Lenovo, Founder and Ziguang—hereafter referred to as the Big Three Notebook Firms or the Big Three) are desperately dependent on foreign suppliers of manufacturing and design of notebooks. While outsourcing of desktops has been rightly viewed as getting rid of low value-added manufacturing, notebook design is much more technically demanding. The higher technical demands can be seen both from the limited number of suppliers available—only certain firms in North America, Japan, Taiwan and Korea have the capability to make these products—and the fact that certain firms retained or still retain some in-house manufacturing of notebooks long after outsourcing their desktop production to outside suppliers (IBM and Toshiba). The number of firms that have real design capabilities (i.e. can design a new model on their own) is even smaller—IBM, Apple and HP-Compaq in the US, the major Japanese firms and a few of the ODMs in Taiwan[83]. Thus, unlike the outsourcing of desktop production, China's Big Three's choice not to produce notebooks has not been based on some idea of letting go of low value-added activities. Indeed, given the low value that the Chinese laptop makers derive from their brands, the manufacture and design of notebooks should surely be an attractive activity in terms of capturing value. As will be shown, the promise of these activities was enough to lure some firms to try to acquire the capabilities. Unfortunately for those hoping to develop domestic Chinese competencies in notebook manufacturing, the efforts to capture this technology came to naught as predicted by the Incapacitation route for domestic favored enterprises described in Chapter One.

I will discuss the reports of specific suppliers of certain large Chinese notebook manufacturers together. I will include some anonymous reports from company insiders because I cannot include these comments in the company-specific section without compromising the interview subject's anonymity. Following this discussion, I will mention information about specific firms from public sources and sources whose identity can be protected even when discussing a particular firm.

Reports from the Chinese firms and their suppliers confirmed the dependency of the Big Three Notebook firms on their Taiwanese suppliers of manufacturing and design. Unlike Dell's model of outsourcing manufacturing and some design functions to Taiwanese ODMs while retaining some design specifications in-house, the Chinese Big Three simply accepted off-the-shelf designs from their Taiwanese designers. Several Taiwanese manufacturers that had produced notebooks for the Big Three declared the Big

[83] This judgment of the capabilities of Taiwanese notebook ODMs is based on discussions I had with Japanese buyers and Taiwanese suppliers of ODM notebook services in January 2001 and November 2002, respectively.

Three incapable of even making design specifications that Dell does due to their near complete ignorance of the underlying technologies (Interviews 155, 166, 201,205, 210, 219). One could dismiss this as simply the typical Taiwanese condescension towards mainlanders except for the fact that a former manager and consultant seconded from the Ministry of Information Industry's CEC (China Electronics Corporation) to one of the Big Three essentially evaluated this firm's capabilities in exactly the same terms (Interview 247). This interlocutor also said that the other large Chinese computer makers operated in the same manner. According to a number of interviews, to the extent that the mainland firms had notebook production, it was the final assembly of kits of semi-assembled notebooks produced for them by their Taiwanese counterparts. Indeed, one firm had moved its final assembly factory from southern China to greater Shanghai because once its suppliers of the semi-knock-down kits moved north, the firm found itself incapable of upgrading or even managing production at such a long distance.

What has sustained many local firms is government support in the form of finance and procurement. A remarkable confession of this widely understood but politically sensitive fact came from a high-level executive for another of the Big Three. This executive readily admitted his firm's reliance on Taiwanese for semi-knocked-down kits (sub-assemblies that the final assembler essentially just has to screw together) for notebook computers and a host of other products. This statement came as no shock even though some firms try to give the best face to their technological dependency. What was surprising was his lack of worry over the imminent threat from big foreign brands armed, he conceded, with better technology, service and branding. With entry to WTO, the restrictions on foreign-controlled Chinese sales channels would be lifted and the Chinese government would face international legal pressure to open up government procurement to foreigners. Yet, in spite of all this, he was not worried. He explained his blasé attitude by telling me that the Chinese government is determined to continue to support local brands despite liberalization of retail and procurement. His belief that things would remain as they were prior to WTO was not blind faith, but based upon discussions between local industry executives and the government. While the WTO would try to enforce its laws, under-the-table agreements between the Chinese state and the major domestic firms were working to continue the business as usual of extensive government purchasing of major local IT firms' products. He emphasized that one would never see any public pronouncements by the government on these pro-domestic policies for the obvious reason that they would encounter foreign opposition. Nevertheless, he stressed that these policies were all designed to keep the foreigners out. He added that a particular concern on the part of the Chinese government was to prevent dependence on foreign technology, especially in light of the government's drive to "informationalize" (i.e. computerize) the government's large bureaucracy. As the empirical chapters will show, the irony of this Chinese technonationalism is that China through such technonationalist policies has unintentionally undermined domestic technological efforts and exacerbated the very dependency it fears.

3.1.2 Supplier Networks for Foreign Notebook Manufacturers

Even though the local Chinese notebook brands have no design and few manufacturing capabilities in notebook computers, another route hypothetically could be available for development of these skills. Foreign firms could utilize local suppliers to aid in the manufacturing process and through these suppliers pass on technology to the host country. This method was a prominent part of acquiring technical skills in Taiwan's consumer electronics and computer industries as well as earlier industries, such as textiles (Kawakami 1996; Fuller 2002; Amsden and Chu 2003; Evans 1995). Unfortunately, Chinese suppliers to foreign notebook manufacturers are conspicuous in their absence.

Taiwanese firms have captured the largest share in notebook manufacturing with over 60 percent of the world market.[84] The former leaders, the Japanese, are a distant second. The Taiwanese began to move notebook production to China in the late 1990s. The remaining large Japanese in-house manufacturers of notebooks, Sony and Toshiba, did not move production to China until 2001-2002. Furthermore, the Japanese are not doing much more than final assembly of these products (Interview 151 and an interview with one of the Japanese notebook manufacturers in Japan in 2002) in China. In contrast, the Taiwanese conduct virtually the whole manufacturing process in China. Given the longer time they have spent manufacturing notebooks in China, the Taiwanese would be more likely than the recent Japanese arrival to have outsourced to local suppliers. Nevertheless, the Taiwanese firms do not make use of local suppliers and rely on relatively closed networks of suppliers brought over from Taiwan.

To collect information on the Taiwanese notebook supplier networks, I interviewed 11 of the 12 extant Taiwanese firms producing notebooks in China.[85] Of the eleven firms interviewed, I had Chinese plant visits at ten of the firms. Given that the

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[84] The market share depends on who does the counting. Taiwanese sources, such as MIC, place Taiwan's market share well north of 60% whereas a recent estimate by Morgan Stanley placed Taiwan's share slightly lower than 60%.

[85] Technically, I interviewed all twelve firms, some of them multiple times, but I excluded one firm from the interview count because the interview took place under the Industrial Performance Center's Globalization Project before the firm had notebook production in China. Furthermore, this firm is notoriously close-mouthed about its operations and very little data was gathered during that interview.

notebook plants are clustered in a few industrial parks in Greater Shanghai, I was able to gather information on the other plants in the vicinity as the firms are in close contact and often use the same suppliers. The two exceptions to this clustering effect are Arima, a minor notebook manufacturer located in Wujiang of Suzhou Municipality, and Quanta located in a relatively remote county of Shanghai. The latter firm is not located in close proximity to other notebook manufacturers although it is an approximately 30 minute drive from the largest cluster of them all, the Kunshan National High-technology Park, which contains half of the twelve Taiwanese notebook manufacturers (Mitac, Compal, Wistron, Elite, Twinhead and Kapok). The other firms are all near at least one other notebook producer. Inventec and AsusTek[86] both have plants in central Shanghai. FIC, Uniwill and AsusTek all have plants in central Suzhou City.[87]

Excellent recent survey work on Taiwanese IT production in Suzhou Municipality shows precisely the lack of mainland suppliers in Taiwanese IT networks generally and the relatively closed nature of the notebook supplier networks (Yang and Hsia 2005). Surveying 28 major Taiwanese manufacturers in Suzhou, including the nine notebook firms there, Yang and Hsia find little localization to mainland firms. They measure the value of procurement decisions made by the local affiliates of the Taiwanese firms relative to the total product value (the P-index). They measure the value of locally procured parts relative to the total product value (the L-index). Yang and Hsia also

[86] It is rumored that AsusTek took over the failed Legend notebook factory in Shanghai. Legend had thought it could try to make notebooks on its own, but discovered that it really did not have ability in this area beyond putting plastic cases on Taiwanese-produced notebook according to a Chinese government official who has worked in transferring technology to China's national champions in this sector (Interview 247).

[87] Suzhou Municipality refers to the prefecture-sized jurisdiction, whereas Suzhou City refers to the county-level jurisdiction under Suzhou Municipality. The distinction is confusing as the Chinese character used (*shi*) has been the same for both jurisdictions ever since Jiangsu Province abolished the use of the term prefecture (the Chinese character *fu*) in the mid-1980s. To differentiate the two in Chinese, additional terms have to be added in front of the phrase "Suzhou city/municipality."

measure the number of new suppliers' value in the total product value (the O-index). The D-index measures the proportion of total product value imported from Taiwan. Finally, the M-index measures the proportion of total value procured from local Chinese firms.

The results of the survey show quite a low level of mainland firm participation in these networks. Local Chinese firms provide only 6.6% of the total value despite local affiliates controlling most of the procurement decisions (69.4% of the total value). This figure is even more striking when one looks at the notebook firms. For notebooks, local Chinese firms provide only three percent of value. According to my interviews, such a low percentage is not surprising given the fact that these local firms do simple metal bending activities or other such low-technology operations. As my interviews suggested, the notebook firms procure much of their components locally—53 percent of their value from locally based foreign-invested suppliers (mainly old suppliers from Taiwan)—without Chinese suppliers making any significant inroads.

What is surprising is how low the local Chinese procurement is relative to the openness of the networks. While only 19 percent of value comes from new suppliers (new to the particular network, not necessarily new firms), local Chinese firms only capture one third of these opportunities. In notebooks, local Chinese firms capture less than a quarter of the value awarded to new suppliers. The new suppliers appear to be Taiwanese suppliers that expanded their customer base when they followed their main customer(s) to the mainland.

Table 4.4 Related indices of Taiwanese IT Manufacturers' Supply Chains in Suzhou Municipality

Source: Yang and Hsia 2005: 22-23.

Company/product	P-index	L-index	O-index	D-index	M-index
Average of the 28 companies	**0.694**	**0.556**	**0.191**	**0.183**	**0.066**
Coefficient of variation of the above companies	**0.222**	**0.239**	**0.497**	**0.523**	**0.741**
Average of notebook companies	**0.62**	**0.53**	**0.13**	**0.17**	**0.03**
Average of LCD companies	**0.70**	**0.58**	**0.20**	**0.15**	**0.05**
Average of motherboard companies	**0.71**	**0.53**	**0.23**	**0.26**	**0.11**
Darfon Electronics (keyboards)	**0.95**	**0.75**	**0.35**	**0.20**	**0.15**
Ji-Haw Industrial (cable connectors)	**0.79**	**0.89**	**0.42**	**0.05**	**0.21**

The low level of Chinese participation in these production networks looms larger than the 19 percent average of the 28 firms when one factors in the value of the different products. Simply put, keyboards and cable connectors, are low-technology low value-added components, and they have much higher levels of value contributed by local Chinese firms. As one goes into higher technology higher value-added components and end products, the level of local Chinese firm participation drops. Motherboards procure eleven percent of their production from local Chinese whereas notebooks, the highest value product in the list, procure only three percent. If calculated in value-weighted terms, the general M-index would be much closer to .03 than to .191.

One could argue that the inclusion of more and more technologically sophisticated suppliers is simply a function of time. With the passage of time, one would think that localization (the usage of Chinese suppliers) would increase. However, an examination of the operations of Taiwanese firms in southern China does not suggest that time will resolve this issue. Before investing in Greater Shanghai, a number of Taiwanese firms producing desktop PCs and networking equipment set up manufacturing operations in the Pearl River delta in southern China. I interviewed seven of the large

Taiwanese IT operations. I did not interview one major PC manufacturing site and several of the large motherboard manufacturers, but I uncovered no secondary sources to indicate that these operations were different from the ones I interviewed. Indeed, Yang and Hsia argue that the Taiwanese operations in the Pearl River Delta have less localization (whether or not localization to mainland Chinese suppliers) than Taiwanese firms in Suzhou (Yang and Hsia 2005: 23-24). My interviews with the PC firms that set up in this area in the mid-to-late 1990s revealed that they did not use any significant local Chinese suppliers. If their local suppliers were not originally from Taiwan, they were other foreign-invested firms in the area (Interviews 170; 210; 219). These other foreign enterprises seemed to be principally Hong Kong-invested firms except for the one firm that had its supplier-list dictated by its customers. This firm remained in the OEM-mode where the customer supplies the designs of the products to be manufactured. Since its customers were primarily American, relatively more of the vendors they designated tended to be the Chinese plants of American contract manufacturers (Interview 170). The two largest network equipment makers from Taiwan also claimed that they were willing to use local Chinese suppliers, but did not do so because they could not find any good ones (Interviews 92 and 93).

The fact that five of the firms had been manufacturing in China for five years or more without significant outsourcing to local firms suggested that the local firms would never be significant suppliers. Even the firm that had been manufacturing for over a decade in China and had a huge production site employing 20,000 workers in multiple factories still had not employed local suppliers to any significant degree. What is more

Table 4.5 Suppliers of Firms in Pearl River Delta

Company	Date of Production in Pearl River Delta Site	Products	Interview Dates (Includes additional interviews with HQ and other plants)[88]	Significant Mainland Suppliers
TW1	1992/1993	power supplies	2000; 2002 (twice)	No
TW2	1996	network equipment	2002 (twice)	No
TW3	1996/1997	network equipment	2002 (twice)	No
TW4	1996	desktop PCs	2002	No (customer-approved vendor list)
TW5	1997	motherboards; desktop PCs	2000; 2002; 2003	No
TW6	1999	motherboards	2000; follow-up with manager in 2002	No
TW7	1999	desktop and notebook PCs	2000; 2002 (twice)	No

remarkable is that this behavior comes from a firm that has a China-based operational strategy (Interview 220). Yet even as this firm was ramping up production and R&D in China, it was not reaching out to local Chinese firms. Production was localized, but the local suppliers were primarily Taiwanese and Hong Kong firms.

3.2 The Chinese Computer Firms

3.2.1 Lenovo: A Legend in Its Own Mind

Lenovo, formerly known as Legend, has been at the forefront of China's development of technology companies and of so-called privately managed (*minying*) firms (see A. Segal 2002) over the last two decades. While some continue to invoke

[88] The initial interview counted was the plant visit interview. The additional interviews are not always plant visits, but they are interviews that provide information on the Pearl River Delta manufacturing operations.

Lenovo as a private firm (Y. Huang 2003, 2005FT), quasi-private firm (A. Segal 2002; B. So 2001) or product of successful enterprise reform (Gu Shulin 1999) that has contributed to China's technological development, an examination of Lenovo's record of technical accomplishments reveals a different story. Like Founder (discussed below), Lenovo had an apparent burst of innovation soon after its founding followed by a rapid succumbing to the disincentives to innovate. Lenovo's decline followed close on the heels of the firm becoming firmly connected to the Chinese state.[89]

Lenovo did start on the *mao gong ji* (trade to manufacturing to technology) trajectory as a firm trading in computer parts in Beijing[90]. However, soon after its start, Lenovo skipped over manufacturing straight to technology or innovation. Lenovo was the first firm to develop and successfully promote a Chinese-language add-on card for PCs in 1985. To be exact, the Chinese Academy of Sciences (CAS) created this technology before transferring it to Lenovo so this spurt of innovation cannot be directly attributed to Lenovo.

Indeed, Lenovo was a by-product of CAS' Institute of Computer Technology's (ICT) desire to create profits in the emerging market of the reforming economy that encouraged the institute to set up a firm to sell ICT's technology. ICT created a firm, called ICT Company, and gave the firm full access to ICT's technology resources and freedom to use the ICT name. ICT also lent the firm 200,000 RMB and granted it full autonomy. Eleven former employees of ICT started the firm and they then persuaded Ni

[89] Despite many people calling Lenovo a private or privately managed firm, the firm's own executives acknowledge the large state stake in the firm. As recently as 2003, the CFO of Legend Jituan (Legend Group), the Hong Kong-listed entity, acknowledge that the state, presumably through CAS, held 65 % of Legend Jituan Konggu (Legend Holdings) which in turn owned 57% of Legend Jituan (Bradsher 2003). In any case, the two entities were basically the same firm using the same personnel until 2001 when the Legend Group Holdings was hollowed out and left with only a few old timers (Interview 46).

[90] Much of this history of Lenovo is based on the account of the firm in Qiwen Lu's *China's Leap into the Information Age* (2000): 63-103.

Guangnan, the inventor of ICT's Chinese word-processing technology, to join them. This product quickly dominated the Chinese market given the poor and often complex-character base[91] of the foreign products.

However, soon after Lenovo's triumph of *ji* (technology), the firm reverted to a path of *mao* (commerce) that would prove a slippery slope into technological senescence. Commerce does not necessarily lead to this result, but in the context of Lenovo's evolving relationship with the Chinese state, this proved to be the path to perdition. As foreign firms were not allowed to distribute their computer products until 2003, AST, one of the largest computer firms of the 1980s, hired Lenovo as AST's sole distributor in China in 1987. This relationship drove Lenovo's expansion of its national distribution network in the late 1980s. This network became a key to Lenovo's future growth.

Due to the prevailing hostile attitude towards firms outside the formal state sector and the jealous guarding of its bureaucratic interests, Ministry of Electronics Industry (MEI—the forerunner of Ministry of Information Industry, abbreviated as MII) did not grant licenses for PC manufacturing to firms outside of the state enterprise system. With its large distribution network for computers and computer peripherals, Lenovo desired to start manufacturing its own PCs. Given the MEI restrictions, Lenovo decided to invest in Hong Kong. Lenovo found a Hong Kong partner, Daw, and a Chinese state partner, China Technology, to create Hong Kong Legend Technology Incorporated. China Technology was a critical partner as this firm was able to acquire loans through the state

[91] The People's Republic of China uses a simplified Chinese character system instituted after the 1949 revolution. Hong Kong and Taiwan use the traditional or complex Chinese character systems. In the initial stages of the PC era, foreign firms employed Taiwanese or Taiwanese-Americans to do much of the Chinese software, but these engineers usually designed software using the complex characters so it was not very useful for the PRC market. For a Western, a useful analogy would be imagining Americans trying to use software designed for users of the Cyrillic alphabet.

banking system. Quickly after forming Hong Kong Legend, the new firm acquired a small local motherboard (the electronic board, which holds chips, and is the core of the computer) firm, QDI.

QDI had rather limited technology resources. In fact, the firm had just two engineers and they left the firm soon after its acquisition by Lenovo. In the early days of Lenovo's motherboard business, much of the development of motherboards rested upon the shoulders of Ni Guangnan. By 1990, the group managed to create two R&D teams under Ni Guangnan. The one in Beijing did localization work—creating Chinese language software for computers—and tested of the motherboards. The team in Hong Kong did the hardware design for the motherboards. Lenovo decided to enter the PC market with its own brand PCs. With its manufacturing outside of China, it longer needed MEI's approval. The firm however began to set up production in Shenzhen as a nominal JV (joint-venture) with a foreign firm, QDI, and two domestic ones, Beijing Legend, and Shenzhen Science and Technology Industrial Park Corporation. QDI and Beijing Legend each had 45 percent and Shenzhen had ten percent.

Legend's motherboard business expanded rapidly. The firm became the fifth largest motherboard supplier in the world supplying five million motherboards. Seventy percent of the business was overseas. At the same time, the firm began to sell PCs successfully in China, surpassing MEI's Great Wall Company as the largest Chinese PC firm and trailing only IBM and AST in the market in 1993. Even before this, MEI reconsidered its discrimination against this non-SOE start-up and designated the firm one of the national computer production bases and the firm was included in the still powerful national production plan in 1992 (Lu 2000: 91). This act heralded the beginning of

Lenovo's entrance into the fold as a state-favored firm. Lenovo was able to endure another three to four years of losses on top of the losses suffered in 1991 and 1992 (Lim 2002: 8). Without state support, this perseverance would have been unlikely. The consequences for Lenovo's innovation, however, were disastrous.

Over the next several years, Lenovo's share of the Chinese computer market increased. Lenovo moved its production site to an underdeveloped area near Shenzhen called Huiyang and concentrated production there. At the same time, Lenovo became more embedded in the state's patronage network. It won a bid for a large national information technology tender in 1996. The state's direct procurement jumped from an already substantial 21 percent to a substantial 31 percent (see Table 4.6). This may have been the push that persuaded Yang Yuanqing, the manager in charge of the PC business, to give the business one last try. Indeed, even after losing money for the previous five years, the firm still slashed prices (Lim 2002: 8). In 1997, it surpassed the major foreign providers to become the largest PC vendor in China.

Inside Lenovo, all was not well however. The chief of technology, Ni Guangnan, wished to pursue continued investment in technology so the firm could retain its software market for Chinese software for PCs and expand into new areas, such as semiconductors. His emphasis on technology came into conflict with CEO Liu Chuanzhi's vision of Lenovo as a firm that would make a gradual transition to technology. These strategic differences came to a head in 1995 and Ni Guangnan, the engineer responsible for basically all of Lenovo's technical achievements, was ousted from the company (Q. Jiang *et al* 1999). Entering the state's favor undermined the incentives to innovate because Liu realized that the firm could continue to enjoy state support even while foregoing the costs of technological development for the foreseeable future.

Even as Lenovo gained market share, the firm lost ground technologically. Foreign software vendors, such as Microsoft, created good Chinese language programs for PCs that completely displaced Lenovo from that market. More disturbingly, the heart of Lenovo's technical-manufacturing nexus, motherboards, gradually lost ground. QDI was not even a global top-ten motherboard firm by 2000. By 2001, Lenovo had to look outside the firm for the latest motherboard technology because it had lost its capacity to design quality motherboards. The firm was also already purchasing heavily from the main Taiwanese competitors to QDI by that time (Interview 72).

For motherboard technology, Lenovo tried to set up a JV with one of Taiwan's largest motherboard firms, Gigabyte. The firms set up a JV in 2001. The claimed purpose was to jointly develop motherboard technologies. I visited the Lenovo facility in Shenzhen where the two firms were supposedly cooperating on R&D. What I saw was a team composed entirely of Taiwanese technical staff from Gigagbyte's factory in nearby Dongguan assisting in the transfer of their designs to Lenovo. A discussion with one of the senior Taiwanese managers from Gigabyte at Lenovo confirmed that Lenovo was not taking any active part in development of new motherboard products as part of the JV with Gigabyte. Soon after, Gigabyte, realizing that Lenovo's scheme for the JV was to receive Gigabyte's technology without providing adequate compensation, cancelled the JV (Yi 2003)[92]. Outsiders correctly predicted that Lenovo would exit the motherboard business

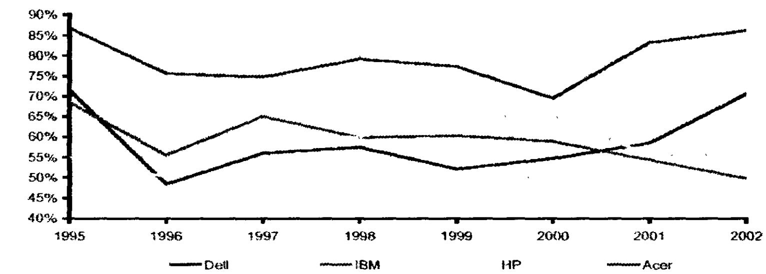
[92] The article by Yi says that Gigabyte had hoped to realize profits through saving on joint procurement with QDI. With QDI in trouble and a declining market share, Gigabyte realized that this plan was impossible and cut itself off from QDI. A PowerPoint presentation by the JV partners dated September 18,

due to the loss of competency in this area (Zhang and Wan 2003: 5). Legend then sold half of QDI to another mainland firm, Ramaxel, at the end of 2003.

At the same time that Legend could not retain its technology, it also suffered from having a poor brand image. The whole point of having a brand is to have a brand premium, but Legend did not enjoy any such premium when compared to the international brands. Indeed, even compared to a second-tier brand, such as Acer, Legend's ASP (average selling price) was much lower (Figure 4.1). Consequently, the firm was earning very thin margins on its computers. Even according to a survey conducted by Lenovo's own government booster, MII, Chinese perceived that local brands had a price advantage but not a quality advantage over the foreign brands (Lim 2002: 10). In one analyst's assessment, Lenovo itself realized that it was so far behind the foreign majors that it was not capable of improving brand perception and thus pricing power in PCs alone. Instead, Lenovo was trying to improve its brand perception by diversifying into an array of consumer electronics (Lim 2003: 12). What's worse, Lenovo was earning very little profits from the computers it was selling. The state procurement was essentially subsidizing Lenovo's losses in the commercial sector. For the five years ending in March of 2002, it is estimated that Lenovo's EBIT (earnings before interest and taxes) was a "razor-thin 0.6 percent (CFO Asia, February 2004)." It is highly likely that with taxes and interest payments Lenovo was in the red over this five-year period. Then again, like many state-favored firms, Lenovo may not have had to pay its interest on loans from the state banking system.

2001 also gives the impression that Gigabyte planned to capitalize on greater scale economies as Lenovo had nothing else to bring to the table besides Lenovo's own motherboard demand and production.

Figure 4.1
Legend's ASP (average selling price) as % of Major Foreign Brands



Source. IDC, UBS Warburg estimates

Behind this gradual withering of Lenovo's technical capabilities was generous state support. In the late 1990s, the state through both government and educational institutions purchased up to half the computers in China. Even in 2002-2003, Lenovo was selling over one quarter of its products to state agencies and state educational institutions and the firm was projected to continue to do so for the foreseeable future[93] (Zhang and Wan 2003: 5). On top of this, some of Lenovo's corporate sales were sales to state-favored firms with the idea that they were strongly encouraged by the government to buy from Legend and other state-favored firms (Interviews 64, 222). For the pre-2002 statistics (Table 4.7), it is not clear if the source counted education as part of the sales of the state. Then again, the education sales were much lower at that time as the state had not started the major procurement drive for universities that began in 2000.

To make matters worse, Lenovo has been facing increasing competition from the foreign brands in the PC market (Wang 2004). After the lifting of the retail network ban, direct sales giant, Dell, was unhindered in the market. In 2003, Dell increased its Chinese sales 45 percent and now is third behind Lenovo and Founder. Lenovo itself has

[93] Zhang and Wan (2003) forecasted sales for Lenovo through 2007 and the state share (government plus education) never dipped below 27 percent.

Table 4.6: Identifiable State Procurement as Share of Legend's Sales
Source: "Legend Holdings: Thinking Different," Nomura Securities, October 3, 2001 and Zhang and Wan (2003).

Year	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2002**	**2003**
State Procurement as Share of Sales (%)	13.9	21.7	31.3	28.3	27.8	25.9	25	27.4	28.2

experienced stagnant sales in a growing market (June 3, 2004, WSJ: B3). To try to get an end run around the increased competition, Lenovo has been expanding its presence in the countryside, but these areas can only buy very low-priced products (ChinaTechNews.com, August 5, 2004).

Lenovo has also been unsuccessful in expanding into new markets. As discussed under the section concerning notebooks, Lenovo like other domestic Chinese firms has been dependent on Taiwanese ODM firms for its notebooks. Of the Big Three, Lenovo has tried the hardest to acquire notebook technology, but its efforts have thus far failed. First, Lenovo tried to set up a joint-venture with Toshiba in Shanghai with the idea of learning from its JV partner. Once Toshiba realized how little Lenovo actually knew about notebook manufacturing and how much it wanted to learn from Toshiba without adequate compensation, Toshiba grew leery of the JV project. Lenovo was stuck with an empty notebook production line it had no idea how to run. Eventually, Lenovo sold this factory to a Taiwanese firm, which is believed to be an affiliate of AsusTek, the large motherboard and notebook manufacturer (Interviews 201; 247).

After the fiasco with Toshiba, Lenovo tried to learn notebook manufacturing from one of its major suppliers of notebooks, FIC. As FIC is a larger player in desktop rather than notebook manufacturing, the quid pro quo for winning the Lenovo order was to let some Lenovo engineers come to Taiwan to learn some of the technology. The arrival of the engineers from mainland China, the place to which all of Taiwan's manufacturing seemed to be moving, understandably caught the attention of Taiwan's press and raised the level of economic angst felt in Taiwan. Nevertheless, sources close to FIC laughed at the attempts of Lenovo to learn their technology. According to their judgment from having interacted with the Lenovo engineers extensively, the Lenovo engineers did not understand how complex thermal conductivity problems are in notebook computers (i.e. if notebooks are not designed well, they easily heat up and burn out) and FIC did not do anything to help them learn these skills. In FIC's judgment, it would be a very long time before Legend would be capable of designing a notebook computer on its own. Other industry insiders agreed (Interviews 112, 247). Two years later, there is no evidence that Lenovo has been able to do so. Given the marketing skills aimed at pleasing state officials and nationalist sentiment alike (the technology tales referred to at the beginning of the chapter), if Lenovo had been able to achieve competency at notebook design and manufacturing, they would have most certainly crowed about it. Thus far, they have been silent.

Similar scenarios have played out with D-link, one of Taiwan's largest telecommunication equipment ODMs, and with AOL Time Warner. Lenovo constructed a JV between D-link and Lenovo's subsidiary, Digital China (Shenzhou Shuma), to sell SOHO (small office and home office) telecommunication equipment in the Chinese market. However, Digital China brought nothing to do the deal except its sales network and clearly wanted to acquire D-link's technology for use outside of the JV so D-Link broke the deal off (Interview 155, 171). AOL Time Warner and Lenovo were supposed to create an Internet portal JV, FM365.com, but this venture failed as well. By Lenovo's own admission, they misunderstood the impact that new technologies, such as wireless LAN, would have on the viability of this operation. In any case, while this venture lasted, AOL Time Warner was supplying all the technology in terms of applications and portal management tools (Denlinger 2004). Finally, Lenovo announced that it was entering the cellular phone market. Lenovo acquired an 80 percent stake in Xoceco in Fujian because Xoceco had a license to sell mobile handsets. Despite the hoopla surrounding Lenovo's entry into the handset business, Lenovo has a very weak R&D team in mobile handsets (Interviews 293, 317, 322).

3.2.1.1 Lenovo and IBM

IBM has been trying to rid itself of its loss-making PC division for several years. After a trip by CEO Samuel Palmisano to Beijing to meet an unidentified high-level government official involved in economic policymaking in 2003 in order to receive the state's permission to engage in talks with Lenovo (Lohr 2004), IBM approached Lenovo with a sales proposal. Lenovo decided to buy IBM's PC division for cash and stock. While this purchase catapults Lenovo into third place behind Dell and HP in global PC market share, it further erodes any profitability within Lenovo because of IBM PC's poor business performance. IBM's PC division has lost money every year since 2001. The division lost almost one billion US dollars for the three and a half years up to June 30 2004 (WSJ, January 5, 2005: B5). What's worse is that IBM's financing of PCs, the crucial revenue-generator that has made the PC division intermittently profitable, will remain within IBM even while Lenovo has responsibility and cost for designing, producing and distributing the PCs (Santiago 2004: 2). Lenovo will also have to pay IBM for warranties and technical-support of the computers.

Lenovo does receive outright is the Thinkpad label, but there are questions about how much this label will be worth when attached to the Lenovo brand[94]. As shown above in Table 4.8, Chinese do not think much of the quality of local brands. Anecdotal evidence suggests the label could take a hit. Foreign buyers of Thinkpads are concerned about potential quality issues (AWSJ, December 13, 2004: A8). Even Chinese owners of Thinkpads have declared they will no longer buy the product FT, December 9, 2004) and IBM's workforce in Shenzhen seems put off by the prospect of working for an inferior domestic brand (FT, December 13, 2004: 26). Basically, analysts and competitors are already operating on the assumption that Lenovo will not be able to maintain the market share previously held by IBM's computers because of Lenovo's poor reputation (FT, December 9, 2004; Santiago 2004). Recent analyst reports see the deal as actually a boon for HP and Dell as they will be able to win over many of IBM's accounts (Santiago 2004; Tseng 2004). A slew of analysts fear the acquisition will also prove to be a drag on Lenovo's ability to realize profits in PCs (AWSJ, December 10, 2004: A8).

[94] Lenovo is allowed to co-brand the Thinkpads with IBM for 18 months i.e. list the IBM logo on the Thinkpads. Many reports state that the co-branding will last five years, but IBM has the option to end the co-branding after 18 months.

Table 4.7 Chinese Regard Foreign PC Brands as Quality Brands

Local advantages over foreign	Urban households
Price	76.1%
Quality	21.1%
Service	69.0%
Specifications	14.6%
Others	2.8%

Source: MII Research, 2000

The one gem Lenovo has acquired is IBM's 1900-person R&D facility in North Carolina. This facility was responsible for research and design for IBM's PCs. While this finally gives Lenovo some technology, it follows the prototypical path of buying foreign technology rather than spending resources on learning and creating technology at home (R. Wu 1996; Jefferson *et al* 1999). Even if Lenovo is able to maintain these assets, which is doubtful given the pressure from the major brands to steal market share, this research center in North Carolina contributes nothing to China's technological-cum-economic development, the object of this study. All the indicators thus far suggest that the R&D functions are going to stay put in North Carolina. Indeed, the HQ of the firm is moving to New York with only one top executive from the Chinese side (WP, December 9, 2004; AWSJ, December 9, 2004).

Rather than following the *mao gong ji* strategy it claims to have followed, Lenovo has gone from technological innovation to stagnation. When a semi-neglected firm on the periphery of state favor, it had harder budgets that gave it some pressure to try to create new and innovative products for the Chinese market. Once it became successful, its incentives to continue to pursue technology were undermined by state largesse. In the most recent phase, Lenovo has made some feeble stabs to develop technology, but the incapacitation engendered by state-generated soft budgets have worked to make sure these attempts have fallen flat. Instead of moving from commerce to manufacturing to technology, Lenovo has followed an ignominious road from technology to state-sponsored technological disinvestment to general firm incapacitation.

3.2.2 Founder: From Innovation to State Dependency

Founder (Fangzheng) followed a trajectory quite similar to Lenovo's. The firm started out with a bang of innovation, albeit state-sponsored innovation. The firm created a new printing technology for the Chinese characters specific to mainland China's market. From this high point, Wang Xuan, the founder of Founder, witnessed the firm grow in size, but wither in terms of technological capacity and financial soundness.

Founder was one of the first and most successful of the so-called school-based enterprises (*xiaoban qiye*).[95] Wang Xuan was a professor in the Department of Electronics at Beijing[96] University (Beida) when he joined a government project, Project 748. The project created a way to print Chinese characters for mass printings, such as newspapers, or electronic publishing systems technology in industry jargon. MEI's Project 748[97] was inspired by visits to Japan following the opening of diplomatic relations with Japan in the early 1970s. Wang created an innovative mathematical solution to the representation of Chinese characters in computer systems that saved

[95] The following history of Founder is based primarily on Lu (2000: 104-149).
[96] Beijing Daxue (Beijing University), like Qinghua Daxue (Qinghua University), uses an old romanization for its official English name. Thus, Beijing Daxue is Peking University and Qinghua Daxue is Tsinghua University. To avoid confusion, I use the standard current *pinyin* romanizations, Beijing and Tsinghua.
[97] At that time, MEI was referred to as the Fourth Ministry of Machinery. MEI led the project, but other ministries were involved in the initial planning, such as the First Ministry of Machinery (later just called the Ministry of Machinery).

critically on then scarce computer memory. In September of 1976, Wang's idea won over the office in charge of Project 748, and Beijing University in conjunction with Wang took the lead in the project.

Project 748 and its successor, Project for the Renewal of Publishing and Printing Industry Technology and Equipment (backed by Vice Premier and Minister of the State Planning Commission, Yao Yilin), finally resulted in a mass production model in 1987. Throughout this time, Professor Wang and his Institute for Computer Science and Technology (ICST) at Beijing University were at the core of the research. ICST created both the system design and software for the electronics publishing system. MEI assigned a MEI-owned firm, Weifang, to build the product.

Two years prior to the creation of a production-ready publishing system, Beijing University, heeding the government's call to improve China's science and technology system, decided to found a company to commercialize technologies created at Beijing University. The new firm was called Beida New Tech Company. From the beginning, ICST served as the source for Beida New Tech's source of technology. In the beginning, Beida New Tech earned money from wholesaling computers between Guangdong and Electronics Alley, a commercial area right next-door to Beida. The initial investment came from Beijing University and a rural township in Beijing Municipality[98].

ICST and Beida New Tech recognized that the technology sold by Weifang as the "Hua-guang" publishing system was actually ICST's. Furthermore, Weifang's machines had seriously problems with overheating. ICST felt this problem was due to Weifang's manufacturing process and that it hurt the image of ICST's technology. In 1988, Wang

[98] Chinese directly-ruled municipalities (Tianjin, Beijing, Shanghai and Chongqing) all cover a very large amount of territory so they have rural, agricultural areas far from the dense urban centers we commonly associate with the municipalities of Shanghai, Tianjin, Beijing and Chongqing.

successfully petitioned the Office for the Renewal of the Publishing and Printing Industrial Technology and Equipment, the government organ in charge of the printing and publishing project, to allow Beida New Tech to go into the publishing systems business in competition to Weifang. Given Weifang's right to Hua-guang name, Beida New Tech changed its product name to Founder in 1991. The company's name changed in 1993.[99] By 1995, Founder's publishing system had captured 75 percent of the Chinese market. The same year, Founder officially took over the ICST as the company lab and Wang Xuan was made chairman of the firm.

While Founder had created a superior product to Weifang's and had created the basic technology for both products, the firm made a beeline to the state trough following the success of its electronic publishing system. The publishing system business is controlled by the state as the major customers are state-owned newspapers (newspapers are still generally controlled by state organs in China). In Founder's new lines of business, state patronage would also be critical. Founder began to enter computer retail in 1993 through an agreement to sell DEC (Digital Equipment Corporation) products in China. Founder soon learned about the computer market and decided to launch its own brand in 1995. Behind this launch was government support in terms of lucrative contracts for the Three Golden Projects (the Golden Card Project for banks, the Golden Gate Project for trade and the Golden Bridge Project for the telecommunications sector) in 1994. The state hired Founder to do the systems integration work, essentially linking the computer systems together, for these projects. The year before the projects Founder had two million Hong Kong dollars (just .3 percent of Founder's revenue) in systems

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[99] Others disagree with the dating of the name change in Lu's account (Lu 2000: 123) and claim Founder as a firm also dates from 1991 ('Founder Holdings Ltd," www.chinaonline.com July 24, 2000, downloaded on January 17, 2005).

integration revenue. During the second year of the project, this figure had loomed to 158 million or 14 percent of Founder's total revenue. Equally as important as the revenue generated from the project was the opportunity to sell computers as part of the systems integration package (Lu 2000: 140-141). With this government support, Founder cracked the top ten computer vendors in China for the first time (F. Lai 1997: 12).

What has happened to Founder? It is still feeding at the government trough and has not been able to break out to the world beyond China's state-controlled newspapers in its previous core technology. The firm, like many other state-connected firms, has taken the route of being the systems integrator intermediary between foreign firms with the actual skills now demanded in integration work and the state agencies that want to buy such services from domestic providers (F. Lai 1997: 10 and Interviews 54 and 64). With Wang Xuan ill and possibly dying, Founder seems to be without any innovation from the old standby of publishing systems or new products. Indeed, Wang himself in 1999 admitted as much.

> Wang Xuan...finally acknowledged the company's long-standing problems in management and operations, which he said had been hidden by the high profits generated by early technological achievements. Emphasizing that management reform was particularly critical to an enterprise as it entered its maturity, he brought Li Hansheng from H-P in April 1999 to revitalize the company...But the financial losses abounded and began to destroy investor confidence ("Founder Holding Ltd." China Online).

Instead, state-sponsored system integration and selling low margin computers now create the bulk of revenues for the firm. There are strong indicators that all of this government-support is leading to widespread incapacitation within the firm. Founder appears to have transformed from a technology creator to an asset destroyer. Revenues are not any higher in 2003 than they were four years earlier in 1999 and 1999 revenue was only marginally higher than revenue in 1996.[100] Founder's publicly listed entity lost money from 1998 through 2002 accumulating over 550 million Hong Kong dollars in losses, which it only slightly offset by 23 million Hong Kong dollars in profits in 2003.[101] Making Founder's financial picture worse is the fact that many of the losses from the later years do not likely reflect losses from the computer manufacturing side as those operations were moved out of the listed company and back into the Chinese parent in 1999.

By 2002, computers production and distribution outweighed the revenues generated by the sale of systems integration services as a middleman or front for foreign firms.[102] IT distribution alone was as large as the income from publishing systems and systems integration together. PC hardware sales were eight times the SI and publishing sales. By 2003, the PC hardware sales were ten time the stagnant sales of SI and publishing. While all of these sources of revenue were driven in large part by state procurement (Interviews 54, 64, 222), the revenues to be generated by being a middleman were small as Founder's role was easily duplicated by a number of other state-favored firms (Interviews 54 and 64) and electronics publishing systems had stagnated due to the fact that by the mid-to-late 1990s Chinese newspapers were only buying replacement systems. While Lenovo's PC sales to the state were at least slightly over a quarter of its total sales, a number of sources affirmed that Founder's sales to the state were likely

[100] Revenue in 2003 was 1.554 billion Hong Kong dollars and was 1,583 in 1999 (Founder Holdings Limited Annual Report 2003: 3). Revenue for 1996 was only 1.483 Hong Kong dollars (Lai 1997: 15).
[101] The financial data came from Chan and Kwong (2001) for 1998-1999, Leung (2002) for 2000-2001 and Founder Holdings 2003 Annual Report for 2002.
[102] Founder had deals with both IBM and Yahoo to allow these foreign firms to enter SI (government procurement) and Internet services (originally closed off to foreign investors) in China.

higher due to Founder's links to Beijing University, which in turn linked it to the education *xitong* (the network or "system" of ministries and other government units covering a single policy area). As mentioned earlier, the education system began a big drive to purchase PCs starting in 2000 so connections to the education *xitong* proved very useful to firms wanted to sell computers to universities (Interviews 222, 247, 40, 56, 104).

If Founder's good relations to the state were still in doubt, the firm was chosen as the only computer maker to take part in the State Economic and Trade Commission's plan to change Chinese firms into Global Fortune 500 enterprises in 1997. Founder was one of 120 Chinese companies to take part in this Large-scale Experimental Enterprise Group (*daxing shidian qiyejituan*) project (Lai 1997: 7; Founder's website at www.founder.com).

Wang Xuan, the power behind Founder, has also held high if mainly honorary positions within the government. He was Vice Chairman of the CPPCC (Chinese People's Political Consultative Conference), a body composed of CCP members and members of the other legal political parties, during the 8th (1992-1997) and 10th CPPCC (2002-2007). He served on the Standing Committee of the CPPCC for the 9th CPPCC (1997-2002). He also served as vice-chairman of the Education, Science and Health Committee of the 9th National People's Congress (1998-2002), the national legislature of China.

Founder had one good idea under state sponsorship and from that starting point the firm has been able to generate a stream of state patronage far beyond the scope of the original state project. This wave of government largesse has simply undermined the incentives and capacity to generate new ideas as Wang himself has admitted. There are even darker clouds over Founder however. The stagnant revenue and significant reported losses are signs that the firm has turned from being simply technological stagnant into a financial black hole on par with many of the formally state-owned firms.

3.2.3 Pigs at the Trough: The School-run Enterprises of Qinghua University

The fact that the other two large computer firms come from Qinghua University is not an accident. Qinghua is very proud to be justly known as the school of China's current and future generation of CCP leaders (C. Li 2001) as well as China's foremost university of science and technology. These firms have been able to parlay these connections first into the computer market and then into other areas offering substantial government procurement opportunities.

The two Qinghua enterprise groups, Tongfang and Ziguang, are large producers of desktop and notebook PCs respectively. Each has been able to become one of the Top Three in their respective arena in recent years. Their rise has been nothing short of meteoric, but has not been accidental. Through their institutional parent, Qinghua University, they are connected to the education *xitong*, a major source of procurement for their computer products (Interviews 247, 56, 40, 104). This connection and state-connections in general have proven very useful given that the government and educational markets have been the fast-growing and use local vendors almost exclusively according to a China-based industry expert with one the largest IT market analysis firms (Interview 112). One of these firms receives 35% of its computer revenue form the educational system alone before considering government procurement by the bureaucracy and SOEs (Interview 56).

The notebook PC brand, Ziguang, started in 1988 as a sales representative for foreign IT companies. The firm expanded to sell scanners for foreign firms, such as Taiwan's Mostek and Microtek, from 1992 to 1995. In 1995, the firm decided to launch its own brand of scanners. In 1998, the firm followed with its own brand of notebook computers and became one of the Chinese Top Three by 2000. The firm benefited from increasing government and educational procurement (Interviews 247, 104). The firm's IT products make up 70% of revenue.

The firm has expanded its product range from scanners, but has not expanded its technological depth. The firm essentially buys off-the-shelf products from the Taiwanese (Interviews 247, 248). This off-the-shelf buying is in sharp contrast to the behavior of European, American and Japanese customers of Taiwanese ODM firms, which have significant industrial and technical design input into the final product. Many would argue that the value in the brand comes from the design functions of brand firms. The only products Ziguang makes on its own are the low-end scanners, which even domestic allies of Ziguang claim are technically easy to produce. The dependence on Taiwanese suppliers across the spectrum of Ziguang's IT offerings is shown in the Table 4.8. The firm likely does not have high-end products in digital cameras and networking equipment because its Taiwanese suppliers do not have such products. In other words, their ability to enter new, potentially higher value-added markets is completely dependent on their Taiwanese suppliers having such capabilities.

For Ziguang, computers and peripherals are the major source of revenue (70%) and this segment is heavily supported by government procurement. For the rest of the company, there is a major profit-center in selling traffic control systems integration to the Chinese government through Ziguang's "environmental engineering center" (Interview 248). The one area that stands out as clearly unrelated to government procurement is the "bio-tech" company of Ziguang, which has HeiMei brand of toothpaste as its main product, but Ziguang only has a minority share (21.4%) in this Hunan Province SOE. Given that Hunan is also a relatively poor interior province, Ziguang may have invested in this firm as part of orders given to Qinghua to help out the poorer regions, similar to Tongfang's actions in Jiangxi (see below).

Table 4.8 Ziguang's Dependence on Taiwanese ODM Firms

Source: Interviews 41, 247.

Product (Increasing technological sophistication as move from top to bottom of this table)[103]	**High-end**	**Low-end**
Scanners	Mostek, Umax, Foxconn, BenQ (formerly Acer Peripherals)	Own production
Digital Cameras	No products in this segment	Various Taiwanese firms
Notebook Computers	Mitac, AsusTek	Uniwill, Twinhead
Networking Equipment	No products in this segment	Accton

Tongfang is also heavily dependent on IT products with little to show for it in terms of its own technologies. Tongfang was created from a bunch of non-educational units or nascent firms within Qinghua University in 1997 and was listed on the domestic

[103] It is arguable about whether Internet equipment or notebooks are harder to design and manufacture. The manufacturing of notebooks cannot be divorced from tricky design problems involving thermal conductivity in the products whereas network equipment manufacture is relatively straightforward. On the other hand, pure design (divorced from the manufacturing process) of networking products is arguably more difficult than pure design of notebooks (Interviews 247, 210, 211).

stock market the same year. These units were involved in air conditioning systems for buildings, data processing, Internet provision, computer manufacturing (on a very small scale—only ten thousand units in 1997) and chemical engineering.

In 2000, the computer division accounted for 51 percent of revenue, the IT services firm accounted for 9 percent of revenue, the chemical and ceramics division accounted for ten percent and the "nuclear engineering" division accounted for 30 percent of revenue (Tongfang 2000). This publicly announced distribution is likely skewed to make growth outside the core computer firm look more impressive. Both the main firm and the nuclear engineering firm, while bragging about Tongfang's diversification and the success of the nuclear engineering firm placed the nuclear engineering firms revenue at 10 percent of revenue, the chemical engineering unit at ten percent of revenue and IT (combining services and hardware) at 67 percent of revenue with the remainder scattered across a number of businesses such as electronic information systems for university libraries and data processing (Interviews 56,54,53, 34, 35).

Once Tongfang was created, it grew rapidly, fueled by even more rapid expansion in its computers sales. Total revenue increased ten fold from 1997 to 2000 from 385 RMB (over 46 million USD) to 5.3 billion RMB (640 million USD). The number of computer units sold expanded 80-fold from ten thousand to 800 thousand in the same period. However, there was no evidence that the firm was making any progress technologically. Nor was it very profitable. The computer business generated lots of cash flow, but there was no serious plan on how to build profits in this marginal business (Interview 56). Rather, in a similar fashion to Ziguang, the firm kept expanding into new government-protected markets.

Looking at Tongfang's expansion, its major businesses beyond computers are geared towards government procurement and fulfilling government missions. Tongfang Nutech, the nuclear engineering firm, is basically creating equipment to X-ray trucks and shipping containers for the China's customs officials. The IT services group within the computer firm aims to do what the other IT services units of the state favored firms do in China—act as a middleman between foreign firms with the technology and the government units that need to purchase these services. This division concentrates at the moment on selling to the "government" (somehow differentiated in Tongfang's view from the other state-controlled customers), electrical power utilities (state-owned entities) and the Taxation Bureau. The firm has won major contracts with various Chinese municipalities to do e-government software, based on technology from its partners, Samsung and a Hong Kong software firm. The IT service division admits it has no technology or design capabilities at the moment, but it hopes to move from outsourcing the design to foreign IT services firms to doing cooperative design to conducting in-house design of the core technologies. Tongfang Optical is supposedly conducting research and production in opto-electronics, but in actuality, the firm is simply selling a database of Chinese academic journals it compiled to Chinese universities. The firm's claim to do development work for new Chinese standards in conjunction with former and current researchers in Taiwan's quasi-governmental ITRI has been refuted by the latter. Present and former ITRI officials do not deny contact with Tongfang Optical, but they claim that Tongfang Optical has not contributed an iota of technical knowledge to this standard-setting process (Interviews 212, 216). Finally, there is the chemical engineering firm of Tongfang, based in backward Jiangxi. This firm was set up in Jiangxi because

Qinghua received an order from higher up in the government to help Jiangxi and then passed this order onto its own enterprise groups (Interview 34).

Tongfang's one business that did not seem to be organized around government procurement or fulfilling government-given missions, is Tongfang's data processing firm, Tongfang Data Technology Company. This firm, however, has origins from a much earlier period. The firm was founded as Qinghua Jishu Fuwu (Qinghua Technical Services) in 1980-81 and signed an agreement with Unisys to do data entry for Unisys in order to pay for the Unisys equipment the school bought. The firm had to do data entry for Unisys for 7 years to pay for the equipment. In 1987-88, Qinghua found a second American client, Mead (the data processing firm that would later be known as Lexis-Nexis) in lieu of the end of the contractual obligation to Unisys. Tongfang specialized in doing legal studies data entry for Lexis-Nexis and over the years has almost exclusively employed high-school graduates for the drudgework of data entry. The firm's sole advantage is the cheap cost of labor in China, but it is beginning to feel pressure from Lexis-Nexis because the firm uses other suppliers located in the Philippines and India that have software service capabilities in addition to data entry. This firm has begun to add software engineers (65) in addition to its 400 data entry workers, but remains completely dependent on doing data entry for Lexis-Nexis.

Beyond the problems of incapacitation and disincentives to upgrade fueled by government largess, these *xiaoban qiye* also suffer from the bureaucratic goals problem. The necessity to invest in a firm in Jiangxi is just one example of the interference in firm operations by political imperatives. Insiders and knowledgeable partners of both firms (Interview 247, 248, 33,34, 56) placed many of their firms' inefficiencies squarely at the door of the management structure. Party officials of Qinghua University with their own political missions were placed in charge of managing these enterprises. Interestingly, each business group viewed the other as having been better able to loosen the grip of party cadres on firm management and bemoaned the fact that their own firm still suffered under cadre mismanagement. These differing views suggest that each business group bought Qinghua University's propaganda about the other business group while knowing full well these pronouncements about reform for *xiaoban qiye* were but hollow rhetoric for their own group. Several insiders testified that even when real profit centers were created, mismanagement under cadre rule destroyed or dissipated the profits. For example, the scanner business for Ziguang enjoyed gross profits on paper, but management frittered away whatever real gross profits had been realized. Ziguang's traffic control system was very profitable for the firm, but the cadre executives diverted these funds to other money-losing operations. For Tongfang Optical, the firm was being forced by the government to enter manufacturing of CD and DVD-ROM machines even though hyper-competition in this area had already whittled away any chance of profitability, even for the private Chinese and Taiwanese makers of these products in southern China.

3.3 China's Telecommunications Equipment Manufacturers

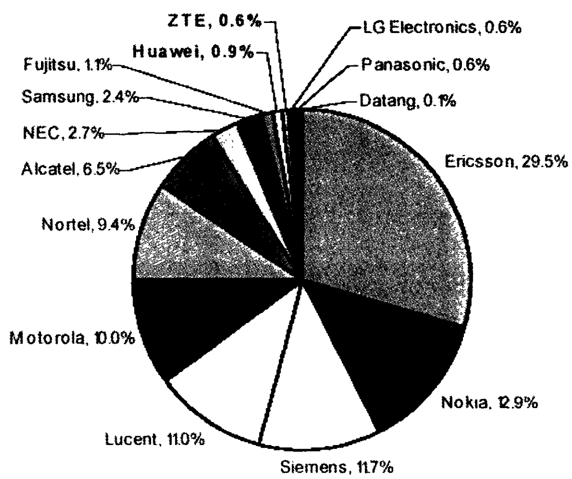
3.3.1 China's Telecommunications Infrastructure Equipment

Telecommunications infrastructure equipment is the equipment that allows telephones and mobile phones to function in vast networks. Telecommunication service providers buy this infrastructure equipment to run their networks. In China, the telecommunication service providers are all state-owned firms.

Like the computer industry, the Chinese telecommunications industry is also filled with state-supported firms that have accomplished nothing except destroy value, such as Shanghai Bell, Datang and Julong. However, the two major Chinese firms that are often seen as having undertaken some technological learning, Huawei and Zhongxing Telecom (ZTE), are also in this sector. Indeed, these two also contributed to upgrading in semiconductor design, albeit marginally (see Chapter 5). These two firms appear to be the exceptions among state-favored firms. However, only Huawei can be seen as a firm that may have made moves to catch up to the technological frontier in a commercially viable, embedded manner in telecommunications equipment. All other possible candidates were investigated and found wanting. However, even for Huawei, there are reasons to be concerned. When one scrutinizes its activities and impressive state connections, the achievements of this firm appears less impressive than its boosters claim them to be.

The Chinese telecommunications infrastructure equipment firms started from the same humble beginnings that many other Chinese IT firms started. The old state-owned telecommunications firms established in the 1950s and 1960s lost out to foreign technologies produced by foreign firms in the 1980s. By 1992, domestic Chinese firms held as little as 1.1% in some products, such as central office exchanges. A number of state-sponsored firms and Chinese majority JVs helped boost local production to 80% of the domestic market by 1997 in certain products, such as SPC (stored program control) switches (the primary fixed line switches). Behind this resurgence of Chinese telecommunications equipment production were government research programs, state procurement and forced technology transfer by foreign partners in JVs (Shen 1999; Telecom Asia 1998; Zhang and Igel 2001: 366).

Figure 4.2 Global Wireless Infrastructure Market (2002)
Note: China's Huawei and ZTE in bold.



Source: Gartner Dataquest, September 2003

Given their initial success, some scholars have made claims about the triumph of firm innovation and state policy in China's telecommunications industry, but time has proven these claims to be wishful thinking. Shen Xiaobai's study of Julong and Shanghai Bell praises these firms as catching up, but these claims were premature. Today, Julong has a pitifully small market share even in the protected and state-monopolized domestic market. Similarly, Zhang and Igel (2001) see an array of domestic and domestic-controlled JVs in conjunction with state support as having innovated in 1990s. Indeed, in

1997, firms, such as Julong, BISC, Shanghai Bell and Datang, all appeared to have great promise. Unfortunately, most of these firms sank into swift decline. BISC, Julong and Shanghai Bell were never able to generate new technologies. In particular, they were unable to make wireless products for that new burgeoning market. Today, the wireless equipment market accounts for over half of the total market in China. Thus, the inability of these firms to enter this market successfully severely hampered their ability to grow with the market.

Table 4.9 China's Major Telecommunications Infrastructure Vendors

Sources: Hoovers Online; Gartner/Dataquest; Zhang and Igel (2001).

	Registration	Products	1997 Revenue	1997 Rank	2003 Revenue	2003 Rank
BISC	1990	Fixed line	1988	5	Negligible (bought out by Siemens)	N/A****
Datang	1993	Mixed	520	6	2075*	4**
Julong (Great Dragon)	1994	Fixed line	5000	1	Negligible	N/A****
Huawei	1988	Mixed	4189	3	31,712	1
Shanghai Bell	1983	Fixed line	4561	2	14,350 (Bought out by Alcatel)	3***
ZTE	1993	Mixed	1997	4	17,036	2

Notes: Revenue in RMB millions.

*Datang's 2002 revenue was used for 2003.

**Datang has been used to distribute Ericsson's products and Ericsson sold 10.25 billion RMB worth of telecommunications products in China in 2003. Including Ericsson's products, Datang ranked fourth. Without Ericsson's products, Datang does not rank in the top ten.

***The figure represents the products of Alcatel. Before Shanghai Bell's acquisition by Alcatel, Shanghai Bell had revenues that were only a quarter of ZTE's revenues in 2001.

****These firms were not among the top ten largest vendors and no exact data was available.

Shanghai Bell, after receiving technology from Alcatel[104] in 1983, has basically stuck with the same system ever since. This firm essentially sold the same switch, for

[104] At the start of the JV, the foreign partner was Bell Telephone Manufacturing (the Belgian subsidiary of ITT), which would become part of Alcatel.

twenty years straight. Shen Xiaobai makes a big deal about the transfer of Alcatel's semiconductor design technology, but in actual fact, this technology has also stagnated. The IC design division has also been reliant on a very old design received from abroad. The design division has also driven away two highly qualified returnees who came to Shanghai Bell full of missionary zeal to reform and reinvigorate it (see Chapter Five).

As for Julong, Gilboy's (2002) claims that the firm never resolved its management difficulties appear to be correct. The firm is now a rather insignificant player in China, even worse off than Shanghai Bell. Its market share has essentially evaporated.

The best many of these firms could manage was to become sales channels for foreign firms. While Datang is selling just a little over two billion RMB (the equivalent of 250 million USD) in equipment, it has become a major sales partner for the much larger and technologically more sophisticated Ericsson, which had ten billion RMB in sales in China in 2003 (MFC 2003: 26). Alcatel bought a majority share in Shanghai Bell in 2001 and merged its own Chinese operations with Shanghai Bell. This merger was an attempt to gain greater access to the Chinese telecommunications infrastructure equipment market, which is controlled by state-owned service companies. It is unclear if the merger will actually increase the sales of the combined firm. Similarly, BISC's erstwhile minority shareholder, Siemens, has bought out BISC, but the market share of this now foreign-owned JV has not rebounded.

Datang has tried to become the center of the Chinese government's drive to create a new "Chinese" telecommunications standard, TD-SCDMA (which was actually created in Europe by Siemens). The government even set up a series of collaborative efforts between Datang and foreign firms anxious to gain access to the details of the new Chinese standard when and if it becomes a reality. However, Datang's weak technological capabilities were soon evident and other domestic Chinese firms were able to barge into the collaborative foreign-domestic efforts designed by the state to support TD-SCDMA. For example, Huawei essentially high-jacked COMMIT, a joint development program for TD-SCDMA involving Nokia, TI and others, and took over as the Chinese partner in place of Datang.

The relative fall of some equipment vendors and the rise of others, such as Huawei and ZTE, points to some limited competition among the domestic telecommunications providers. Competition has functioned on two fronts. Chinese telecommunication service providers in the recent past have switched from more expensive to less expensive equipment vendors among the domestic firms (Zhang and Igel 2001: 365). There has also been competition in creating new products, particularly wireless products. As mentioned, firms that could not generate new wireless products lost out. They lost despite their right to sit on the same government review boards that tested and approved foreign telecommunications equipment for the Chinese market. Huawei and ZTE learned how to copy foreign designs while testing and opening the equipment of foreign vendors as part of the approval process.[105] These other firms failed to make the most of the same opportunities for learning.

Looking at the firms that have done well, Huawei stands out as the largest and now the most international of China's telecommunications firms with forty percent of its

[105] This access to sit on these review boards was deemed to be a big boost for Huawei and ZTE's ability to learn the technology according to interviews and a foreign telecom executive I discussed this issue off the record with in December 2002. The telecom executive was at a lost to explain why other domestic firms with the same rights to sit on the board were not able to capitalize on the opportunity.

2004 sales overseas. Gilboy's explanation of Huawei's success is that this firm's connections with the highest levels of the PRC government guaranteed success. He suggests a tight relationship between Huawei's CEO, Ren Zhengfei, and a prominent member of the finance *xitong*, probably Zhou Xiaochuan (Gilboy does not identify this person by name but does mention some of this anonymous person's previous work as a high official in finance). He also invokes Ren's PLA background and the seldom acknowledged but always suspected link between Huawei and a PLA research institute.

Contrary to Gilboy's claims, there is little evidence that Huawei has a favorable political position vis-à-vis the other domestic telecommunications firms. While Zhou Xiaochuan is prominent, he is not anymore prominent than a host of other officials below the Politburo Standing Committee (PSC). As for PLA connections, Zhou Huan, the CEO of Datang, also comes from a PLA background.

There are other reasons to consider the explanation of the unique position of Huawei incorrect. Consider the second largest Chinese telecommunications infrastructure firm, ZTE. This firm is tied to Shenzhen's government through ownership stakes and various provincial authorities hold small strategic stakes. There are also personal ties that link local Shenzhen officials, who are obviously concerned about local firms, to top leaders. Shenzhen's party secretary from 1998-2002 was Huang Liman, who has been the reputed lover and documented confidant of outgoing president, Jiang Zemin (Nathan and Gilley 2002: 162), who gave up his final official stronghold on the Central Military Commission in 2004. Looming larger than Jiang's dalliances is the fact that former Jiang protégé, Li Changchun, is a recognized national leader and has become a PSC member (Nathan and Gilley 2002). From 1998 to 2002, Li Changchun was party secretary of Guangdong, the province in which both ZTE and Huawei are located. Given the patronage networks Chinese leaders accumulate through the positions they hold, it is logical to think Li Changchun used his influence with Jiang to boost both of these firms while provincial party secretary and as PSC member will continue to support these firms from his former base of operations, especially ZTE since it is a locally owned SOE.

Let us now turn to Shanghai Bell, which has done comparatively worse than Huawei or ZTE. This firm also has impressive political connections to the top of the CCP leadership as well. Jiang Zemin's faction is called the Shanghai Gang, but this does not mean he favors Shanghai above all else. However, Jiang's favorite, Huang Ju, has been mayor and then party secretary of Shanghai from 1994 to 2002, and what is good for Shanghai Bell is good for Shanghai. Huang Ju is now a member of the PSC and vice premier of the State Council (China's executive/administrative branch). Even with Jiang's receding from the scene, Zeng Qinghong, another prominent member of the Shanghai Gang, is considered to be the second most powerful or even rival to Hu Jintao for power within the PSC and the country. Zeng's career was based in Shanghai before coming with Jiang to Beijing when the latter was suddenly elevated in the wake of the Tiananmen Massacre. Given his ties to Shanghai and the Shanghai Gang, it is improbable that he would not want to help out Shanghai through helping Shanghai Bell. Finally, there is Wu Bangguo, another member of the PSC and former Shanghai mayor and party secretary (1991-1994), but there are questions about whether his links to the Shanghai Gang are strong.[106] Obviously, this support may be lower now that Shanghai

[106] Cheng Li's August 2002 piece for China Leadership Monitor (www.chinleadershipmonitor.org) argues that Wu is a member of the Shanghai Gang, but Nathan and Gilley (2002: 102) argue that his links to Jiang and the Shanghai Gang are tenuous. They claim Jiang only brought Wu to Beijing because senior leaders blocked him from brining his protégé, Huang Ju.

Bell is in foreign hands, but does not suggest that Shanghai Bell has suffered from being less well connected prior to the late 2001 takeover by Alcatel.

Gilboy also ignores the extremely prominent role of MII in procurement. The dominant telecommunications providers in China (China Telecommunications, China Mobile and China Unicom) are all MII-controlled firms. A number of the failed firms have direct links to MII. MII has significant stakes in Shanghai Bell, Datang and Julong. Technically, MII does not owned Datang (the State Asset Management Commission took over from MII), but the boundaries between MII and the firm are still porous. Datang's whole research organization is composed of MII research institutes. Some have suggested the existence of complicated internal factional struggle within MII itself, particularly in the wake of the game of musical chairs in which the heads of these three firms swapped places in 2004 (Modoff and Goldberg 2004: 7), but Gilboy does not use the argument of internal MII politicking as the reason for Huawei's supposed political advantage. In any case, it is unclear how those outside of the very top of the party hierarchy can hold sway over MII. A PLA background is all well and good, but MII pays obeisance to the Politburo Standing Committee, not the PLA.

The most damning piece of evidence against Huawei's supposed unique position of privilege is from Huawei's competitors. One would think, particularly in the context of particularistic competition, that Huawei's competitors would complain bitterly about Huawei's supposed privileged position if the firm had one. However, the competitors I talked to did not think Huawei had an upper hand in securing government procurement. This is not to say that they denied that government support was critical, it was just that they did not think the government favored certain domestic firms over others. Rather, they all were equal beneficiaries of government support (Interviews 168, 186, 141).

The fact that the state supports Huawei is uncontroversial. Huawei's Ren Zhengfei himself emphasizes Huawei's connections to the state as a competitive advantage. As he puts it, albeit somewhat obliquely, "The difference between Huawei and Western firms is simply that we at every level of management are close to our customers [author's translation]," (R. Jiang 2003: 119) with the customers of course being overwhelming the Chinese government-owned firms[107] until Huawei's very recent success in overseas markets. Ren has also stated this fact about the crucial role of government support in the face of large foreign competitors more bluntly, "If it were not for the protection through the national government's policy, then [our firm] would have been easily destroyed (R. Jiang 2003: 120)." However, Ren does not claim that Huawei receives an advantage over domestic firms in China. In reference to Ren Zhengfei's remark, business commentator Jiang Ruxiang notes the crucial government role for many domestic firms, "This kind of philosophy of seeking to survive in this tiny fissure [of opportunity] really is the situation of almost all domestic firms, they face formidable [foreign] competitors, but they can also from 'government protection' receive a huge advantage (R. Jiang 2003: 120)." The historical accounts of the growth of the domestic industry also note government support but do not view it as biased towards Huawei (Zhang and Igel 2001; MFC 2003).

Huawei and ZTE have been able to turn this government procurement into a strategy where they create products after the leading MNCs in this sector. In short, they

[107] In commenting on Ren's statement, Jiang explicitly states that customers means local units of the state-owned telecommunication service providers (Jiang 2003:119).

are fast followers, and widely recognized as such by their foreign competitors (Interviews 288, 226, 224). However, there are factors that mitigate their apparent accomplishment. This fast followership does not seem to be due to hard R&D work internal to the firm alone. As mentioned, Huawei, ZTE and other Chinese telecommunications executives sit on the committees that approve new imported equipment for the Chinese telecommunications market. This gives them unprecedented access to understand and reverse engineer the products of the Nortels, Lucents, Ericssons, Motorolas and Samsungs of the world.[108] Indeed, whereas Samsung used its scale and scope economies to become a player in CDMA telecommunications infrastructure equipment, Huawei and ZTE have leveraged access provided by government protection to learn about competitors' technologies.

This access makes the documented IP violation foibles of Huawei that much more embarrassing. With such privileged access, it is striking that Huawei still has been caught red-handed violating other firms' IP in other places. For example, Huawei photographed illegally the internal design of Fujitsu's equipment at international trade shows and Cisco successfully sued Huawei for copyright infringement. Huawei also tried to outsource equipment from a Taiwanese ODM, but the ODM quickly terminated the agreement because they felt Huawei's real goal was to steal technology given Huawei's unceasing demands for access. In contrast, ZTE has a relationship with the same firm, but is a passive partner. In essence, ZTE slaps its name on a product designed and manufactured by a foreign firm (Interview 94, 211). Neither picture is one of local telecommunications firms generating much technology on their own. In terms of the Amsden-Tschang model, they are only at best at stage 3 according to testimony from

[108] Discussion with a Nortel executive, December 2002.

internal firm sources and key suppliers (Interviews 226, 94, 149, 167, 168). Dimitri Kessler's (2005) recent work also documents how limited and reverse engineering-focused Huawei's R&D is.

Another mark against these firms is precisely their ties through procurement and finance to the state. Beyond the obvious government-dominated procurement, these firms also enjoy privileged access to the financial system. ZTE is a SOE as well as a prominent firm in a strategic sector so it is difficult to imagine that the firm would somehow be excluded from the generous soft loans given to other large SOEs. Gilboy has documented Huawei's generous "illegal" loans on top of state-approved ones. Gilboy also reports insiders' claims that Huawei has sustained losses in recent years in contradiction of the firm's publicly released financial statements reporting profits. Thus, even for these fast reverse engineering firms, it is not certain that they are actually creating any value. Huawei's recent success in foreign markets appears less triumphant when viewed in this light. The firm is primarily entering small markets ignored by the large foreign competitors (Economist, January 6, 2005). International buyers state Huawei's low prices as an advantage, but this is not an advantage if it is not actually supported by lower costs of production. With the state buying 85 to 88 percent of ZTE's production and still sixty percent of Huawei's even after the export surge, there is plenty of financial room to sell exports under cost. Losses are easily sustainable, but they also have the potential to turn into a sustained pattern of asset destruction just as in many other state-favored firms.

3.3.2 Downwardly Mobile: Brands without Technological Brawn

The mobile handset market in China stands out in that government procurement does not play large role. This is a real customer-driven market. However, the government has controlled access to this customer market through licensing and through limiting foreign-owned channels of distribution. Despite these controls on foreign firms, foreign firms have dominated the market until quite recently. In the first few years of the 21st century, the local handset providers made significant headway, but in 2004 they lost share again.

Whether or not they regain market share is not the concern here because market share is not an important benchmark of technological activity. When looking at the technology behind the local brands, they are found wanting. TCL, Bird, Kejian and others have gained national recognition for their brands, but as the chart below shows, brand is only a small part of the value in the mobile handset value chain. What makes things worse for these local brands is that the estimates below are based upon international market averages where the big international brands compete. Firms such as TCL and Bird simply do not have the brand cachet of Nokia, even in China, so the value they capture is even lower than in the chain below. The average selling price of foreign phones sold in China was 115 percent of the average selling price of domestic phones (Deutsche Bank estimates).

In contrast, foreign MNCs occupy wide swathes of the value chain. The local firms at best occupy the manufacturing, sales and distribution and brand segments. In fact, most of the local sales channels in mobile phones in China are not owned by the brands so the value they capture from sales and distribution is even smaller than the values for those segments in the table above. In Table 4.11 below, the segments covered by the two largest mobile handset firms, Nokia and Motorola, are compared to the prototypical mainland Chinese handset firm. Sony Ericsson, as the major MNC with the slightest coverage across the value chain, was also included. Nokia's coverage is

Table 4.10 Breakdown of Value Chain in Mobile Handsets

Note: Margins are in percentages, not dollar values.

Breakdown (US$)	Vanilla voice		Feature phone		Smart phone	
	ASP	Margin	ASP	Margin	ASP	Margin
Components	34	7	85	9	115	9
Platforms and IPR	8	20	14	26	19	30
Supply chain/BoM	2	20	9	30	12	40
Software OS and GUI	4	40	8	40	12	40
Design and integration	11	20	33	30	46	40
EMS manufacturing	10	11	18	13	24	14
Sales and distribution	15	15	15	15	20	15
Brand	6	10	18	25	24	35
Total	89	13	199	18	270	22

Source: Deutsche Bank AG estimates, DB report " The silent revolution thick client, thin bandwidth" dated 14 Apr. 2003

arguably wider than it appears in the table because Nokia has significant input into the design of key components it sources from ST Micro (IPC interviews). Interviews confirmed that none of the major Chinese makers of handsets were successfully doing even the final "design and integration" of their handsets and the new, small local firms doing design and even the user interface (GUI) were essentially doing such crude designs that they functioned as bottom feeders in the market, providing low quality phones for low prices (Interviews 57, 135, 145, 155, 175, 187, 189, 196, 197, 224, 229, 236, 253, 291, 292, 293).

Table 4.11 The Value Chain Coverage of MNCs and Chinese Brands
Source: Deutsche Bank and firm interviews

	Motorola	Nokia	Sony Ericsson	Chinese brands
Components				
Platforms and IPR				
Supply chain				
Software OS and GUI				
Design & Integration				
Manufacturing				
Sales and distribution				
Brand				

Note: The solid colors denote activities done completely in the firm, the mixed colors denote partially outsourced activities.

A number of sources testified to the lack of design conducted within local firms. The local firms often acknowledged their reliance on foreign sources of technology (Interviews 145, 187, 267). Foreign designers of mobile handset technology also noted their provision of technology to local firms and the lack of any design or technology generation ability on the part of the local firms including the largest firms, such as Bird, TCL and Konka (Interviews 135, 175, 196, 253, 291, 292, 317). The major vendors often sell complete packaged solutions including the major components and software and guidance on how to integrate these solutions so the brand has only to assemble and sell the products.

Even TCL, competing with Bird as the top local vendor, has little to show for its acquisition of Alcatel's mobile handset division[109]. Alcatel had already sold its microelectronics division to ST Micro, including design activities for mobile phones. Essentially, TCL received the Alcatel name for this purchase and not much else. Alcatel's brand was not very strong as it had less than one percent of worldwide market share. Furthermore, its design and technology operations outside of ICs were not strong because it relied completely on outsourcing to firms with in-house design capabilities (Chan and Seghal 2004). Deutsche Bank cites TCL as having stronger technical capabilities compared to other Chinese firms as it can start with chipsets and design its own phones whereas other firms have to accept complete modules (essentially everything but the plastic casing) from their foreign vendors (Wong, Lim and Ye 2004). However, a number of interview subjects claim that TCL's ability to design from chipsets alone is quite weak (Interviews 291, 293, 317).

4. Hidden Dragons: The Contributions of FIEs

4.1 General Trends of FIE R&D

In this section, I will examine FIEs to see what technology activities they are pursuing in China. I will examine the activities of particular firms and evaluate them using the Amsden-Tschang framework. This section will also present as comprehensive enumeration of R&D engineers trained in hybrids and regular FIEs as possible based upon my interviews augmented by additional sources on foreign R&D activity (Z. Wang 2001, 2002; S. Chen 2004). No outside sources were used without interview

[109] Technically, TCL and Alcatel have formed a 55:45 JV, but this JV is commonly seen as a means for Alcatel to rid itself of its loss-making mobile handset division and eventually exit this market entirely (ChinaTechNews.com, April 29, 2004).

confirmation of the existence of a particular firm's R&D activity in China. The main findings are that the regular FIEs contributed more in terms of sheer numbers of engineers trained and the hybrid FIEs were contributed more in terms of the skills (as measured using the Amsden-Tschang framework) they were passing on to local engineers. I will use the terms MNC and regular FIE interchangeably in this section.

The 20 largest global IT firms are presented in the table below although the table excludes the telecommunication service companies, such as AT&T, NTT, Telefonica and Telecom Italia as China's telecommunications market remains closed to them. I interviewed 8 of these 20 firms for the dissertation research and three others as part of MIT's Industrial Performance Center's Globalization Project. For six others, I drew on the interviews conducted by other members of the Industrial Performance Center team. Thus, I have coverage of 17 of the top twenty firms from interview sources. For the top ten computer equipment providers, I have directly interviewed five of the top ten firms in China. I interviewed another firm extensively at its Japanese headquarters about its global operations across multiple divisions. I will not identify which firms I interviewed to help preserve the anonymity of interview subjects.

The most comprehensive and up-to-date study of the R&D activities of foreign firms in China is Kathleen Walsh's *Foreign High-tech R&D in China* (2003) so this work is a good starting point to examine the R&D activities of foreign firms. Walsh correctly observes that there has been significant change over time with an intensification of the R&D efforts of foreign firms in China. This development of Chinese R&D efforts fits a

Table 4.12 Top Twenty Global IT Firms in 2003
Source: *OECD Information Technology Outlook 2004*

Firms	2003 Revenue (USD Millions)	Firms	2003 Revenue (USD Millions)
1. IBM	86902	11. Nokia	37670
2. Siemens	85894	12. Dell	35404
3. HP (Hewlett-Packard)	71256	13. Microsoft	32187
4. Hitachi	67157	14. Mitsubishi	30848
5. Sony	63353	15. Philips	29947
6. Matsushita	62744	16. Intel	28527
7. Toshiba	47944	17. Motorola	26293
8. Samsung	47613	18. Canon	25760
9. NEC	41090	19. EDS	21731
10. Fujitsu	38480	20. Sanyo	19856

Table 4.13 Top Ten Global Computer Equipment Firms in 2003
Source: *OECD Information Technology Outlook 2004*. Referred to in source as "IT equipment and systems."

1. IBM	6. Dell
2. HP (Hewlett-Packard)	7. Sun Microsystems
3. Toshiba	8. Hon Hai Precision
4. NEC	9. Seagate
5. Fujitsu	10. Apple

global pattern observed by Reddy (2000), Dalton *et al* (1999)[110] and Shin-horng Chen (2004) of MNC R&D spreading to developing world which traditionally was neither home to nor offshore R&D location for "first-world" MNCs.[111] There are both demand factors pushing MNCs to locate R&D in developing countries and supply factors pulling the MNCs to certain locations. These factors are different from the early stages of R&D internationalization when MNCs moved R&D resources outside the home economy to

[110] Dalton *et al*'s work describes the trends of the developed world cross investing in R&D facilities so it fits better the internationalization mode. However, this work also uncovered the new trend of a more dispersed R&D activities with ten percent of US R&D facilities in developing countries, such as India, China, Taiwan, Brazil and Mexico. This is true even though the book significantly undercounts the number of such R&D centers in China (Walsh 2003: 25).
[111] See Louis Wells (1983) for the contrast between MNCs from the developed economies and MNCs from the developing world.

other parts of the developed world as many of the push and pull factors dealt with the sheer size of already developed and protected markets (Westney 1993; Dunning 1994; Patel and Pavitt 1998; Dalton *et al* 1999). Chen neatly summarizes the differences in the table below.

Table 4.14 R&D Globalization

Source: Modified table from S. Chen (2004) based on Reddy (2000).

	R&D Internationalization (starting in the 1970s)	R&D Globalization (starting in the 1980s)
Demand-side Forces	Need to enhance market-share in local markets abroad Host government policies	Shortage of R&D personnel in industrialized economies Increasing demand for R&D personnel Increasing R&D costs
Supply-side Forces	Large and protected markets with unique characteristics Proximity to market and production	Availability of R&D personnel in some developing economies Low-level of wages of personnel and divisibility of R&D into core & non-core activities Changes in policy regimes, including IPR in host economies

China supplies relatively cheap technical labor and can take advantage the divisibility of R&D activities (as discussed in Chapter Three) in the lower right box, but China's IPR regime is still quite poor according to numerous investors I talked to acknowledge.[112] There is little evidence that the IPR regime in China drew foreign investors. On the demand side, IT managers continually complain about a shortage of personnel, but what they really mean is a shortage of personnel at the right price. In any case, as Figure 1.2 in Chapter One showed, the Chinese are educating large numbers of

[112] In all my interviews, I did not meet one firm that claimed that IP problems were not rife in China. The challenge for firms is not to change the entire external environment, but to manage their business in ways to insulate themselves from this environment. For example, Microsoft has licensed its OS to every major computer vendor in China and has an aggressive pricing strategy for China and the developing world generally i.e. much lower prices for the developing world.

people. According to UNESCO, thirty-five percent of these graduates studied science and engineering disciplines so China's education system provides a potential R&D army for MNCs (Pack 2004: 367). The supply of trained technical workers in low-wage China has been its major lure.

Even with a large supply of engineers, MNCs have taken time to seize this opportunity in China. In part, this time has been necessary because local graduates still need to be trained. For any significant task, foreign firms virtually unanimously felt local employees still needed training. Of course, part of this problem is universal. Fresh graduates in the US and elsewhere also require on-the-job training as foreign firms attested. This training time aside, MNCs moved slowly during the 1990s to place real R&D centers in China.

Walsh (2003: 86) provides a three-stage chronology of the movement of MNC R&D activities to China: exploratory and strategic partnerships stage (early-to-mid 1990s), expansion of R&D (mid-to-late 1990s) and consolidation of R&D (late 1990s to the present). In the initial stage, little actual R&D took place in these "show" R&D centers. As Walsh (2003: 87) notes:

> Most of these collaborations, however, involved little, if any, R&D, comprising instead simple donations of advanced equipment (such as computers) for training purposes, the establishment of R&D "labs" at universities (which appeared in some cases to be little more than rooms set up with foreign-donated equipment), or research funds for development work conducted by joint venture or university partners to assist in localizing foreign products. Since the main objective in many of these agreements was to appease Chinese officials and obtain approval for a joint venture—not to conduct R&D—it is unlikely that much advanced technology or know-how was transferred via these early agreements.

My own findings concur with Walsh's assessment of these early efforts, particularly the R&D within universities. A senior official at Qinghua, the premier science and technology university in China, told me that the MNC "labs" there were simply donated equipment and the ones I saw did not differ from this description. Furthermore, none of the MNCs I talked to suggested that they conducted any serious research within the confines of the university system.[113] In the second stage, she sees foreign firms extended their contacts with universities, but I found little evidence of this beyond the internships and other recruiting devices. Walsh acknowledges that recruiting rather than outsourcing research has been one of MNCs' main motives for these activities. She mentions that she met with one of the first groups of university researchers working for foreign firms in 1998, but offers no evidence that this type of arrangement is widespread beyond the internships[114]. Her third stage is similar to Reddy's globalization of R&D. MNCs have recognized the feasibility of setting up substantial R&D centers in China, a low wage location, and have proceeded accordingly.

How many FIE R&D centers are there in China? Walsh conducted more than 36 interviews for her study, but these included interviews subjects who were not managers of MNCs. The list of R&D centers Walsh (2003: 92) compiled on behalf of the Stimson Center, a Washington DC-based think-tank, contains 223 MNC R&D centers in the ICT (information and computer technology) area. Walsh concedes that this list may not be complete and the list does contain those university "labs" and other programs that may be simply "show" R&D centers of no real value. It is hard to evaluate the extent to which

[113] Walsh states that she interviewed researchers at universities that said they were doing development for MNCs, but she apparently had no confirmation from the MNCs.
[114] Walsh (2003: 98) does concede that hiring university students means essentially that these students come to do work in the R&D facilities not on the university campus.

the chaff of the R&D world are included in with the wheat on the Stimson Center's list because the names of the individual R&D centers are not yet publicly available. I contacted Walsh last year about the possibility of viewing this list and she said the Stimson Center had not yet decided whether to make the list public. It is not yet publicly available as of February 1, 2005. The Chung-hua Institute of Economic Research (CIER) in Taiwan concluded that China had 148 R&D centers across all industries, but CIER's methodology to arrive at this figure is unknown although CIER researchers have told me that they have cooperated with Wang Zhile, a researcher at the Ministry of Commerce. Walsh was told by one R&D center that there were probably only 50 real R&D centers in all of China (Walsh 2003: 92). One clear fault of Walsh's list is that she ignores the ECE R&D centers. Walsh counts 41 US MNCs and only three from Taiwan—yet Shin-horng Chen interviewed 38 different Taiwanese firms with R&D centers in China and he by no means thinks his interview list is comprehensive. In my own research, I collected data on technical personnel involved with R&D centers of 33 different FIEs. Some of these FIEs had multiple R&D centers in China. These 33 firms do not include those interviewed Taiwanese firms that only had limited design-for-manufacturing activities in their Chinese plants.

Even with the supposed consolidation of the MNC R&D centers in the China, Walsh (2003:99) finds three different types of relationships between the R&D centers and their MNC parents. She sees a majority of these R&D centers as satellite organizations that act as listening posts and modify products for the local market. The second type of R&D center takes a discrete part of the R&D task from the parent corporation. The third type (represented by a very small number of these centers) claims to be fully integrated and equal partners in decisions with their MNC parents. This claim of equal decision-making seems a bit farfetched given the trend of major MNCs coordinating research across a number of international centers. While the ECE (ethnic Chinese economy) hybrid firms may sometimes achieve this, Walsh's data seems to be comprised of only American and European firms.[115] My research found the former two types of R&D centers across FIEs, but found the third category only in hybrid firms. Overall, Walsh (2003: 99) admits to scant evidence about the performance of these R&D centers, "There are few indicators of progress available and collection of much more detailed data is needed to make an accurate assessment." I hope in the rest of this section to contribute to the creation of a more detailed assessment of the R&D activities of the MNCs in China.

One overall measure, albeit a crude one given how discretely R&D can be divided in this era of cheap global communications, is the number of US utility patents earned by corporate researchers based in China. US utility patents are the gold standard of technology patents because the US is still the world's largest and one of the most sophisticated technology markets and, unlike China[116], has an effective legal mechanism to protect the property rights that patents confer. When one looks at the US utility patent trends in China (see Table 4.15 below), several patterns emerge. First, the hybrids followed by the FIEs are the dominant holders of US utility patents. Three of the top five patent holders are hybrids and only one is a domestic firm. Four of the six firms with ten

[115] I cannot be absolutely sure that only American and European firms were interviewed as the Stimson Center has not released the firm-level data, but given the undercounting of other firms in the list compiled by Walsh and her mentioning of specific firms, all of which are from North America and Europe, point to the high likelihood that other firms were excluded from her sample.

[116] One mark of the ineffectiveness of domestic Chinese patents as opposed to foreign ones is the absence of a connection between Chinese patents and new product creation. Y. Sun (2002) found that there was no statistically significant relationship between domestic Chinese patents and the ability to create new products. On the other hand, Sun found a significant positive correlation between foreign technology inputs and the ability to create new products. In other words, foreign technology inputs was much more worthwhile in new product creation than holding Chinese patents.

or more patents are hybrids. Of the firms ranked in the top ten (there are fifteen such firms due to ties), seven are FIEs, six are hybrids and only two are domestic firms. Hybrids account for 503 of the 650 utility patents from China whereas the FIEs account for 103 and the domestic firms account for only 45. Even when the largest hybrid patent holder, Hon Hai, is removed from the counting, the hybrids still have more patents (148) than either the FIEs or domestic firms. Also, one Taiwanese firm, China Petrochemical Development, had a significant patent presence (37 patents) in China (Floyd and Meyer 2002: 43), but was not included because I could not find data for this firm for 2002-2004 (probably due to the firm listing its patents under a slightly different English name than the one used by Floyd and Meyer).

One significant pattern that shows the commitment of the hybrid firms to a China-based strategy is the extent to which their portfolio collection is weighted toward China. Only one foreign firm, Microsoft, has more than one percent of its patent portfolio in China whereas every hybrid firm has more than one percent from China. Several large firms, such as Hon Hai and Inventec, with significant patent portfolios from their Taiwanese home bases that they acquired before their embracing a China-based strategy in the late 1990s, have much larger portions from China at fourteen and forty percent, respectively. Even Microsoft's anomalous position may be explained by the nature of the work done in China versus what is done in the US. Microsoft is conducting hardware R&D for its X-box game machines in China and hardware R&D generates far more patents than software R&D. One can see this by comparing Microsoft's total patent holdings compared to other global top twenty IT firms. Other than Nokia, which did not make its serious push into IT until the early 1990s, all the other large IT firms generated many multiples the number of patents that Microsoft generated and they were hardware firms.[117] Hardware simply generates more patents. This fact can also be seen by the fact that IBM opened up its patent portfolio in software and it amounted to only 500 patents out of IBM's more than 40,000 global patents. Beyond Microsoft, the only FIE firm to have even one thousandth of its patents from China was Agere.

The patent data also confirms the predictions of the nationality of MNCs theory that argues that firms will favor their national home base. The hybrids, a type of firm that embraces China as part of the national home base, have a significant presence in China. Moreover, the few patents generated by domestic Chinese firms also tend to be generated in China. TCL was the lowest with only one third of its patents originating in China. All the other domestic firms generated more than half their patents in China.

Unfortunately, the domestic firms simply did not generate many patents. Their lack of learning and innovation is precisely why the hybrids have played such a prominent role in China's upgrading. Beyond the fact that they generated only 45, only seven of these patents were in IT products. Haier's patents were in white goods (refrigerators and washing machines) and Sinopec's large patent portfolio was petroleum-related. More dismally, many of the so-called leading firms of China's *guojiadui* (the national team of firms championed by the state) were conspicuously absent from any contribution. Major IT firms, such as Lenovo, Founder, Bird, Konka and Ziguang, were absent as were television giants, Changhong and Hisense.

For the regular FIEs, conspicuous in their absence from the list of China-origin patents were 13 major IT firms from Tables 4.12 and 4.13: IBM, HP. NEC, Samsung, Toshiba, Nortel, Mitsubishi, Dell, Canon, EDS, Sanyo, Sun Micro and Apple. Cisco, the

[117] Agere and Epson are FIEs on the list, but neither of these firms is a top twenty global IT firm.

twenty-first largest IT firm and largest networking equipment firm in the world, also does not have patents from China. In fact, seven of the top-ten telecommunication equipment firms[118] did not have any patent activity in China. Also, many large non-hybrid Taiwanese firms do not have a patent presence in China, including TSMC, Quanta, Compal, AsusTek and Tatung. The only non-hybrid Taiwanese firm with US patents originating from China was Acer and that firm did not have any new patents from China during the 2002 to 2004 period.

One final observation about the patent trends in China is that the patenting has accelerated. Corporations received 503 patents from 2002-2004 and only 139 prior to 2002. In 1997, corporations received only 9 utility patents by Chinese researchers.

4.2 The View from the Firm: R&D Activities in Regular and Hybrid FIEs

Turning to specific foreign MNCs, firms such as IBM, Motorola and HP have tried to be good corporate citizens in China for several decades. Indeed, most of the large MNCs set up subsidiaries in China by the early 1990s though some of them came slightly later, such as Nokia's entry in 1994. However, these firms did not really establish R&D in China early on despite government pressure to do so. Even Chinese government officials, such as Ministry of Commerce's Wang Zhile (Z. Wang 2002: 66-67), admit that the Chinese government tried to coerce MNCs in transferring technology and that this coercion failed to be effective. Several firms announced R&D centers relatively early, but these centers did not amount to much. This stands true even though these firms were doing this to please the China government. Very much like the case of Motorola's

[118] According to the OECD (2004), in 2003, the top ten telecommunication equipment firms were: Nokia, Motorola, Cisco, Alcatel, Ericsson, Nortel, Lucent, L-3 Communications, Avaya and Qualcomm.

Table 4.15 China-origin US Utility Patents of Domestic Firms, Hybrid Firms and Major Foreign IT Producers

Source: Floyd and Meyer (2002) and US Patent and Trademark Office (updated through Jan. 25, 2005)

		2002-2004 US Utility Patents from China	**Prior to 2002** US Utility Patents from China	Total US Utility Patents (China-origin)	Firm Type	Total US Utility Patents (World)	China-origin Patents as Fraction of Total US Utility Patents**
1.	**Hon Hai* (Foxconn)**	304	51	**355**	hybrid	2539	**0.139818826**
2.	**Inventec***	47	31	**78**	hybrid	197	**0.395939086**
3.	**Microsoft**	37	3	**40**	FIE	3467	**0.011537352**
4.	**Sinopec***	29	5	**34**	domestic	65	**0.523076923**
5.	**UMC***	12	17	**29**	hybrid	2519	**0.0115125**
6.	**Winbond***	14	8	**22**	hybrid	761	**0.02890933**
7.	**Leco***	5	5	**10**	hybrid	84	**0.11904762**
8.	**Intel**	7	1	**8**	FIE	9327	0.000857725
	Nokia	6	2	**8**	FIE	3301	0.00242351
9.	**Delta**	6	1	**7**	hybrid	293	**0.023890785**
	Epson	6	1	**7**	FIE	5310	0.001318267
	Siemens	6	1	**7**	FIE	19623	0.000356724
	Philips	5	2	**7**	FIE	19421	0.000360435
	Motorola	4	3	**7**	FIE	16389	0.000427116
10.	**Huawei**	6	0	**6**	domestic	7	**0.857142857**
11.	**Fujitsu**	3	1	**4**	FIE	16142	0.000247801
	Lucent	2	2	**4**	FIE	7572	0.000528262
	Acer	0	4	**4**	FIE	514	0.007782101
	Haier	4	0	**4**	domestic	4	**1**
12.	**Agere**	2	0	**2**	FIE	1377	0.001452433
	ZTE	2	0	**2**	domestic	2	**1**
	Matsushita	2	0	**2**	FIE	20846	9.59417E-05
	SMIC	2	0	**2**	hybrid	3	**0.666666667**
13.	**TCL**	1	0	**1**	domestic	3	**0.333333333**
	Hitachi	1	0	**1**	FIE	30443	3.28483E-05
	Tongfang	1	0	**1**	domestic	1	**1**
	BYD	1	0	**1**	domestic	1	**1**
	Seagate	0	1	**1**	FIE	2626	0.000380807

*The data for the "Prior to 2002" for these firms extends only to 1997. Very few corporate US utility patents were issued before 1997 for China and none of the firms was very active (more than one patent per year) other than UMC, which had 3 China-origin US utility patents in 1997.

**The fractions for firms that had more than one percent of their total US utility patents sourced from China are in bold.

semiconductor plant discussed in Chapter Five, certain firms had an interest in pleasing the Chinese government and found that the state could be easily pleased without actually forking over much technology.

IBM is a case in point. IBM's first business with the People's Republic of China (IBM had done business in China in the 1930s) was setting up a computer system in Shenyang in 1979. IBM did not however decide to set up a Chinese subsidiary until 1990. Interview sources and Wang Zhile state that CEO Gerstner came to China in 1994 and decided to make a big push into the China market. IBM set up a number of IBM-controlled JVs with MII-owned Great Wall to produce computer products. Gerstner as CEO went out of his way to cultivate the Chinese leadership, making 5 trips to China between 1993 and 2000. He also organized a dinner for President Jiang with twenty top American CEOs at the 50th anniversary celebration of the UN in New York to show that American business was not in line with anti-Chinese rhetoric coming from the US government. Jiang was reportedly very impressed with Gerstner's gesture (Z. Wang 2001: 208). Moreover in 1995, IBM was the first MNC to set up a research (as opposed to development) center. However, IBM was and is not doing any basic research connected to its products in this center. Instead, IBM is essentially sponsoring basic scientific research completely divorced from commercial applications. This research intentionally will not lead to creating Chinese engineers who will then work for Chinese or foreign competitors to create product competing with IBM's own. In other words, these Chinese scientists are safely ensconced in pure science research precisely to protect IBM's commercial IP as people close to the project admit (Interviews 221, 276).[119] In this

[119] I received permission to talk about IBM's R&D center by name. Anonymous insiders confirmed what I heard from the source that cleared me to use the company's name when discussing this center.

sense, the research is not even as commercially applicable as the examples of slider suspension engineering of hard disk drives and conceptual development of communications algorithms that Amsden and Tschang give to explain what constitutes "pure science" in their framework. IBM's other research efforts have also been quite limited and will be discussed with other firms anonymously in order to protect the identity of the interlocutors.

The major computer firms are either not doing any R&D or are doing routine work in China. For example, one of the global top three computer firms is doing routine software customization for the local market (10/28/2003 telephone follow-up to previous interviews). The firm's own managers do not pretend that this center does anything more than final code writing for software that fits under stage 4 of the Amsden-Tschang typology.

Another global top-three computer firm has several design centers in China, but these centers are not very sophisticated. As one of the firm's R&D managers pointed out, this firm only really needs and uses PhDs for the sophisticated work in its home base and sends its routine work out to several different countries in Asia. The firm employs less than four hundred engineers in its Chinese R&D centers and these engineers are spread across a variety of tasks including localization, and code writing and function design (see Table 4.16 below) for Linux and other software products and middleware solutions (the software between the user interface software and the software embedded in the hardware) for mobile phones. At best, these tasks are detailed product design tasks of stage 3 of the Amsden-Tschang framework.

The manager made clear that the Chinese teams are simply delegated routine tasks. Each project had an "owner" team, located in the firm's global HQ. These owner teams conceive the projects, receive approval from company executives and then execute the projects. The Chinese teams do not have the ability to conceive of projects so they were simply used by the leading design teams abroad to help do the grunt work of the projects. The Chinese teams are essentially at the bottom of the firm's R&D hierarchy as the Indians were still better at software than the Chinese teams—the need to modify products for the Chinese market justifies the existence of the Chinese teams. The manager noted that all of the product architecture is still controlled by operations in the home country of the MNC because the engineers there have the broadest knowledge of the firm's array of products and are more able to create new solutions to drive industry standards. They also possess a cultural advantage of being in the home country of the firm (Interview 276).

One major Japanese firm (MNC 5) employed three thousand engineers to write code for software programs for the firm's hardware products. Given the common characters shared by written Japanese and Chinese, the Japanese firm found Chinese better suited to their needs than the English-speaking Indian software engineers. Like many of the code writers for other firms, these engineers were towards the very back-end of the R&D process, stage 4 of the Amsden-Tschang framework (Interview 296). The design flow in software can be conceived as proceeding in 7 stages from most sophisticated to least sophisticated as show in Table 4.16 below. This firm's software programmers were doing code writing, the simple software writing that precedes the very routine testing functions. Most of the software conducted in MNCs in my sample is simply this type of code crunching (CD/OT).

The major foreign telecommunications firms were equally concentrated on the back of the R&D process, stages 3 and 4 of the Amsden-Tschang framework. While some of these firms had impressively large R&D operations in terms of manpower (see

Table 4.16 Stages of Software Development
Source: Industry experts.

Stage	Description
URD	Concept Design
SD	System Design
FD	Function Design
CD/OT	Code Writing
IT	Integration Test
ST	System Test
AT	Acceptance Test

MNC 11, 17 and 19 in Table 4.17 below), they were generally doing the final code writing for software needed for the products or detailed design on both the hardware and software. They admitted that their teams to create new applications of known product lines (the product architecture of Amsden-Tschang stage two) were not located in China. The local teams were either doing the detailed design and final work on these global products or doing the detailed design necessary to localize these products for China (Interview 224, 236, 288, 311).

One firm (referred to as MNC 1 in the Figure 4.3), one of the largest mobile phone producers in the world, tried to move beyond this type of work. Or to be more precise, overseas Chinese engineers led by the ethnic Chinese head of the firm's Chinese mobile handset division wanted to create a full-fledged center to design new generations of mobile handsets in China. The director felt that the firm had to create the handsets in the market to be competitive in the market and he led to the establishment of actual design and development work in the Beijing mobile handset research center. Before this time, the architecture design was located in the foreign headquarters and the local research center (founded in 1998) did little actual design. Experienced "foreign" (mainly ethnic Chinese) engineers brought in from headquarters designed the user interface (which fits most appropriately into stage 3). Before the director-led initiative, the only development work done in China was to "slap on" Asian language software.

Headquarters did not interfere at first with this new local initiative and the Beijing design center created its first phone while drawing upon the home firm's prodigious technological resources for IP. The engineers brought in to do the user interface began to train local engineers in this and other skills. However, the firm was hit with a huge resource allocation problem when it decided to cut back from designing 20 to 50 products during the period of 1999-2002 to designing just three to five products each year. The firm essentially took back the design and development work from the Beijing team and gave it to engineers in the home country. The firm did this despite the fact that it had become somewhat dependent on sales of mobile phones and infrastructure equipment in China, which made up more than twenty percent of the firm's global revenue. The lure of the local market had not prevented it from sticking to its home base.

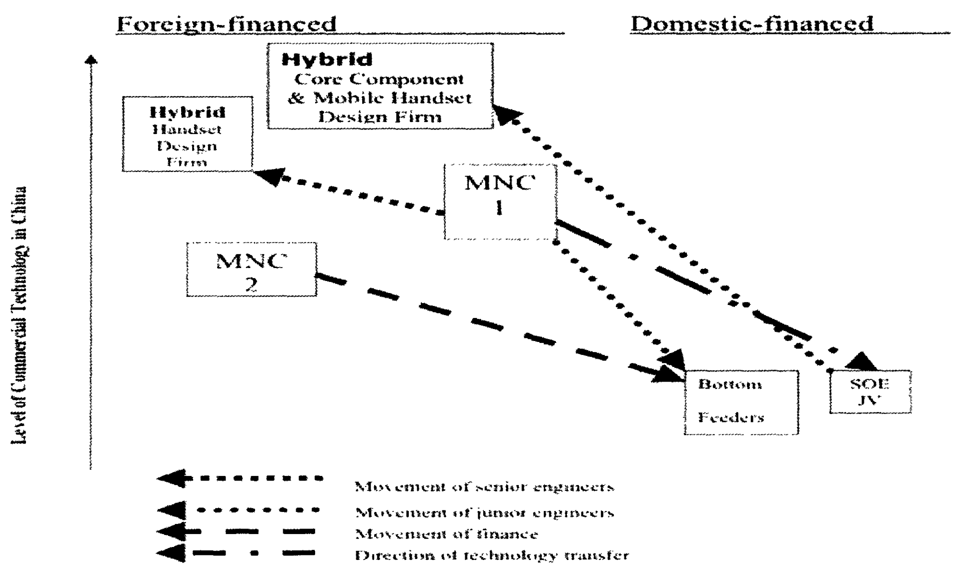
This reorganization of R&D spurred the director of the Chinese R&D center into action. Through a personal connection, he received venture funding from a Taiwanese angel investor, who had made his own fortune as a high-technology entrepreneur. The director took a team of local and overseas Chinese from the Beijing research center and founded his own handset design firm in the greater Shanghai area. This firm set out to create a mobile handset design company akin to firms such as Cellon (a Franco-American firm), which has a large design operation in China, and Alphacell (an Israeli firm). The major differences between those design firms and this one is this firm targets the high-end of the market, both in China and globally, and it aims to produce its own brand. The firm does the whole design in-house and then outsources the manufacturing. The firm has already employed local engineers to create a series of new, cutting edge mobiles phones. This work comprises stage 2 R&D as well as stage 3 and 4 activities.

The firm does not have the right to sell in China because it does not own a license. This protectionist hurdle has been easily circumvented through paying a local state-owned firm for the use of its license, a common though illegal practice. This ploy is yet another example at how ineffective the state is at monitoring firms because the license the firm uses is from a MII-owned firm. MII is the gatekeeper in charge of distributing licenses and keeping a lid on competition in this sector and yet MII's own firm is undermining this policy.

The failure of MNC1 to pursue more substantial activities and its interaction with other firms demonstrate the different strategies and behavior of the different types of firms. The MNC's lack of strategic commitment to China drove the creation of the hybrid design firm listed above, but it also spurred the firm's other local engineers into action. A number of local engineers left the firm to set up their own design houses, but these engineers did not have all the requisite skills. Their firms are really bottom feeders that aim to design phones with poor capabilities and user interfaces to the lowest rung of the Chinese market (referred to as bottom feeders in Figure 4.3). These firms are engaged in a ferocious competition with little profits. One of these firms received investment (a minority share of the firm) from another foreign telecommunications giant. This MNC (referred to MNC 2 in Figure) wanted to appease the Chinese government so they invested, but they do not actually use the invested firm as a supplier. In other words, the investment was just written off as the cost of doing business in China.

MNC 1 was also involved in a JV with a state-owned firm in which MNC 1 was the minority partner. This JV was a competitor in the telecommunications field, but the MNC needed to demonstrate a willingness to transfer technology to local firms. While it may not have transferred the latest technology to its JV partner, third parties, who subsequently hired away the core group of engineers trained in the JV, confirm that the MNC did provide training in substantial design skills. Unfortunately, the management of the JV was from the SOE parent and was typically inept. They tried to create far more products than their team could handle effectively. The end result was they were unable to get any products on the market before the products became out-of-date with little or no profit margins. However, an American subsidiary of a Taiwanese firm came to save the day (at least form the perspective of the demoralized engineers in the SOE-controlled JV). This firm set up a major design operation in East China to design core components and handsets. It discovered that the SOE actually had some well-trained engineers due to its partnership with MNC 1, and it cherry-picked the good ones to become a large part of its design team. This mass hiring further hollowed out the SOE at a time when MNC was ignoring the JV because the MNC felt it had fulfilled its part of the bargain with the Chinese state to transfer technology (Interviews 291-293). The transfer of human and financial capital between these firms is shown in Figure 4.3. Although the domestic firms received substantial resources in engineers, technology and finance from the foreign firms, the domestic firms were still not able to create commercial technologies at more than a very low level.

Figure 4.3 Movements of Human and Financial Capital and Technology in China's Mobile Handset Market



In contrast to the regular FIEs, there were a number of hybrid firms that contributed to technological upgrading. Whereas the regular FIEs contributed by training thousands of engineers in relative simple tasks, the hybrids contributed by training engineers in sophisticated as well as simple tasks. The regular FIEs trained more engineers, but the hybrids trained their engineers in more sophisticated technologies. Moreover, the hybrids were probably undercounted. Many hybrids are small start-ups and relatively hard to track down. There were a number of promising hybrids recommended by foreign venture capitalists operating in China that I was unable to interview due to time and financial constraints.[120]

Another aspect of the hybrids' contribution should be considered. While the large regular FIEs have contributed less absolutely in terms of skills, they have also contributed less relative to their own technological capacity. While this relative contribution is not part of determining technical contribution as defined in Chapter One, it is important when considering the future. Simply put, the hybrids are conducting activities involving their highest level of skills in China. Thus, as they increase their own skill level, one can reasonably expect their Chinese operations will employ and even help to generate these new skills. Only a few hybrids conduct stage 1 activities anywhere in the world, but those that do already have those activities at least partially in China. As these hybrids advance closer to the technological frontier, the absolute level of the skills they contribute to China will increase. In contrast, the MNCs on the technological frontier show no signs of transferring those skills immediately to their Chinese R&D bases.

The largest hybrid in terms of R&D personnel is a Taiwanese conglomerate that makes a range of IT components and end products. This firm has had an explicit strategy to become a greater China rather than Taiwanese company. Beyond the sheer size of the

[120] The same cannot be said for the small domestic start-ups. I went to visit the officials and firms of almost all the major industrial, university and science parks the three main centers of China's IT industry (the Pearl River Delta, Yangzi River Delta and Beijing). These officials were more than happy to show off the firms they viewed as success stories. These firms were either hybrids or local firms engaged in commerce rather than technological innovation. Venture capital firms also found few local start-ups with technological capabilities.

firm's research effort in China, which employs three thousand engineers, the firm's effort is impressive because the commitment to develop sophisticated technologies in China. This firm is one of the few firms conducting stage 1 (basic research) in China—the type of research that relies exclusively PhDs and creates the intellectual property (IP) upon which technology products are based (Amsden and Tschang 2003: 555). US utility patents won by the firm's Chinese researchers are often in the basic technologies underlying some of its key products rather than simple tweaking of established products (USPTO). In some areas, the firm's China-based research is not simply on par with its original Taiwan home base, but has surpassed it. Indeed, the firm rejected Taiwanese government overtures to create a new big Taiwanese R&D base until it had already completed its major new base in Beijing. Even researchers from Taiwan who have downplayed the sophistication of the Chinese R&D centers of the Taiwanese concede that this firm's telecommunications R&D surpasses the R&D in this area done in Taiwan (Interview 278). This is true in two key technologies that are part of its push into telecommunications. First, the firm's research into creating telecommunications infrastructure equipment is entirely based in China. Secondly, the firm's mobile handset design, which started out as a small unit in Taiwan, has Chinese operations that are set to pass the Taiwanese one in size and sophistication. The overall handset design division will be led by a Taiwanese American, who formerly worked for one of the telecommunications giants, but this manager will be based in China not Taiwan. According to the firm's internal plan, the 80 designers in Taiwan will expand to 180, but the seventy designers in China will expand to 250 (Interview 317). Competitors also confirm that this new design team will be a force to be reckoned with (Interview 293).

A major Taiwanese computer manufacturer also has embraced a strategy of building up "twin towers" in China and Taiwan. As part and parcel of this strategy, the firm has cultivated China as the sole base of its software operations. Their software operations go beyond code writing to crafting the whole embedded software system needed for their own-designed notebook computers. Without these Chinese operations, the firm could not design a notebook. Originally, the hardware systems were completely designed in Taiwan leaving the firm with a clearly defined division between the software base in Taiwan and the hardware base in China. However, recently, the firm has begun to move hardware research to China without moving any software research back to Taiwan. While already a third of its research engineers are in China (excluding production engineers in Chinese plants), the fraction should increase because two-thirds of the total engineering staff are Taiwan-based hardware engineers (Interviews 278, 237). The other Taiwanese notebook producers have not embraced a China-based strategy and none of them have software or hardware system design (as opposed to simple code crunching) in China (Interviews 278, 279, 259, 255, 237, 219, 206, 205, 204, 201 and others).

This hybrid computer firm does not pursue any basic research (stage 1) in China, but the firm does not pursue such research in Taiwan or anywhere else in the world. The firm has followed the classic evolutionary path of Taiwanese ODM firms building design operations after becoming large contract manufacturers for the major international brands (Lee and Chen 2000). Thus, it has slowly worked its way from production backwards through the stages of research. What is critical is that the firm has as much stage 2 research, new product development (its most sophisticated research), in China as it has in Taiwan.

Another Taiwanese firm has quietly embraced a China-based strategy. It has done so quietly because it embarked on this strategy after the 2000 Taiwanese presidential election brought Chen Shui-bian, a fiercely anti-China politician, to power. Similar to UMC, it chose to invest heavily (and illegally) in sophisticated activities in China so it has assumed a low public profile unlike President Dai of Inventec or Guo Tai-ming of Hon Hai, who in the late 1990s proclaimed that they were embarking on China-based strategies. This firm's strategy is of interest because it has chosen to do its most and least sophisticated R&D in China. On the low end, due to its heavy concentration of plants in China, the firm does much of its design for manufacturing in its mainland plants. On the high-end, far from its largest manufacturing base in southern China, the firm has invested in an R&D center with 100 PhDs doing basic research on product technologies and new product generation (stages 1 and 2). In contrast, the firm's much larger R&D center in Taiwan only employs 170 PhDs and concentrates mainly on new product generation and detailed design (stages 2 and 3) although there is some joint research between the Chinese and Taiwanese facilities.

Another hybrid firm from Hong Kong moved almost all of its design functions to China. This left a mere ten researchers in Hong Kong while employing 120 in China. The new facility does advanced work in conjunction with the Hong Kong researchers, but also covers the breadth of the firm's R&D from new product generation to design for manufacture.

Alongside of these established firms are new start-ups. In addition to the handset design firm already discussed, there are several other promising start-ups that I discovered in the course of my research. One of these firms is founded by the ex-director of one of the few regular FIEs to found an IC design center in China (see Chapter 5). His new firm develops and designs new wireless local area networks (WLANs) because the demand for these machines is large and growing given China's small fixed line infrastructure and the relative high cost of installation of fixed lines into existing buildings. The team has 200 engineers and they are creating new WLAN products for a range of MNCs to sell in China and elsewhere. The entire R&D team is based in China and includes the founder and five engineers with whom he worked at a global top ten telecommunications MNC before directing the IC design firm (the design firm was a spin-off from the telecommunications firm).

A returnee from Canada has created a product design company making web cameras. This firm has linked up with a major foreign IC (integrated circuit) producer that wanted to find new markets for its chips. The firm designed in the chips of this MNC and the MNC wants to help the start-up sell the cameras abroad as well as in China. This start-up concentrates most of its activities in Shenzhen, but has eschewed the national-grade technology park there because it feels the services for returnees are actually very minimal, just cheap office space (I heard this lament from nearly every start-up in every state-run park and incubator I visited although many did not turn up their noses at cheap rent). The firm designs its own-brand products and products marketed under some of the major Chinese brands, which do not have the capabilities to create these products themselves.

4.3 Overview of the Engineers Trained and R&D Activities Conducted in FIEs

Through my interviews, I have been able to confirm the size and activities (according to Amsden and Tschang's typology) in the R&D centers listed below. In the preceding section, I discussed the details of many of these firms. Others I have not discussed in detail because pointing out that yet another MNC was doing code writing in China is repetitive. The regular FIEs (marked as MNCs in the Table 4.17) R&D centers are all top twenty-five global IT firms or top ten global firms in software or telecommunications, except for two 1990s start-ups. I have also included Taiwanese firms that have eschewed the China-based strategy, but are still operating some R&D in China. Finally, I have included a category "Other Taiwan" that denotes those large product manufacturers from Taiwan that employ a few design for manufacturing engineers in their local Chinese plants. I estimated that there were approximately 20 such plants with 20 engineers each although the actual plant total is probably much higher. This category is based not only on my own observations from interviews and plant visits, but the works of S. Chen (2004) and Yang and Hsia (forthcoming). These Taiwanese scholars observed that many Taiwanese product plants employed design-for-manufacturing engineers at the manufacturing site.

For the hybrids in Table 4.18, the first four firms are established firms i.e. they had a home base in one of the ECEs before embarking on a China-based strategy. The other four were start-ups or, in the case of Hybrid 8, a new business for an established firm. As can be seen from the totals, far more engineers were trained by the regular FIEs than the hybrids. When one turns to examine the activities pursued, the hybrids come out ahead. Only one firm among the regular firms, Microsoft, was pursuing new product generation (stage 2) research. As mentioned, Microsoft is conducting much of its X-box design including architectural design that constitutes new product generation. This firm's R&D activity is one of the cases already presented. Among the hybrids, all the firms

Table 4.17 Foreign R&D Centers: Personnel and Research Activities

Sources: Interviews and Z. Wang (2001;2002).

Code	Nationality	Researchers	Products	A-T Stages
MNC1	N. Am	900	TC/software	3 and 4
MNC2	N. Am	200	PC/software	4
MNC3	EU	700	TC	3 and 4
MNC4	Japan	13	PC/software	4
MNC5	Japan	3000	IT/software	4
MNC6	EU	114	TC/software	4
MNC7	N. Am	300	TC/software	4
MNC8	EU	200	TC/software	3 and 4
MNC9	Japan	1500	consumer	4
MNC10	N. Am	150	IT/hardware	2,3 and 4
MNC11	N. Am	1400	TC hard&soft	3 and 4
MNC12	Japan	48	consumer	4
MNC13	EU	30	PC/software	4
MNC14	N. Am	30	software	4
MNC15	Japan	20	machinery	4
MNC16	N. Am	60	IT/software	3 and 4
MNC17	N. Am	2000	TC/software	3 and 4
MNC19*	N. Am	2000	TC/soft&hard	3 and 4
MNC20*	N. Am	400	TC/ind. design	3 and 4
MNC18	Korea	700	consumer	4
MNC21	Korea	200	consumer	4
TW1	Taiwan	200	PC/software	4
TW2	Taiwan	100	TC/software	3 and 4
TW3	Taiwan	300	TC/software	4
TW4	Taiwan	75	TC/soft; Manu	3 and 4
	Other Taiwan	400		4
Total	Regular FIEs	**15040**		

TC: telecommunications; IT: general information technology; Comp: components; PC: computers; Manu: manufacturing; Consumer: consumer electronics.

4.18 Hybrid R&D Centers: Personnel and Research Activities

Source: Interviews and Z. Wang (2001;2002).

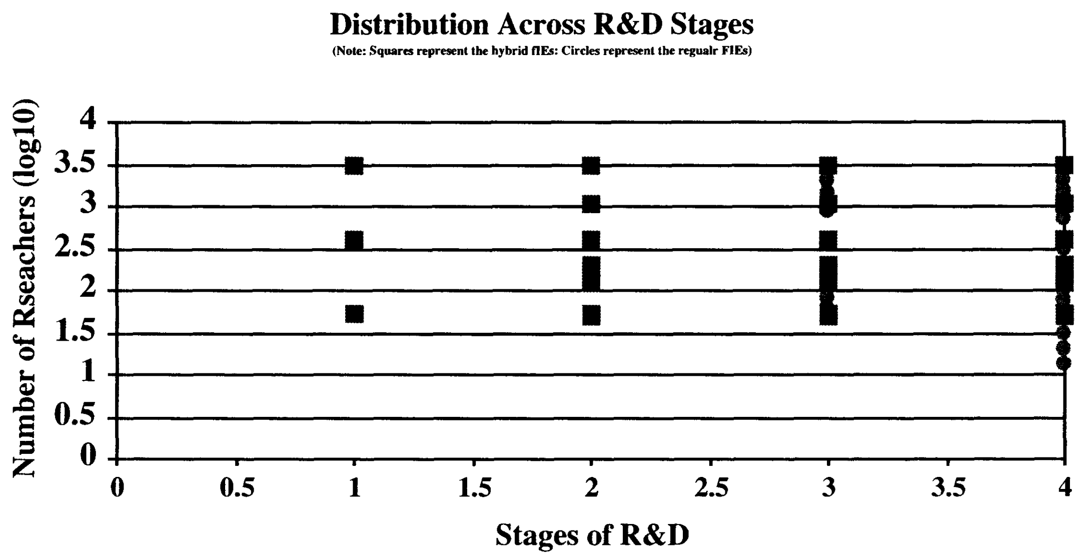
Code	Nationality	Researchers	Products	A-T Stages
Hybrid 1	Taiwan	3000	Comp;TC/soft &hard	1,2,3 and4
Hybrid 2	Taiwan	1100	PC/software&hard	2,3 and 4
Hybrid 3	Taiwan	400	Comp; Manu	1,2 and 4
Hybrid 4	Hong Kong	120	Comp	2, 3 and 4
Hybrid 5	Overseas	50	TC/soft&hard	2, 3 and 4
Hybrid 6	Overseas	50	Consumer/soft&hard	2, 3 and 4
Hybrid 7	Overseas	200	TC/soft&hard	2, 3 and 4
Hybrid 8	Mixed	55	Comp;TC/soft&hard	1,2, 3 and 4
Total	Hybrids	**4975**		

TC: telecommunications; IT: general information technology; Comp: components; PC: computers; Manu: manufacturing; Consumer: consumer electronics.

were conducting new product generation and some were involved in basic research where a PhD is required. A better way to conceptualize this dichotomy is through presenting the stages covered by various hybrid and regular FIEs in Figure 4.4 below. The regular FIEs are clustered in stages 3 and 4 were much of the activity of the hybrids is in basic research and product generation.

When one considers the domestic firms, almost none of them qualify as contributing to technological development. TCL is a marginal contributor and has only approximately 100 engineers engaged in product development. The firm is at best doing detailed design according to the reports of suppliers discussed above. If the standards are lowered further, Huawei (despite violating the standard of commercialization by selling the majority of its products to the state) could be included. Huawei's three thousand design engineers are at best engaged in detailed design based on other firms' products. If

Figure 4.4



the standards are lowered further, we could count every Chinese firm remotely related to IT and having a US utility patent as having contributed 100 development engineers. In this case, Tongfang, BYD and Haier could be included.[121] Even with granting all of these exceptions, the domestic Chinese firms would still have trained a mere 3400 engineers in detailed design and design for manufacture. This figure is lower than the hybrids and a mere fraction of the regular FIEs, and I have not interviewed all of the latter two types of firms that have such design activities in China.

[121] Including Haier is dubious because all four of Haier's patents were modifications of white goods (washers and refrigerators) rather than IT products. Furthermore, a partner of Haier and Chinese government officials familiar with the firm claimed that the firm's R&D abilities were very weak and generally limited to testing products. Tongfang's inclusion is dubious because the firm's boundaries with Qinghua are quite porous and this may simply be Qinghua research that was taken by or awarded to the firm.

5. New Firms and Foreign Venture Capital in China

The superior upgrading of the FIEs can be connected to the financing of these operations. For the established firms, regular FIE and hybrid alike, external financing mainly comes from the same sources of finance they draw upon for their operations elsewhere in the world. Thus, there is no reason to expect that these mechanisms of finance will operate differently for these firms when they create Chinese operations. However, the new hybrid start-ups mostly draw upon foreign venture capital. While these venture capital firms are the same ones that start-ups in the advanced industrial world have drawn upon for finance in the past, there is still the question of how these venture capital firms operate when they enter China. Given that venture capital firms try to operate locally and interact intimately with the firms they invest in, there is the possibility that the venture firms investing in China either change their practices when they enter the new, Chinese environment or do not enter China at all, opting instead to monitor their invested firms at a distant. In either case, the specter of VCs failing to keep firms on the straight and narrow arises.

Happily, the major foreign VCs operating in China do not seem to have changed their hands-on tactics to manage their investments in an efficient manner. The main mechanisms to monitor their investments still are the time-honored ones: 1) spending the time to assess investment prospects 2) participating in the actual management of the firms and 2) sitting on the board of directors of the invested firms. The emphasis the foreign VCs still place on due diligence for potential investments and active participation of the management of their invested companies can be seen by the co-location of the VCs and their investments. The lead investors insist on having offices in proximity to the firms in which they invest because they wish to be able to stay actively involve in the management of these firms. One firm with an office in Shanghai claimed that it had a three-hour rule. No investment in China could be located more than three hours by car from the firm's office in Shanghai. In explaining this rule, the firm stressed the need to be near by in order to help manage the invested firms and approvingly cited best practice in Silicon Valley where co-location is also highly valued. The major firms with significant lead investments around China invariably had offices in each major area of investment. Many VCs have numerous local offices in China before a single investment in the locale proceeds. This practice is in place to assess potential local investments because they feel that they cannot accurately conduct due diligence and the subsequent management at a distance. The foreign VCs in China also limit the number of investments in which they take the lead because each lead investment consumes large amounts of the lead investor's human resources to manage and monitor the invested firm. Even the relatively small VCs had multiple offices in China if they aspired to invest in multiple places. As for governance mechanisms, I did not uncover a single firm backed by foreign venture capital that did not have an investing venture capitalist on its corporate board. Just like VC practices abroad, accepting VC funds in China also meant accepting VC participation in the firm's governance.

Chapter Five

From California Dreaming to Silicon Success: China's Upgrading in Integrated Circuits

1. Introduction

On a very hot and humid day in July of 1998, I unwittingly imitated those celebrated British companions of mad dogs under Hong Kong's noon sun by making the three and a half hour train trip from Shanghai to Wuxi clad in coat and tie. My mission was to see first hand the fruits of China's efforts to leapfrog into advanced semiconductor technologies. I had been forewarned by two different sources about what to expect. Some MIT professors had made the same trip six months earlier only to find an operation where the new fab (the fabrication facility) remained empty because the state-owned firm charged with operating it had no idea what products to produce for the market. Later, a Lucent employee, a Chinese returnee who was committed to helping China's technology industry and involved in the technology transfer from Lucent to the project, reported much the same. Nevertheless, the Lucent employee invited me out to see the infamous 908 Project for myself. I left Wuxi that evening with two convictions: I would never be able to remove the ring around the collar from the shirt I was wearing and China's IC industry was stillborn.

Almost three years later, I visited a respected fab manager who had worked for US fabs and TSMC before moving to China to pursue his lifelong dream of bringing technology to China. He was working out of a prefabricated office surrounded by fields of mud and a very large hole out of which were rising some girders serving as hopeful hints of the possibility of a building. Despite these bleak surroundings, the site was bustling with activity and the international team recruited to create the new pureplay foundry, SMIC, was an impressive one with engineers from TSMC and UMC, the two largest pureplay foundries in the world, as well as prominent IDMs (integrated device manufacturers), such as TI (Texas Instruments). The firm did not yet have a fab, but they had a viable strategy and the team to execute it. These two features put them two moves ahead of the Project 908 firm, Huajing. Clearly, China's silicon fortunes had taken a turn for the better.

Four years after my first visit to Wuxi, I went with some MIT electrical engineering professors to see SMIC's fab in operation. The electrical engineers were clearly impressed and complimented the fab manager on his success. The engineers had started the trip pessimistic about China's prospects, but the visits to SMIC and other firms changed their minds. After four years, at least one of my convictions still held true. My shirt had been ruined that day in Wuxi. As for China's silicon future, the changes wrought in those four years had shattered my firmly held conviction that China's technological future was bleak

This chapter is the story of China's silicon success. Microelectronics (meaning semiconductors or, even more colloquially, computer chips) was chosen because microelectronics is commonly seen as one of value centers and technology drivers of IT (Macher *et al* 1999). The sub-sectors of semiconductors examined are fabrication (chip-making) and design. The sophisticated technology needed for semiconductor production makes this segment of IT a good critical case for exploring routes to technological upgrading. ICs are a critical case because FIEs are generally assumed to be unwilling or unable to transfer the most sophisticated technologies to host countries (Song 1998). If such firms are fostering technological upgrading in the advanced technology of microelectronics, then such firms may be even more willing and capable to upgrade in other areas in the IT industry in China.

This chapter will examine the more technology intensive segments of the semiconductor production chain (as presented in the IC industry chain in Chapter Three), design (both detailed and innovative) and fabrication. The chapter will not examine the assembly and testing of the ICs, often referred to as the backend of the IC production chain, because the backend is less technologically intensive and is not the core technology and value creation center of the semiconductor production chain.[122] Historically, the developing world has had assembly and testing operations due to the labor-intensive nature of the work, and these operations did not necessarily lead to the development of the more technologically sophisticated front-end skills of design and fabrication.[123]

Using the same four types of firms discussed in the first and fourth chapters (hybrid FIEs, normal FIEs, favored domestic firms and neglected domestic firms), this chapter will evaluate how these firms contribute to the technological upgrading in China's IC design and fabrication segments. To review, the process of measuring

[122]Interviewing Intel employees in March of 2004 re-confirmed this notion of the non-critical nature of the backend. Intel prides itself on having "bleeding edge" (i.e. the most advanced) technology in A&T (assembly and test), but the firm only keeps the proprietary A&T technology in-house for six months or so. Furthermore, the A&T process technology would not be kept in-house at all except for the fact that this effort entails relatively small capital expenditures compared to the expense of investing in fabrication facilities. In other words, the limited technological benefit of in-house A&T is only justified by the relatively low cost of protecting this technology by doing it in-house. Intel only creates the A&T technologies in the US and actually deploys them to A&T factories abroad. This practice has been Intel's SOP for many years. Unlike in fabrication, the A&T process technology and the operation of the manufacturing facility are not intertwined and inseparable. This provides Intel the opportunity to create the relevant A&T technology in the US but deploy this technology to operating factories in lower cost locations, such as Malaysia, Costa Rica and China.

[123] Taiwan and Korea developed their design and fabrication skills after having A&T plants in their countries for at least a decade prior to their first fabs. Furthermore, the firms that operated the fabs were by and large not the firms that had run the A&T plants. Other countries, such as Malaysia and the Philippines, have had large clusters of A&T plants, but have never been able to develop much of a front-end of semiconductor manufacturing.

technological upgrading is a 4-step process: 1. compare the technological activities of the firm in China to the general level of technology of that activity in China to see if these activities represent a technological advancement upon existing activities within China 2. compare the technological activities to the international frontier and to other LDCs to see if China has gained any ground on the rapidly moving technological frontier 3. determine if the technological activities are commercially viable 4. check embeddedness at the firm-level and by searching for institutions for the continued utilization of the technology either through new firm generation or luring of the existing firms to come to utilize this technology in the host economy. The chapter will examine the first three and a half steps through examining the performance of the relevant firms in design and fabrication. Both IC fabrication and design will use process technology lithography line-widths (measured in microns) to measure the distance to the technological frontier, but evaluating the design technologies will incorporate additional metrics, such as design type (digital versus analog/mixed signal), product type (e.g. DRAM) and reliance on reverse engineering.

This chapter will argue that the domestic Chinese firms failed to contribute to China's technological upgrading either because they did not improve the technological content of the activities they undertook or because they did not embed these technology activities in China, leaving the control of the technology in the hands of foreign joint-venture partners. As for the FIEs, the chapter will argue that the hybrid FIEs pursued embedded technological upgrading in China by pursuing technological activities that were more advanced than the norm in China while also embedding them through the training of local staff and to a lesser extent, training supplier firms. The regular FIEs did contribute to embedded technological upgrading though the number of regular FIEs contributing was small and overall the regular FIEs did not do so as consistently as the hybrid FIEs. In contrast to Chapter Four, the hybrids contributed by far the most trained technical personnel. The common trend shared with Chapter Four is the greater sophistication of the skills generated by the hybrids.

2. IC Fabrication

2.1 State Projects

The Chinese state attempted a series of grand projects to leapfrog into the silicon age. However, what these projects lacked were participating firms that could be viable commercial entities, independent of state largesse. Instead, the plans were burdened from the beginning by being attached to particular SOEs and the managerial and production efficiencies associated with this type of firm. These firms were blessed and cursed by state beneficence. With assured state support, these firms were able to enter more advanced semiconductor manufacturing, but the state support undermined any financial discipline that could have forced the firms to hone their competitive advantages. Instead, these firms were either late in achieving the goals set for them or dependent on their foreign partners for technology or both.

The semiconductor industry can be said to have started in 1956 when China's first transistor was created (Dewey Ballantine 2003, hereafter referred to as DB 2003: 23 fn 64). Others date the start of China's semiconductor industry from 1965 when China created its first integrated circuit only seven years after the ICs were invented in the US by TI and Fairchild. When the Chinese Academy of Science (CAS) started its integrated circuit research in 1965, China was far ahead of Taiwan and Korea in ICs as neither of these economies had any IC industry to speak of (DYBG 2002, No. 11). This period of self-reliance (*ziligengsheng*) lasted until well into era of economic reforms with the first major effort to improve China's commercial fabrication technology starting in 1991 with the 908 Project.

2.1.1 The Chinese Semiconductor Industry's Huangpu Academy: Huajing and the 908 Project

The Huajing Group was originally Wuxi Factory No.742, established in 1960. The factory has been hailed as the "Huangpu Military Academy of China's semiconductor industry," referring to the famed KMT[124] military academy in Guangzhou that trained most of the military cadres of both the KMT and CCP. The factory did indeed train much of the early personnel of China's fledgling semiconductor industry, and, as Chinese semiconductor engineers of a certain age never tire of reminding people, in the early 1960s China's semiconductor technology was at least as sophisticated as Japan's. Despite these prestigious origins, Huajing as the center of the state's semiconductor industrial policy in the 1990s was a failure.

In preparation for the 8th Five year Plan (1991-1995), the Huajing Group was selected to be the vehicle for a project to lift China's semiconductor manufacturing up to 6" wafer technology, which was the largest wafer size at that time.[125] The government decided upon the plan in August of 1990 so the plan was dubbed the 908 Project. The

[124] KMT is the abbreviation for the Wade-Giles romanization of the Chinese name of the Nationalist Party that ruled China prior to the Chinese Communist Party (CCP) takeover.
[125] Semiconductor fabrication plants (or fabs as they are often called) are categorized in part by the size of the wafers (the round pieces of silicon on which circuitry is placed) processed in the fab. The wafers have grown larger with successive generations of fabrication technology. The latest fabs use 12-inch (300mm wafers.

government spent 2 billion RMB to complete the modest goals of the project to build a six-inch fab (fabrication facility) with .8 to 1.2-micron process technology, which even at the time was not the technological frontier in process technology, and a modest monthly output of 12000 wafers (DYBG 2002, No. 14: 2). Despite the modesty of the goals, the project took 8 years to complete, and when it was finished, the fab remained virtually empty as Huajing had no idea how to operate the fab as a commercial enterprise.

The resulting problems from this long delay in ramping up the project were manifold. By the time the plant came on line, the technology was very backward as eight-inch fabs were already mainstream. The capacity was also quite small so it was hard to earn back the initial investment. According to one internal report from MOST, massive losses hinder the advance of the entire Huajing Group (DYBG 2002, No. 14) though the losses might have been partially recouped when Huajing started to rent the fab to the ECE firm, Central Semiconductor Manufacturing Corporation (CSMC).

The primary foreign partner for the technology transfer was Lucent Technologies. Lucent was very eager to sell more telecommunications infrastructure equipment in China and participating in this technology transfer project seemed to be a good way to curry favor with the owner of the customers of this telecommunications equipment, the Chinese state. Lucent not only provided process technology, but also provided a design library so Huajing could design its own products. Lucent did not take a stake in the firm nor promise to be a major customer.

Unfortunately, even with Lucent's help, things did not go as planned. Engineering professors from MIT who visited in January of 1998 reported that the firm's own engineers had no idea what products to design despite access to the design library.

The fab was essentially empty because there were no products to produce. In the summer of 1998, a Lucent employee heavily involved in the technology transfer reported much the same dilemma.

Happily, there was already a glimmer of hope for the fabrication operation. CSMC, a Hong Kong-registered firm with strong links to a Taiwanese semiconductor firm, Mosel-Vitelic, had appeared and proposed to rent the fab in order to convert the fab to use as a foundry for low-end products suitable for the technology of the fab. Huajing agreed to this proposal in 1998 and operations commenced. In 1999, CSMC took formal ownership of the fab through the establishment of CSMC-HJ, a 51% CSMC owned joint venture. By 2002, CSMC had taken control of another fab line, a five-inch line, from Huajing (according to company materials given to the author in July of 2002). A planned national champion had become a subsidiary of an ECE firm. Hardly what the central state, especially the technocrats at Ministry of Electronics Industry (MEI), had envisaged when they embarked on the 908 Project back in 1990.

What happened to the design library Huajing received from Lucent? Later evidence bears out the early pessimistic reports from the MIT engineers and the Lucent employee that the design library was never effectively used to design products. Huajing Group has a wide array of low-end products, but these are all very low-end and low profit items. Huajing's well known and relatively large (by Chinese industry standards) design house, Semico (Xike), is also regarded as a typical reverse engineering design house among technology people familiar with the Chinese industry (Interviews 8, 266, 312). Furthermore, in 2002, China Resources, a Hong Kong red chip[126], bought a controlling

[126] Red chips are Hong Kong-listed firms with links to the Chinese government. China Resources is linked to the Ministry of Commerce (MOC).

share of Semico. Huajing also did not contribute much from spinning off or diffusing technology in China. A former Huajing employee, who subsequently received training abroad in a large IDM, remarked that a lot of Huajing's designers had left the firm to set up their own fabless design companies in Wuxi, but these engineers are just doing the same thing they did ten years ago, reverse engineering of low-end designs. He was emphatic that there was no way these ex-Huajing employees could do contemporary, large scale design know as System-on-a-Chip (SoC), where many functions are integrated into the chip design requiring very large and complicated designs (Interview 312). In short, Huajing did not manage to make much of the assets that Lucent gave the firm, many of these assets eventually left Huajing's control and the firm also failed to diffuse technology to others.

From a technonationalist perspective, precisely the perspective used by the Chinese state, the failure of Huajing was a failure on two fronts: 1) Chinese-controlled technology did not get much closer to the technological frontier in the IC industry and 2) the selected national champion was not strengthened. However, this study does not denigrate the transfer of assets to "foreign" control if foreign control enhances the capabilities of Chinese or the industrial infrastructure in China. On these grounds, Huajing was a modest success though a success in way not envisioned by the government and perhaps even excoriated by some more strongly nationalists elements inside and outside the government. The takeover of two fabs by CSMC while using the same engineers that were originally in Huajing offered these engineers the opportunity to learn how to operate more efficiently and to learn the foundry business, albeit with relatively backward process technology. As one former Mosel-Vitelic and CSMC manager observed, CSMC uses the same engineers from Huajing, but they are under better management (Interview 7).

The reason this success was so modest as compared to the latter foundries, SMIC and Grace, was the inability of the government to get the six-inch fab up and running at the time when six-inch fabs were still relatively close to the technological frontier. Having a fab with old process technologies would only attract an investor who was seeking to do low-end fabrication because that is all the fab would be adequate to handle. Thus, Huajing attracted the new Mosel-Vitelic affiliate, CSMC, to start a foundry business rather than a top-tier foundry. Mosel-Vitelic is a small IDM rather than a pureplay foundry. The expertise the firm had to offer in terms of running a pureplay foundry business was quite limited. Furthermore, in 1998 the image of China in the IC industry was poor so there were not droves of Taiwanese engineers willing to come over to impart their knowledge to the locals, but just a few top personnel. Nevertheless, CSMC did at least manage to come up with a business plan that filled the fab with orders and taught Chinese engineers how to run a foundry business using a six-inch wafer line. Thus, only with CSMC, did the fab begin to function as a commercial enterprise and the fab was still one of China's first two six-inch fabs.

The hybrid FIE, CSMC, accomplished embedded technological upgrading where the domestic champion, Huajing, could not. CSMC was the first foundry in China with a six-inch, .8 to 1.2-micron fab that competed in the open marketplace. Therefore, the firm did upgrade over China's existing fabrication technology. The technology was ten years behind the technology frontier in 1998, but this gap was smaller than the gap between China and the global frontier in the reform era prior to CSMC (see Table 5.3). The process technology employed at CSMC was embedded in the local environment due to the use of local engineers to run the process with only handful of Taiwanese executives in the firm at any one time.

Why is CSMC a hybrid FIE rather than a regular FIE? CSMC is a hybrid FIE because the firm clearly is conducting a China-based operational strategy on all three criteria outlined in the introduction: self-description, weight of operations and ethnicity of the firm's management/owners. CSMC explicitly proclaims its desire to serve the growing manufacturing base of China. All of the firm's fabs are in China. Finally, the firm is clearly an ethnic Chinese-owned and managed firm with its managers and owners being ethnic Chinese from Taiwan and Hong Kong. Examining the balance of operations, the firm's operational resources are based almost entirely in the PRC despite registration in Hong Kong. Although CSMC is financially connected to Mosel-Vitelic through that firm's Hong Kong affiliate, CSMC is operationally independent because the firm is in a completely different line of business, foundry manufacturing services (provision of chipmaking for other firms) than Mosel-Vitelic, which designs and produces its own DRAM. Outside of China, there are only sales offices.

Since 1998, CSMC has maintained its strategy of being a low-cost fab following far behind the technology frontier. Even when the recent moves to enter into .35-micron production through the purchase of equipment from Agere and technology from Chartered are successfully implemented, CSMC will trail approximately ten years behind the technology frontier as the lead firms first implemented production-ready .35-micron technology in 1994 (Mathew and Cho 2000: 136). Nevertheless, CSMC narrowed the technology gap that China had with the advanced industrial world and even today it is unclear if any domestic firms have control over production-ready .35-micron technology. Without the entry of other leading hybrids, SMIC and Grace, CSMC might still be China's leading firm in terms of the level of embedded technology. This fact is quite surprising given CSMC's strategy of following far behind the frontier whereas the China's state-sponsored firms (HHNEC, Shanghai Belling, ASMC and Huajing) all have or had plans to try to catch up to the frontier. Like the tortoise and the hare, these ambitious state firms aspiring to be close followers of the leading international firms have discovered that they have been beaten by the plodding, pragmatic CSMC with its dull strategy of providing low-cost foundry services at a distant from the frontier. CSMC's success only dims in the bright light of the success of the hybrid FIE fast followers, SMIC and Grace, which have beat the Chinese state firms at their own ambitious strategy of catching the technology frontier.

One positive but unintended consequence of the failure of Huajing's fab and the subsequent takeover of operations by CSMC was the gradual inflow of talent from Taiwan. Nasa Tsai, president and one time chairman of Grace Semiconductor, came to China via CSMC. Tony Liu of Advanced Semiconductor Manufacturing Corporation (ASMC) also spent time at Huajing before moving on to head ASMC. As for locals, many moved on to other firms after receiving some training in conjunction with CSMC. As put in the MOST internal report, Huangpu Military Academy has an alternative meaning to the one suggesting it is the cradle of China's IC industry. Just like the Communists who left the Huangpu Military Academy and fought a civil war with their KMT classmates, engineers have left Huajing for competitors (DYBG 2002, No. 14). However, most of the outflow appears to be to other Chinese-owned fabs rather than to the cutting edge FIE foundries because the latter tend to prefer fresh university graduates to train to their system as opposed to engineers from SOEs, who generally have institutional baggage from their previous employers.[127]

2.1.2 The Big Statist Push: The 909 Project

With the advent of the Ninth Five Year Plan (1996-2000), the Chinese government embarked on a second major effort to catch up to the technological frontier, dubbed the 909 Project as it followed the 908 Project. MII[128] and Shanghai Municipality created the Huahong Group with shares distributed between the two government entities in a 60:40 split. Huahong was charged with the task of being the Chinese SOE that would hold a majority share in the 8-inch JV fab that was the centerpiece of the project. Then, NEC was selected as the JV partner and technology source. For the JV, Huahong NEC (HHNEC), Huahong put up 500 million USD for 71.4% of the equity and NEC put up 200 million USD for 28.6% of the equity. In 2002, HHNEC already had a staff of 800 (DYBG 2002, No. 11). The goal was to create a commercial 8-inch fab with .5-micron technology.

909 Project was expensive. The total expenditure was 10 billion RMB or 1.25 billion USD. This was three times what Taiwan spent during its whole ramp up stage and

[127] The leading FIE foundries, Grace and SMIC, both targeted fresh university graduates, and considering the personnel problems I uncovered at two SOE fabs, it is not difficult to understand why. The two SOEs had engineering practices that were inefficient and downright negligent. One firm told a graduate student who went there to help them improve their productivity that they did not really have any idea about their throughput and often had to guess (Interview 263). The director of the other firm's fab became so fed up with what he termed the bad corporate culture of his firm that he wrote a memo to his employees to explain how fabs were supposed to operate based on his experience in managing fabs for US and Japanese firms in the US. His main point was that professionalism meant doing one's job for the company to the best of one's ability and putting the company's interest first, attitudes he saw lacking in his SOE.

[128] MII was created form merging MEI and MPT in 1998. See footnote 132 for details.

Huahong could have bought its own fab for this amount. This technology was later upgraded to .35-micron though one report mentions some .24-micron capacity (DYBG 2002, No.11). The firm also has incurred heavy losses through operations. In 2001, the firm lost 80 billion RMB (6.4 billion USD) alone. This huge lost more than made up for the nominal profits of 30 million RMB in 1999 and 3.5 to 5 billion RMB in 2000 (DYBG 2002, No. 11: 7).

Naughton views the 909 Project as a move away from what he dubs China's critical technologies approach to technology policy. According to Naughton, China during the reform era prior to the 9th FYP (Five Year Plan)[129] pursued a very rigid state-planned form of techno-nationalism in which the state carried out plans to develop indigenously various technologies deemed critical for economic and security reasons. These plans were carried out by state-run institutions, research units as well as SOEs, and eschewed foreign cooperation (Naughton 1999). Contrary to Naughton's claims that the 909 Project represented a major break from China's statist, critical technologies approach, the internal analysis by MOST officials (DYBG 2002, No. 11) suggests a mere shift in tactics from a state-planned approach in the 908 Project to a JV approach in the 909 Project with technonationalist, state-driven plans forming the strategic backbone of the project. According to MOST's report, the goals set out for HHNEC were three-fold. The first goal was to establish an independent IP portfolio in the IC industry to break the control that America and other leading countries had over IC technology. The second goal was to use China's huge market to create an internationally competitive IC giant. This goal is the one that clearly shows how little China broke with their past

[129] Naughton does not explicitly state that the 9th FYP was the turning point, but he does date the change in attitude from that period.

technonationalist ambitions in promoting the 909 Project. The idea of using the large market to create a competitive IC industry is one that continues to be promoted by local and central government officials alike. The third goal was to train a large group of specialists in IC technology, industrial technology and management of the IC industry. Discussions with sources familiar with Huahong confirmed these technonationalist ambitions (Interviews 12, 114).

The goal to create Chinese IP was understandable given the international context of the 909 Project. Undoubtedly, the technology export controls of Cold War-era COLCOM and the subsequent though weaker Wassenaar Agreement heightened China's sense of vulnerability and dependency in this area. In the latter half of the 1990s, the ability of China to import US capital equipment for 8-inch fabs was still much in doubt due to the stringent American interpretation of the Wassenaar Agreement and was one of the reasons that China chose NEC over competing bids by IBM and Rockwell. The ability of Motorola to import 8-inch equipment in the late 1990s was the first sign that the US was beginning to relent, given the looser interpretation of the Wassenaar Agreement by other major IC capital equipment manufacturers.[130] While the first goal was understandable given the international context and the third goal was one shared by technoglobalists and techno-nationalists alike, the goal of creating a state-owned national champion in the IC industry shows how little the Chinese state had departed form the earlier thinking on technological development.

[130] There are persistent rumors that Motorola imported more advanced equipment than US export controls of the time allowed in the late 1990s or 2000, probably due to Motorola correctly anticipating the loosening of the export controls.

MOST officials in an internal report conclude that the 909 Project failed to achieve any of the three goals. The MOST team still concludes that the 909 Project did much better than the original self-reliance model would have. They estimate the self-reliance approach would have used 15 years to achieve the technological jump that HHNEC achieved in 5 years i.e. an 8-inch fab with .35/.25-micron technology and 20,000 wafers per month (DYBG 2002, No. 11: 6). This estimate may be correct, but there is some doubt as to whether HHNEC actually has this level of technology. Customers of Chinese wafer fabs with knowledge of HHNEC's operations argue the firm does not really have operational .25-micron technology and doubt that the firm actually runs 20,000 wafers per month (Interview 266). Nor do the MOST researchers explain how they arrived at the estimation of 15 years though it is easy to understand that developing the technology internally would have taken much longer than the importation of technology from Japan. Still, the MOST officials correctly note that the technology really remains in hands of the Japanese and no Chinese IP has been created.

The fact of Japanese control of the technology was confirmed by three sources very familiar with the firm and the situation is even bleaker than the MOST officials' account because the technology captured by HHNEC is narrower than the MOST officials realized. The first source was two managers familiar with HHNEC and the HuaHong Group. They were interviewed in 1998 early in the HHNEC's history (Interview 12). Their concerns that China would not be able to control the technology might have been relieved through later technological transfer as it is reasonable to expect technology transfer to take some time. Unfortunately, such technology transfer to Chinese hands did not happen as later sources stated. One source very familiar with

HHNEC's internal management stated bluntly in 2002 that the technology remained firmly in Japanese hands through management of the training process. The Japanese made sure to train the Chinese engineers in specific tasks in order to retain knowledge of the whole process of fabrication in Japanese hands. No Chinese engineer learned much about the process outside of his narrow specialty and the Japanese made sure not to train anyone capable of managing the integration of these tasks (Interview 114). A potential customer of HHNEC reported in 2003 that HHNEC not only did not have the level of technology it reported to have, at least not in a stabilized ready-for-manufacturing state, but when conversing with HHNEC's engineers about the .35-micron technology that he needed to fabricate his chips, it became evident that the Chinese engineers could not actually run the process with the technology on hand. As the Chinese engineers explained to the potential customer, the technology necessary to run the .35-micron technology remained in Japan and the Chinese engineering staff did not have access to this technology. To verify that HHNEC could actually fabricate the chip he wanted, the customer would have to confer with Japanese engineers in Japan. Even though .35-micron technology was far from the frontier in 2003, the Japanese still resisted turning it over to Chinese engineers (Interview 273).

The MOST researchers view the creation of a national champion as a failure given HHNEC's losses, but they have a more mixed view of the training of technical personnel. They believe the firm has trained lots of technical personnel citing 45000 man hours spent training the Chinese personnel and the expenditure of 10 million RMB to send engineers to train at IMEC, the EU semiconductor research center in Leuven, Belgium. On the negative side, the MOST officials point to a lack of trained Chinese managers within HHNEC. What would be amusing if it were not so sad is the conclusion drawn by the officials from MOST that one of the major problems with the Huahong Group is that the group is run by a bunch of government hacks or as they more politely phrase it, "As for Huahong Group's managerial staff, most are originally government officials who now are involved in the work of management. Talented people with real skills in modern enterprise management are rarely seen (DYBG 2002, No.11: 7)." They also note that the Chinese face great difficulty in entering the core operations of the firm. The MOST evaluation of the training at HHNEC may not be harsh enough as reports from interlocutors suggest that even the training of the engineering staff was strategically limited by Japanese partners to ensure that the process technology did not fall into Chinese hands (Interviews 114, 273).

Judging HHNEC by the standard of embedded technological upgrading, the firm has failed. Even if the firm does have 8-inch wafers running at .25-micron process technology, a large improvement over previous fabs in China, the firm has failed to pass this technology onto local employees or local suppliers, the key criteria for the test of embeddedness at the firm level. Instead, the process technology remains firmly in Japanese hands and there is no evidence that this control has or will change over time (Interviews 12, 114, 273).

Internal analysis by MOST officials viewed the history of China's semiconductor industry as broken into three periods (the early reform years, the Huajing and HuaHong projects), with three different respective models (the self-reliance, foreign-domestic cooperation and foreign-domestic joint-venture models). They came to the blunt conclusion that all three models failed bluntly stating that, "The three kinds of models led to the same basic result (DYGB 2002, No. 11: 5)." Despite the failures of three different types of government support, the MOST officials see no way out for HHNEC except for more government procurement. Their main suggestion for how the Huahong Group can turn around HHNEC is for the firm to rely IC card sales to the government as part of its National Management Systems Project. More dangerously, they suggest the firm needs "to lift up its financial capability and expand its cash flow," which given its SOE status means spending more of the state's money on this dubious venture (DYBG 2002, N0. 11: 7). The fact that the officials involved in technology policy still view the problem in part as one of insufficient investment lends credence to Steinfeld's idea (Steinfeld, forthcoming) that Chinese managers have a distinctly different view of what the market or hard budget constraints are actually supposed to do.

2.1.3 Other State-owned IC Firms

Before Huajing's completion, foreigners had already invested in China's IC fabrication segment. These firms were generally technologically backward JVs with SOEs. One of the firms (ASMC) was briefly majority foreign-owned, but it too has been a technologically backward captive[131] fab.

Philips established a JV called Philips Semiconductor Corporation in Shanghai in 1989. To lure Philips to invest, Shanghai's government had to navigate China's labyrinth of competing bureaucratic interests. Shanghai's decision to court foreign investment grew out of neglect by the central government in the area of high-technology development. This JV was in planning ever since the Shanghai government decided to

[131] Captive refers to that fact that fab serves only one customer rather than having many customers as in the pureplay foundry model.

promote high technology in its new technology park, Caohejing, in the late 1980s. MEI was much more interested in its own industrial base in Wuxi, what is now called Huajing, than in developing Shanghai because MEI's Sichuan Research Institute for Solid State Circuits had a large branch center in Wuxi (Simon and Rehn 1988: 137). MEI[132] continued its neglect of Shanghai's IC industry because the ministry did not own Shanghai's IC firms.[133] The classic *tiao tiao kuai kuai (*vertical ministerial authority versus regional authority) problems became severe enough that Shanghai's Institute of Metallurgy, officially an institute of the Chinese Academy of Science, had to create a second institute in order to participate in the Caohejing project (Simon and Rehn 1988: 144 fn 62).

Shanghai turned to foreign investment as the only way to gain access to the technology that it badly needed for its outdated IC manufacturing plants (D. Simon and D. Rehn 1988: 137). While the Pudong New District had not yet received the preferential policies that put it somewhat on par with the SEZs, Shanghai already was one of the Open Coastal Cities (OCCs) as of 1984 although Caohejing was not granted the national Economic Trade and Development Zone (ETDZ) status that 11 areas in the other 13 OCCs received. In 1985, after a year of intense lobbying by Shanghai Mayor, Wang Daohan, Shanghai was able to receive approval from the State Council for Caohejing to be a national level project and a key base of China's electronics industry. However,

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[132] MEI and MPT (the Ministry of Post and Telecommunications) merged in 1998 to form the Ministry of Information Industry at the 9th National People's Congress following the 15th Party Congress in the fall of 1997. In 1988, MEI and the Ministry of Machine building were merged after a proposed attempt to merge MEI and MPT was successfully opposed by MPT (Simon and Rehn 1988: 170).

[133] Despite all the talk of Jiang Zemin's leadership being leadership by a Shanghai clique, Jiang followed in line with MEI's policies when he was in charge of MEI earlier in the 1980s. Nor in the late 1980s after leaving the post of minister at MEI and taking up the offices of mayor and then party secretary did Jiang actively affect any change in MEI's neglect of Shanghai.

problems remained with MEI intent on concentrating on its project in Wuxi in cooperation with the Jiangsu provincial government and Shanghai working on its own project (Simon and Rehn 1988: 138-139).

In the familiar manner of competition between vertical and regional chains of command in China, regional lobbying had opened up more space to preferential policies, but the goal of coordinating amongst rival authorities, in this case Shanghai and MEI, remained out of reach. Simon and Rehn view the proliferation of IC industry projects essentially as the resolution of jurisdictional conflict and competition by allowing a number of bases to spring up, but they appear too optimistic about this being a final peace if one rife with potential coordination problems (D. Simon and D. Rehn 1988: 139).

The Philips JV started operations in 1994. The firm was majority controlled by foreign interests with Nortel buying a 34% stake in the firm in 1995 leaving Philips with 38% and Chinese state banks with 28% in 1995. At that time, the name was changed to ASMC. The firm planned to fabricate mainly chips for TVs and most of these were exported (whether in TVs assembled in China or otherwise is unclear).

The firm had quite old technology from its foreign partners. It had a five-inch line using 3-micron bipolar, CMOS and powerMOS[134] technologies and, by 1998, a six-inch line for .8 to 1-micron CMOS technology (ICE 1998: Section 5, pp. 10-11). The latter technology was roughly in-line with Huajing's technology and lagged ten to twelve years behind the global frontier. Philips has been the major consumer of the fab's chips, accounting for upwards of 85 percent of production in 1995 (Geppert 1995). The firm's two older fabs still lag far behind the frontier and the firm's model as essentially a captive

[134] CMOS stands for complimentary metal oxide semiconductor and powerMOS stands for power metal oxide semiconductor. These are two semiconductor technologies.

fab is not a very promising one as it leaves the captive foundry completely dependent on one firm's orders.[135]

Nortel eventually sold its shares to Shanghai Belling, another SOE in 2000, leaving majority control in Chinese hands. This transfer of control may be the reason why the Philip's appointed executive, Jon Macro, left, and ASMC hired Tony Liu, formerly at CSMC. With Philips no longer in de facto control, there are doubts about whether it will still be an important customer.

Recently, ASMC announced that it had built and started pilot production of an 8-inch fab and then received a technology licensing agreement with Jazz, an American foundry specializing in niche process such as bipolar and silicon germanium. However, it is unclear how far this project has proceeded as little news is forthcoming from ASMC or Jazz about the project. In sum, ASMC at best is a fab that lags substantially behind the frontier and is attempting to make the difficult move from a captive fab to a pureplay foundry with niche processes.

Does the limited success of ASMC have anything to do with the peculiarities of its main JV partner, Philips? In other words, is Philips so stingy about technology or abusive of JVs that ASMC had no hopes of evolving into a competitive foundry because of Philips? Such an explanation appears unlikely because Philips' other big Asian JV founded in the late 1980s is none other than TSMC. Philips provided technology and the freedom for TSMC to pursue its foundry model, and Philips was richly rewarded by TSMC's tremendous success. The case of TSMC does not suggest that ASMC's failure

[135] See discussion of the problems faced by Taiwan's captive DRAM fabs in Fuller *et al* 2003.

to grow beyond a technologically backward, captive fab has to do with Philips' manner of dealing with JVs and its proprietary technology.

ASMC's technology was on par with CSMC's so on those grounds the firm should have been deemed to be contributed as much to China's technological upgrading as CSMC did. However, it is unclear if ASMC's technology is actually embedded in China, especially for the period when the foreign interests owned a majority share. As a captive fab to Philips, much of the technology to run the fab may have remained in Philips' control just like in the HHNEC case. After the fab went to Chinese majority ownership, Philips had even less incentive to transfer technology to a firm it did not control, especially given the fact that the Chinese owner was a competing firm, Shanghai Belling. Probably not coincidentally, the highpoint of ASMC's technology relative to the global technology frontier occurred in 1998 when the firm was still controlled by foreign shareholders. The fact that ASMC has not been successful in branching out to serve other firms beyond Philips suggests that the firm has not captured much technology within the firm unlike Philip's other foundry JV, TSMC. Thus, ASMC may have technology roughly on par with CSMC's, but it fails to meet the requirement of having that technology embedded in China, the same failing as Huahong NEC. At best, ASMC achieved some upgrading of questionable embeddedness and only achieved this modicum of success when under foreign control.

Shanghai Belling is another major IC fabrication firm in China. This firm was a joint-venture between Shanghai Bell, a local state-owned telecommunications equipment manufacturer and Alcatel, Shanghai Bell's erstwhile joint-venture partner, through their own JV, Shanghai Bell Alcatel. This IC firm mainly supplied chips to Shanghai Bell with 85% orders coming from Shanghai Bell as of 1995 (Geppert 1995: 39). This dependence did seem to change much over time according to sources familiar with the firm (Interviews 141, 147, 267). Unfortunately for Belling, Shanghai Bell ran into trouble in the mid-1990s as other Chinese telecommunications equipment vendors, such as Huawei and ZTE, grabbed market share from Shanghai Bell (see Chapter Four). These problems may have increased with Alcatel's selling of its microelectronics division to ST Micro though this author was unable to find any evidence that Alcatel's microelectronics division placed orders directly with Belling other than the orders made for Shanghai Bell Alcatel's equipment for the Chinese market. Consequently, Belling suffered the loss of its own customer base though not before the firm was the first IC producer to list on China's stock markets. This loss of customers is perhaps the reason that Shanghai's Huahong Group was made the controlling shareholder on July 7, 1999 with 38.45% of the firm's shares through a transfer of capital to Shanghai Bell Alcatel (www.huahong.com.cn and UBS Warburg). The firm has tried to branch into design of ICs, but thus far this venture has not been successful (Interviews 141, 149).

People who have worked at the firm reported its production process to be a disaster. The firm never really knew what its production yield would be and just took a rough guestimate. Nor did the firm's engineers want to let outsiders see their production performance data despite the outsiders being at Belling in order to help Belling's process technology (Interview 263). This practice stands in stark contrast to TSMC's data processing that allows its customers in far away places like Boston to receive real time data on their wafers being processed at TSMC's Taiwanese fabs. In 2003, Shanghai Belling remained a very small capacity 4-inch fab (7000 wafers per month) with very old technology (1.2-microns)[136] and few customers due to the fact that it was an orphaned captive foundry for a struggling SOE.

The other main SOE was another JV with NEC, SGNEC (Shougang NEC). Shougang or Capital Steel is a very large steel manufacturer located in western Beijing that tried to diversify into many other industries during the 1990s (Steinfeld 1998). This firm from the start was not aiming for the frontier of technology and had an old six-inch fab. The firm began the assembly of ICs in 1994 and fabrication of ICs in 1995. The firm currently uses six-inch wafers and claims to have .35-micron technology, which would place it ten years behind the technology frontier though it is highly unlikely the fab's technology is that advanced.[137] Like HHNEC, the firm is dependent from orders from its Japanese partner. There is still a significant presence of Japanese personnel at the firm suggesting that the firm's technology is still in Japanese hands. Furthermore, given the reliable reports of the lack of technology transfer of.35-micron process technology and below at HHNEC, it is highly unlikely that NEC would transfer technology to its Chinese partner at this older fab before it transferred technology to Chinese partners at HHNEC because the latter is a newer fab and a higher priority in the eyes of the Chinese government. Engineers of this firm had hoped to use a new Shougang affiliate, Shougang High-tech, to start an eight-inch fab (Interviews 32, 191), but, as will be discussed below, this endeavor did not come to pass.

2.3 The Hybrid FIEs

2.3.1 Catching the Frontier: SMIC

[136] DB (2003: Figure 10) though DB overstates Belling's condition because it includes Belling's 8-inch fab, which as will be discussed further on in the text, was not to be.
[137] Though the firm claims to use .35-micron technology given the optimistic claims HHNEC makes it is likely that SGNEC also inflates its technological prowess.

Semiconductor Manufacturing International Corporation (SMIC) was founded in April of 2000. Given the failure of major state-supported projects, including projects involving foreign technology, the notion that a foreign start-up could succeed where the state-supported firms had failed seemed dubious. While the plan was to take advantage of the modularity of the IT industry by focusing on the fabrication (chip-making) part of the semiconductor industry, the pureplay foundry model developed in Taiwan, this model already had two Taiwanese behemoths dominating the market. Surely, the established rivals would quash the Chinese start-up if it tried to compete head-to-head with them. If the start-up were to survive, the firm would simply have to relegate itself to some small niche market. Thus, went the conventional thinking on the new start-up in 2000 (TCNA, Dec. 11, 2000). Two years after its founding, SMIC started production of wafers at a technological level quite close to the international frontier. SMIC's emergence forced the Taiwanese foundries to invest in China-based operations only shortly after the industry-leader, TSMC, was vocal in dismissing China as a suitable place for foundries (TT, Jan. 1, 2002: 17).

The success story of SMIC can be demonstrated on both technological and market share grounds. On market grounds, SMIC has become the fourth largest pureplay foundry surpassing the older and more established Korean firm, Dongbu Anam. SMIC even does well when compared to all firms that compete in the foundry market (this data includes firms that produce their own designed devices, the integrated device manufacturers (IDMs), as well as offering foundry services for other firms' chips). In this larger group of firms, SMIC still ranked sixth ahead of Hynix, another Korean firm that has offers extensive foundry services. SMIC's revenue exploded at an annual rate of

630 percent while the industry grew 13.9 percent during 2003, SMIC's first full year of production (SS, March 17, 2004).

Table 5.1 2003 Top Five Pureplay Foundries

Source: M. LaPedus, "China Moves up in Pure-play Foundry Rankings for '03," SS, March 17, 2004.

2003 Rank	Company	2003 Revenue	2002 Revenue	% change
1	TSMC	$5.855 billion	$4.655 billion	26%
2	UMC	$2.74 billion	$2.154 billion	27%
3	Chartered	$725 million	$485 million	49%
4	SMIC	$365 million	$50 million	630%
5	Dongbu Anam	$330 million	$260 million	27%

Table 5.2 Top Global Foundries (includes pureplay and IDM)

Source: M. Lapedus, "Chartered Passes IBM in Foundry Rankings; SMIC Grows," SS, March 17, 2004.

2003 Rank	Company	2003 revenue	2002 revenue	% change
1	TSMC	$5.855 billion	$4.655 billion	26%
2	UMC	$2.74 billion	$2.154 Billion	27%
3	Chartered	$725 million	$485 million	49%
4	IBM	$555 million	$760 million	-27%
5	NEC	$425 million	$320 million	33%
6	SMIC	$365 million	$50 million	630%
7	Hynix	$340 million	$245 million	39%
8	Dongbu Anam	$330 million	$260 million	27%

Moreover, SMIC is adding capacity and has not completely equipped the capacity of its current fabs so the firm has plenty of room to gain further market share. The firm acquired Motorola's underused fab in Tianjin in late 2003. SMIC's 12-inch fab in

Beijing, called Beijing Semiconductor Manufacturing Corporation (BJSMC), started production at the end of 2004. These two fabs alone may have added 20,000 wafers per month by the end of 2004 at the same time that the Shanghai fabs ramp up to near full capacity at 89,00 wafers per month (Wallace 2004), almost double SMIC's 2003 year-end production of 49,000 wafers per month (SMIC SEC Form F-1, February 11, 2004).[138] Before even adding the other planned fab to start production in 2006, SMIC will have capacities of 90,000, 45,000 and 35,000 wafers per month in its Shanghai, Beijing and Tianjin fabs, respectively (Wallace 2004). This represents almost three and a half times the capacity the firm had at the end of 2003, capacity which SMIC like competitive foundries in Taiwan (Keller and Pauly 2003: 147) has been able to run at near full utilization (SMIC SEC Form F-1, February 11, 2004). Unlike many IC firms, SMIC has thus far been scrupulously on target in scheduling its ramp up of operations so this schedule may very well be met.[139]

What SMIC has done on the technological front has been even more impressive. The firm has utilized two sources of technology, partnerships with foreign firms and ethnic Chinese engineers (in this case a mix of returnees from the US and Singapore and Taiwanese), to nip at the heels of competitors on the leading if not the bleeding[140] edge of technology. SMIC employs .13-micron technology in its Shanghai fabs and plans to use .11-micron technology in its new 12-inch fab in Beijing. This technology is just a year behind the international technology leaders and even further ahead of the domestic

[138] The former Motorola fab's capacity is reported to be 12,000 (DB 2003 Figure 10) though SMIC hopes to increase utilization to 35,000 wafers per month by the end of 2005 (Wallace 2004).

[139] Controlling for the release date of information, SMIC's estimates about ramp up has erred by a quarter or so whereas information from Grace, its main competitor, has erred by a year or more. The sorry history of delays and false claims in the history of Huajing and Huahong make SMIC look even better.

[140] Intel likes to refer to it latest technologies as the "bleeding edge" presumably to set its technology apart from other firms, such as TSMC, that have technology arguably hovering about the technology frontier in IC fabrication technology.

competition. This partnering for technology and drawing overseas Chinese talent follows the well-known Taiwanese model (Mathews&Cho 2000; Fuller *et al* 2003). SMIC has technology partnerships with a number of international firms, including erstwhile competitor Chartered, Toshiba, Fujitsu, TI and Infineon. The firm also has deals to gain access to the IP libraries of a number of IP vendors/IC design houses, such as Virage, Accent and Shanghai-based Verisilicon. The firm has even cooperated with Europe's premier semiconductor technology research center, IMEC, to co-develop advanced semiconductor technologies. Both Chartered and Toshiba have taken small stakes in the firm in return for the technology transfer (DB 2003: 96). Chartered's investment may have been made on non-business considerations given that the firm is a known Singaporean government-linked company (GLC) via its major shareholder, the state-owned Singapore Technologies. Singaporean GLCs have been very active in trying to promote the Singapore-China economic relationship through investment by Singapore Technologies-linked enterprises.

The leap made in technology in IC fabrication in China with the coming of SMIC can be seen in the chart below. The chart only counts technology that can be deemed embedded in the Chinese environment. In this case, the embeddedness is determined by the existence of a large number of Chinese process engineers taking part in the process and in managing the process. In contrast to HHNEC, Chinese are in real positions of technological knowledge in SMIC and the firm is training more local engineers all the time. SMIC is not hiding its knowledge in some offshore center of research like NEC and there are no reports that SMIC is trying to limit the knowledge of its local workforce. Given that SMIC's operations are entirely China-based, limiting the knowledge and technical prowess of the local workforce would not make any sense. CSMC also contributed to China's embedded technological upgrading as the firm basically relies on local engineering talent to run its fab, but that firm's strategy is the low-tech route in which it takes trailing edge technologies and becomes a low-cost distant follower of the market leaders. Thus, the real leap toward the frontier still came with the advent of SMIC and Grace though as we shall see Grace is much further behind. Motorola tried to localize, but the firm never really got the fab up and running regardless of the nationality of the engineers running the plant. Due to the failure to ramp up a fab in China, Motorola is discounted.

Table 5.3 China's Gap with the World IC Fabrication Frontier

Source: Dewey Ballantine 2003; Mathews and Cho 2000; ITRI/IEK 2002.

Year	China (embedded)	Years Behind World Frontier
1979	25 to 30mm wafers	16 years
1986	5-microns technology	14 years
1995	3-microns	19 years
1998	.8-microns (CSMC)	10 years
2002	.13-microns (SMIC)	1 year

The table has several features that are important to note. First, CMOS (complimentary metal oxide silicon) fabrication process was used as the standard for the chart from 1986 onward because this technology has been the mainstream fabrication technology since at least the 1980s. Secondly, the early data uses wafer sizes instead of lithography micron-widths as the measure since that was the only data available for both China and the US.[141] Finding the exact data on lithography technology for that period would not change the assessment that the Chinese industry was far behind the US

[141] DB (2003: 23 fn 64) quotes a Technical Assessment Report sponsored by the US government in 1979 that cites a gap of 16 years for 1979 and gives the technology in terms of wafer diameters. More tellingly, the report also mentions that the Chinese firms often processed broken wafers because of the shortage of materials.

industry in 1979. The table also uses figures for in-production lithography as the concern in this work is to examine commercializable technology rather than technology achieved in a research lab without regard to cost or production practice.

Even if bipolar technology, a process technology often used for niche analog chips, were used, the result would look similar. In bipolar technology, a FIE, SIM-BCD, has led the major breakthrough in catching the frontier. SIM-BCD started production of 1-micron bipolar in 2002. In comparison, the technological frontier was .35-micron technology and the Taiwanese were only at .8-micron technology (DB 2003: Figure 10; ITRI/IEK 2002). In this niche product, the catch up is not as dramatic, perhaps in part because this technology is not a mainstream foundry technology and not a specialty of ECE firms. Instead, certain IDMs, such as Analog Devices, have maintained control over the cutting edge in this area.[142]

SMIC has been able to gather a corps of leading IC fabrication engineers drawn from the top foundries and American IDMs to come China, but what has been missed in much of the commentary on the rise of the new China-based foundries has been the training that these engineers provide to local recruits. While some commentators assume that the new foundries are and will remain dependent on overseas talent because of the dearth of experienced local engineers in this area (DB 2003: 15; Woetzel 2003:52), the whole point in setting up fabs in China is to take advantage of the skilled educated if inexperienced workforce in China. China creates as much as 15 times the number of engineering graduates as Taiwan does every year (Woetzel 2003:52). While employers coming from Taiwan's IT industry generally report that these graduates have not had the

[142] Analog Devices (ADI) has a long relationship with TSMC as a foundry partner and was an investor in TSMC's US affiliate (Wafertech), but ADI keeps analog products in-house and gives TSMC orders for digital products. Interview with Analog Devices manager, August 2001.

same exposure to technology that their Taiwanese counterparts have had, the employers also feel that the young Chinese technologists are educated and training can make up for the lag between their educational experience and the educational and workforce training opportunities available to Taiwanese engineering students. Localizing the staff is a strategic goal at all the foreign-invested pureplays in China as localization is their key competitive advantage given the lower wage rates for comparable engineers to competitors abroad (Interviews 14, 20, 123, 181, 182). SMIC has a slogan "*yi lao dai er xin*" (one old one brings along two new ones) to describe its emphasis of experienced engineers training many local staff (DYBG 2002, No. 12). The firm hopes to be able to use veteran staff to train twice as many junior staff. This process appears to have worked thus far as the firm has three front-end fabs and one backend fab up and running, and almost double the local engineering staff compared to overseas engineers as of August 2002. Combining local and returnee engineers together, well over two-thirds of the engineers including managers are natives of the People's Republic. Localization of engineering talent in SMIC is well underway.

Table 5.4 SMIC's Localization of Engineering Talent

Time	August 2001 (DYBG No. 12)	August 2002 (Interview source)
Local Engineers	650	700-800
Overseas Engineers (managers/senior engineers)	393: 240 Taiwan; 120 US; 30 Italy; 3 Japanese	470 from Taiwan; 150 returnees (some from Chartered); a few foreigners
Total Staff	1043	2600

In general, the foreign-invested foundries in China have emphasized the need to train local talent as the basic competitive strategy because these local engineers are cheaper than bringing in expatriates even when training costs are included (Interviews 14, 20, 123, 181, 182). Engineers have been running back and forth between SMIC and Grace, the two main competitors for engineering talent in China's foundry industry. "Engineers look at brand. Thus far, SMIC has better brand so engineers go there," as another employer in Zhangjiang High-tech Park (Interview 137), home to both SMIC and Grace, put it. This interlocutor was uncertain which firm if any would win out in this battle for talent, but the prospect of engineers' talents not being captured by the firms that train them appears less likely now that SMIC has successfully listed and Grace is preparing to do so as well. With listings on foreign boards, these foundries hope to follow the Taiwanese model of retaining engineers through stock bonuses. These bonuses are regarded as so critical to success in Taiwanese foundries that two Taiwanese scholars of high-technology industry insisted that TSMC's real strategy in placing a fab in Shanghai was to delay the listing of SMIC and Grace on the grounds that no one would be interested in SMIC's IPO if they could instead buy the stock of the leading foundry that also had a new and compelling China strategy. These scholars thought in the spring of 2003 that SMIC would collapse due to the loss of its team if the firm could not list within a year. Fortunately for SMIC, the firm was able to raise 937 million in its listings on the New York Stock Exchange and in Hong Kong in March of 2004.[143]

One major concern of the foundries in China has been IP protection. They are concerned less about losing intellectual property (IP) to customers than they worry about customers losing faith in SMIC's ability to protect their IP. The main reason for this

[143] Some have claimed that SMIC raised only $714 million (M. Clendenin "Imminent IPO Set to Fund SMIC Billion Dollar Capex," EET, March 9, 2004), but this figure is the figure of money that went to selling shareholders rather than money that went to the firm itself. The total sum raised between the two types of sellers was $1.712 billion with almost $59 million in IPO fees (SMIC SEC Form 42484).

concern is the fact that IP is most easily expropriated during the transfer of designs from the design houses to the foundries because all the necessary data is encapsulated in a GDS-II digital file. China does not have a good reputation for IP protection and, alarmingly, mask-level data (essentially the data that dictates what circuits are engraved into which level of silicon) is not protected under Chinese IP laws (Interview 273). The hybrid foundries recognized that meeting the concerns of foreign customers, precisely the sophisticated customers they were targeting, required them to try to reassure the customers that the IP would be protected. Meeting concerns for IP protection was also a major initial stumbling block in the development of Taiwan's foundries' development, and if the Taiwanese foundries had not risen to the challenge, then the foundry model would have most likely failed. Executives at China's hybrid foundries frankly admitted that if they could not assure protection of customers' IP, they would fail (Interviews 181, 182).

SMIC has clearly met this challenge as the firm has been able to lure an impressive list of international clients to become major SMIC clients. The firm's main customers have been technologically sophisticated foreign firms, such as ISSI, Fujitsu, Samsung and TI (Texas Instruments). One major coup that SMIC pulled off was luring Broadcom, the leading wireless technology fabless design house and erstwhile loyal client of TSMC, to fab in SMIC's facility in China.

SMIC has run into IP problems on another front. The customers apparently trust the firm, but TSMC, a competitor, has sued SMIC for IP violations. Given the number of ex-TSMC employees at SMIC, undoubtedly there was at least some leakage of tacit knowledge embodied in TSMC's human capital i.e. the engineers. The fact that TSMC uncovered someone within their firm, whom they accuse of being a SMIC spy, undoubtedly made life more difficult for SMIC, but it also suggests that TSMC is now taking SMIC seriously as a competitor, enough at least to throw legal obstacles in its path. TSMC had already earlier talked seriously about suing SMIC or China for illegal subsidies under WTO statues (Lin 2003b). This legal war against competitors is a time-honored tradition in high-tech. For example, Intel sued Taiwan's VIA repeatedly once VIA became a major threat in the PC chipset market. Unfortunately for TSMC, given the licensing agreements SMIC has with many other firms, TSMC's allegations did not have the technology coverage, that Intel's lawsuits against VIA's main product line had. At least one commentator noted that Taiwanese firms suing others for IP violations was the pot calling the kettle black given the none too legally tidy history of the foundry model in Taiwan (SS, March 26, 2004). In the end, the matter was settled out of court with SMIC paying TSMC 1785 million over six years to end all of its legal actions (WSJ, January 31, 2005).

To consider another competitive metric, SMIC has already displayed signs of becoming a serious global competitor through its capital expenditure. In the first quarter of 2004, the firm made a quarterly profit, which is quite a good performance given that the firm did not really go into volume production until 2003 (SS, April 26, 2004). SMIC is also set to be in the top five in capital expenditure in 2004 (see Table 5.5) trailing only TSMC and UMC among pureplay foundries. Both Grace and SMIC will invest more than other pureplay competitors, such as Chartered and Dongbu/Anam. Being able to invest in new fabs is one of the critical competitive metrics in the pureplay foundry business as it will be hard for new pureplays to compete with TSMC and UMC if they only have limited capacity to offer potential customers. To quote one analyst who argued in defense of SMIC's aggressive fab building and situating some new fabs in Beijing, "...SMIC has no other choice but to expand its fab capacity—if it truly wants to be a big player. In today's foundry market, the larger players must offer a range of services, processes and options—such as 200- and 300-mm capacity—in various locations to satisfy the customer base (Lapedus 2003b)." This expansion contrasts with Huajing and HHNEC's profligate use of capital that resulted in few gains in fab capacity.

Despite SMIC's technological prowess and growing market share, one has to examine the firm's ownership and financing to determine if this growth has any sustainability. Simply put, is SMIC a SOE by another name with the majority of its financing deriving from soft budget constraint sources connected to the Chinese government? The answer is no. SMIC is still FIE with majority of control outside of Chinese government hands. SMIC does in fact have low-interest financing from the Chinese government, but this fact in and of itself is not remarkable as SIA, the industry lobby of the US semiconductor industry, points out that TSMC, Taiwan's and the world's leading foundry, still receives more in tax subsidies from Taiwan's government than taxes it pays to the government (DB 2003: Figure 13). Historically, China is not any different from virtually any other nation that decided to develop a semiconductor industry by lowering the barriers to entry through subsidies (Mathews and Cho 2000).[144] Nor is SMIC unique as an object of subsidized loans. Both the foreign firms, such as Grace, and obviously the domestic ones and Chinese controlled JVs have

[144] This support is not just a matter of history in the East Asian NICs. Recently, a Korean Development Bank-led consortium of banks extended one billion dollars of low-interest credit to Korea's sole pureplay foundry, Dongbu. See "Dongbu set for Billion-dollar Bail-out, Says Report," SS, April 9, 2004.

Table 5.5 2004 Top Semiconductor Capital Spenders
Source: IC Insights.

Forecasted Top 25 2004 Capital Spenders*

2004 Rank	Company	Headquarters	2003 ($M)	2004 ($M, Budget)	04/03 % Change
1	Samsung	South Korea	3,550	4,100	15%
2	Intel	U.S.	3,650	3,800	4%
3	UMC Group	Taiwan	739	2,120	187%
4	TSMC	Taiwan	1,080	2,000	85%
5	SMIC	China	492	1,950	296%
6	ST	Europe	1,221	1,600	31%
7	Infineon	Europe	886	1,585	79%
8	Sony	Japan	1,200	1,520	27%
9	AMD	U.S.	586	1,500	156%
10	Micron	U.S.	1,075	1,450	35%
11	Toshiba	Japan	1,050	1,430	36%
12	Renesas	Japan	800	1,400	75%
13	TI	U.S.	800	1,300	63%
14	Matsushita	Japan	500	1,230	146%
15	NEC	Japan	850	1,200	41%
16	Nanya	Taiwan	600	1,140	90%
17	Hynix	South Korea	600	1,100	83%
18	IBM	U.S.	850	925	9%
19	Grace	China	575	800	39%
20	Philips	Europe	343	730	113%
21	Chartered	Singapore	221	700	217%
22	Elpida	Japan	750	600	-20%
23	Powerchip	Taiwan	470	600	28%
24	Dongbu/Anam	South Korea	260	570	119%
25	Fujitsu	Japan	375	475	27%
—	Top 25 Total	—	23,523	35,825	52%
—	Others	—	5,582	7,435	33%
—	Total	—	29,105	43,260	49%

*Includes joint venture spending

received subsidized loans from the Chinese government. Given the amount of money Huajing and HHNEC have lost over the years, most likely these two firms have been allowed to write off much of their debt so their effective subsidization has been much higher than SMIC's.

The real issue is whether the majority of funding and control are coming from China's state-run banking system and thus presenting the danger of undermining any incentives for performance through soft budget constraints. The large majority of SMIC's shares are held by private entities with small shares owned by companies connect with the Chinese and Singaporean governments. Dewey Ballantine's study states that Shanghai Industrial Holdings, a Shanghai municipal firm, is the largest shareholder, but their report's own data shows that is not correct so the report must have meant that Shanghai Industrial is the largest shareholder with a known quantity of shares as one or both of Walden and Goldman Sachs have larger shares[145]. Indeed, at least prior to the IPO, Goldman, Walden and H&Q Pacific combined owned 52% of the firm (DB 2003: Figure 25). Assuming that other entities of the PRC government held undeclared shares and the other known or suspected shareholders (Hon Hai, Toshiba, SMIC's management, Chartered) had minimal shares, the ownership of the PRC government could be no more than 42.7% of the total shares based on the ownership shares compiled by Dewey Ballantine though subsequent SEC filings proved that this was not the case (see below). After issuing ten percent of the firm's equity to Motorola in return for the purchase of Motorola's Tianjin fab, the total possible Chinese government equity would be no more than 32.7% and that figure is too high as it assumes the other shareholders, including management, hold virtually no shares in the firm. The board of directors has only 2 directors out of 8 with a firm connection to organizations linked to the Chinese state, Shanghai Industrial Holdings and Beijing Jade Bird (Beijing Qingniao), as shown in the table below. There are no representatives of the central government units on the board unless one considers the Beijing University-affiliated company, Jade Bird, to be an organ of the central state as opposed to a Beijing SOE.[146]

[145] Dewey Ballantine 2003, Figure 25 states that the combined holdings of Walden and Goldman are worth $467 million compared to Shanghai Industrial's $183 million so, mathematically, either one or both firms has to have a larger holding in the company at least prior to the IPO unless non-cash equity is very large.

[146] Determining the lines of authority of a *xiaoban qiye (*university-run enterprises) such as Jade Bird illustrates how hard it is to distinguish between the formal and functioning lines of authority among state units. In theory, Jade Bird is under Beijing University, which is under the central government's MoE (Ministry of Education). In reality, Beijing university's enterprises operate in the city of Beijing so they are more much interested in cooperating with local officials to promote Beijing Municipality's economic

A review of SMIC's debt situation shows a growing amount of Chinese government-issued debt, but this Chinese government-issued debt is growing smaller in relation to overall debt and equity issued even before the effect of the IPOs in New York and Hong Kong are factored into the equation. The debt as of October of 2003 stood at $480 million from both central and Shanghai state banks and the equity stood at $1090 million. From this two to one ratio, the cash from equity and non-Chinese state debt ballooned to $1.635 billion and the debt from Chinese state banks rose to $765 million

Table 5.6 SMIC's Board of Directors

Sources: SMIC SEC Form 42484, March 12, 2004; www.smics.com.

Board Member	Primary Affiliation
Richard Chang, Chairman	SMIC
Lai-xing Cai	Shanghai Industrial Holdings (Shanghai government)
Ta-lin Hsu	H&Q Asia-Pacific (VC)
Yen-pong Jou	Global Growth Fund and International Equity Income Fund
T. Kawanishii	Elected by other directors; SIP Consortium (Japanese research institute); formerly of Toshiba
Henry Shaw	Asiavest Partners (VC)
Lip-bu Tan	Elected by other directors; Walden (VC)
Yuan-yuan Wang	Beijing Beida Jade Bird Co. (Chinese SOE); Beijing University

(Clendenin 2004) so the ratio of state debt to cash from equity and foreign debt remained stable at one third of the total. Once the equity raised from the IPOs is figured in, the amount from Chinese state banks falls to one quarter of the total. Thus, neither control of the firm nor the majority of its funding come from Chinese government sources.

prospects than the firm's formal line ministry (MoE) is. In practical terms, it is likely that Jade Bird is participating in SMIC through its cooperation with Beijing Municipality in promoting Beijing's IC base as both Beijing municipality and Jade Bird are involved in SMIC via the Beijing-based SMIC joint venture, BJSMC.

On March 12, 2004, SMIC released its next SEC filing with information on the holdings in the firm after the IPO. The break down is presented in the chart below. The main point of interest is the holdings by government-affiliated firms. Beijing Beida Jade Bird, a firm run by Beijing University and thus a form of SOE, and Shanghai Industrial together own 14.8 % of the firm. Equity held by the firm itself was still 28%, and with the affiliated companies of the non-state shareholders the shares add up to almost half the total at 41.2%.[147] There are two small shareholders that may have Chinese state connections, Shanghai International Shanghai Growth Investment and Anfu Holdings, though both of these firms had less than one percent even before the IPO (SMIC SEC Form 42484: 35-26). Thus as of March 12, 2004, the total possible post-IPO state holdings were forecast at below 16.8%. In comparison to the SOEs involved in the IC industry, such as Huajing and Huahong, SMIC is neither under the control of nor anywhere as close to dependent financially upon the Chinese state.

SMIC meets all three criteria of having a China-based operational strategy. SMIC is foreign registered and invested firm. Foreign investors exercise majority control of the firm. The firm's headquarters and top management are in China. Indeed, the vast majority of the firm's operations and personnel are in China with only small sales offices abroad. The firm has a pronounced and public China-based strategy of serving the IC

[147] Straight addition of all the post-IPO holdings reveals ownership of 117%, which is mathematically and legally impossible. However, the firm notes that the holdings of the company of 45% may overlap with holdings by firms represented on the board excluding Shanghai Industrial as represented by Lai Xing Cai, (SMIC SEC Form 42484: 131 notes 6). By implication, this company and affiliated holdings do not count the other large shareholders because the discrepancy would be too large if any one of these large shareholders shares were included. Thus, the straight addition double counts the affiliates of directors of the pre-IPO board, which are listed separately at 13.2%, and then counts again the holdings of current private board directors, which represent Vertex Management, Vertex Israel II, Walden Pacven and AsiaVest for an approximate total of 3.8% of shares (the exact total is difficult to estimate because the holdings of firms with less than 1 percent are not listed in percentages). Subtracting the double and triple counted portions, one arrives at 100% (SMIC SEC Form 42484: 32, 35-36, 130).

Table 5.7 SMIC's Shareholding Distribution after the IPO

Source: SMIC SEC Form 42484, March 12 ,2004.

Shareholder	Post-IPO Shareholding Percentage	Majority Chinese State-owned?
Shanghai Industrial Holdings Ltd.	10%	Yes
Motorola	7.8%	No
Global Growth Fund and International Equity Income Fund	5.8%	No
Beijing Beida Jade Bird	4.8%	Yes
SMIC	28%	No
Shareholders on the Board (excluding shareholders above)	13.2%	No
Other Shareholders (includes Anfu and Shanghai International)	13.7%	No (at most, state share is less than 2 percent of the 13.7%)
Shareholders from IPO	16.7%	No
Total	**100%**	

industry from its fabs based in China. Finally, the firm is managed and partially owned by ethnic Chinese.

2.3.2 Grace: The Other Hybrid Foundry

Grace is another hybrid FIE and is following the same model as SMIC though Grace lags behind SMIC in technology and revenue thus far. The firm's development shows the contribution of hybrid FIEs to upgrading is not a one-firm wonder. The comparison with SMIC also highlights the weakness of government connections in determining success among hybrid FIEs because Grace's better connections have not given the firm any competitive advantage over SMIC.

Grace has the potential to be a major player in the pureplay foundry market. The firm is essentially following the same model as SMIC by bringing over experienced engineers from the Taiwan and the US to manage and train the local engineering workforce. The firm has been slower to ramp up than SMIC due to what appears to be a more precarious funding situation, but when its two fabs are fully outfitted, Grace will have enough capacity to compete as one of the top five pureplays in the world with 100,000 wafers per month. SST, an American flash memory design house, had plans to buy 12000 wafers per month from Grace by the end of 2004 (SS, March 8, 2004).

Despite the relatively slow ramp up compared to SMIC, the firm is training local engineers. The firm had 160 overseas managers and 400 local engineers by end of 2003. Other reports claim Grace had 150 Taiwanese engineers much earlier (SST, April 2002). Thus, the firm has been embedding the technology it has in the local economy by training local engineering staff in a manner similar to SMIC if smaller in scale due to grace's smaller size of operations.

The firm also has .18-micron technology from SST, which puts it behind only SMIC among China's fabrication facilities (SS, November 21, 2003). Grace received its original .25-micron technology from Oki and sent many young engineers to be trained in Oki's facilities in Japan. Similar to SMIC, the firm has made deals to boost the IP offerings it can provide customers. The firm has procured Shanghai-based Verisilicon's .18-micron IP library and Toshiba's embedded microprocessor IP (Grace's website: www.gsmcthw.com). The firm's major clients are Sanyo and SST.

Grace has kept mum about its ownership structure and has not disclosed the investors in its first two rounds of funding. For example, it is unclear whether or not Oki has a stake in Grace. In total, SST has invested 83 million USD in Grace through the first two rounds of investment (SS, March 8, 2004). Winston Wang, son of the Formosa

Plastic's Wang Yongqing, owns the Cayman Islands holding company that owns Grace, Grace Semiconductor Manufacturing Corporation. Presumably, he does not want to disclose the ownership of this holding company because it is owned by Taiwanese investors close to the Wang family who would rather not have a confrontation with the Taiwanese government over illegally investing in semiconductor facilities in China.[148] At least one insider alluded to the fact that Grace had received investment from Winston Wang's siblings' firms, VIA and FIC (Interview 14).

Grace also shows that good government connections are not the determining factor of success if your firm's strategic plan is not based on government procurement. Nevertheless, Grace like SMIC has been consistent in wanting to compete in the world pureplay foundry market rather than trying to rely on government procurement, like Shanghai Belling has done. If one had to predict based solely on government pedigree which foundry start-up would excel, one would have picked Grace because this firm combined the Wang family, a wealthy Taiwanese family with significant investments in China, with Jiang Mianheng, former head of the Institute of Metallurgy in Shanghai (the main research institute for Shanghai's semiconductor) and son of former (then current) president of China and chairman of the CCP, Jiang Zemin. Some have said that Jiang Mianheng had a major holding in the company, but it appears that the Shanghai government-owned firms, rather than Jiang himself, have a minority stake in the firm, possibly about ten percent. Shanghai's stakes in Grace –affiliated Shanghai Honghe Electronics and Shanghai Honglian Electronics, both located in Shanghai's Pudong New District where Grace Semiconductor is located, are both approximately ten percent so a

[148] As of 2002, Taiwan legalized investment in 8-inch wafer fabs in China, but the Grace investments were made two years prior to the legalization.

similar stake in Grace seems likely. Someone very familiar with Grace's inner working said that perhaps they had given Jiang personally some shares, but these shares did not add up to much (Interview 14).[149] In any case, Jiang's involvement in the firm has not led to Grace beating SMIC to the market even though the two firms were founded approximately the same time and initially all of the attention was on Grace due to the connection to Jiang Zemin.

SMIC's foreign investment, even prior to the IPO of more than 900 million USD and using a high estimate that assumes 1/3 of equity is Chinese state-owned, almost equaled the total known debt and equity of Grace, which has a total worth at 1.6 billion USD. Using these metrics, SMIC's low-ball pre-IPO foreign investment stood at 1.3 billion USD. SMIC has parlayed this ability to lure foreign investment into building fabs. In contrast, Grace still has to scrounge for investment despite the initial more favorable treatment in terms of lending by the Chinese state.[150] Jiang's involvement at best ensured

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[149] DB (2003: 97) arrives at the ten percent figure from looking at the Chinese holdings in two other enterprises, Honghe and Honglian. which were called Grace Technology and Grace Fabric in the Wall Street Journal article (R. Flannerty, "Chip-plant Venture Discussed by Firms in China, Taiwan," WSJ 21 August, 2000), cited in DB. However, the WSJ article clearly states that the ten percent stakes are owned by two companies associated with Jiang, Shanghai Alliance Investment (Shanghai Lianhe) and Shanghai Simtek, and not by Jiang himself.. In "Jiang Zemin's Son's Telecommunications Kingdom," from March 11, 1999 of Lianhe Zaobao (United Morning News at www.zaobao.com), it is noted that Jiang manages Shanghai Alliance and is on the board of Shanghai Information Investment (SII), but emphasizes that these are SOEs in which he has no stake. However, the article approvingly tells how Jiang who used to be unable to get his phone calls answered by the Shanghai mayor's office ten years ago (This is a joke because it refers to back when Jiang Mianheng's father was mayor of Shanghai though the article's dates on when Jiang Zemin was mayor are slightly off because by 1989 he was already Shanghai Party Secretary) has now used his political influence to overcome bureaucratic inertia in order to found a new telecommunications company, Shanghai Simtek, with the other two firms as shareholders. Thus, Simtek and Shanghai Alliance are SOEs rather than Jiang's personal firms. One further note is that Shanghai Information Investment is actually a subsidiary of Shanghai Shiye, the parent company of Shanghai industrial Holdings that owns shares in SMIC. The existence if not the size of the stakes of the Shanghai government's holdings in Honghe and Honglian were confirmed by a list of firms in the Shanghai Pudong Kangqiao Industrial Zone at www.shec.gov/cn/introduce/pdkqq/e15.htm, which listed both firms as having joint Shanghai and Taiwanese ownership.

[150] The difference in the ability to attract foreign investment may have had to do in part with the principal players on each side. While Winston Wang came from a rich family, he was and perhaps is still partially estranged from the paterfamilias, Wang Yongqing, due to Winston's sexual peccadilloes in the mid-1990s,

more favorable treatment by the state in the first few years of both aspiring foundries. As late as 2003, Grace's debt to Chinese state banks at 830 million USD was almost double that of SMIC's state debt at 480 million USD (Clendenin 2004 and DT, July 15, 2002), but the Jiang connection to Grace had not completely cut off its bitter rival, SMIC, from support. On the contrary, there were rumors that the new loans to SMIC at the end of 2003 were a sign that the state had decided to cut off Grace from further support.

Beyond the difference in the ability to lure foreign investment, the lack of weight government connections have in determining firm success is related to the common business strategy of the two firms. They wanted to be globally competitive foundries. Thus, they could not rely on government procurement of IC cards used by the Chinese government for IDs as their mainstay of their business. The reason was not just because of their strategy of serving a global customer base, but also because the government's IC cards were generally designed using older generations of technology, such as .35-microns technology, that were not the technologies SMIC and Grace needed to perfect in order to be competitive global foundries. These two firms' fabs from their starts were manufacturing at more advanced technologies than.35-micron.[151] Indeed, only 25% of

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and, more importantly, his former venture in ICs, Nanya, a DRAM firm, did not do well under his tenure. Similarly, his main executive at Grace has been Nasa Tsai, who came out of Mosel Vitelic, a Taiwanese IDM, and served at CSMC briefly. Tsai has not had experience at cutting-edge foundries, such as TSMC and UMC. In contrast, Richard Chang of SMIC founded WSMC, a pureplay in Taiwan that he later sold to TSMC, and had served for a long time at TI, a firm renowned for its cutting-edge process technology. His VP of manufacturing, TY Chiu, had run several fabs for TSMC and had also worked for a long time in US IDMs. From an investors' point of view, the SMIC team just appears more likely to be able to run a foundry operation due to the foundry experience of the team.

[151] For SMIC, the most mature technology used was .35-micron and the mature technology has overall been accounted for a little over 21% of products for both 2002 and 2003 while .18-micron and below have risen from 4.75% in 2002 to almost 44% for 2003 (SMIC SEC Form 42484: 46). Grace claimed to have no product offerings above .18-microns for 2003 (www.gsmcthw.com).

the orders from leading fabless firms were using .35-micron and above process technology.[152]

Like SMIC, Grace is clearly a hybrid FIE as its operational strategy is China-based despite being a FIE. The firm meets all three criteria of being a hybrid. The headquarters and the vast majority of its operations are in China. The firm's professed strategy is to be a China-based pureplay foundry firm. Finally, the owner-management is ethnic Chinese.

2.3.3 The Taiwanese Pureplay Foundries

Reacting to the creation of SMIC and Grace, the Taiwanese pureplays re-evaluated what if any role China could have in their strategic plans. Prior to SMIC and Grace, neither firm considered China a suitable place to invest in IC fabrication (IPC Interviews). With the re-evaluation forced upon them by the emerging competition, UMC in the guise of Hejian (its Chinese affiliate's name) began to adopt an increasingly China-based operational strategy. In other words, UMC began to act more like a hybrid FIE. In contrast, TSMC, as a regular FIE with little interest in adopting a China-based operational strategy, dragged its feet before investing in China and still shows no signs of regarding its fab in China as a critical core asset.

The Taiwanese pureplays' behavior towards investing in China demonstrates the split in strategic thinking between firms in Taiwan. UMC has played a resentful second fiddle to TSMC ever since TSMC surpassed UMC, a struggling IDM at that point, in sales in 1994 on the back of the successful pureplay foundry model that TSMC invented.

[152] The figures for fabless design were FSA's (the Fabless Semiconductor Association) figures for 2003 from Grace's website, www.gsmcthw.com, and are a good proxy for leading fabless firms because low-end low-tech design firms from the developing world are not members of FSA nor are low-tech design firms the target clients of SMIC and grace based on the author's interviews with company sources.

The relations between the chairmen of the two firms are notoriously bad due to the rivalry. TSMC as a primarily Taiwan-based firm has done spectacularly well while UMC has always tried to play catch up. Due to its lead position and performance, TSMC can and does charge about a thirty percent premium over UMC on wafers.[153] Naturally, TSMC should be more comfortable with its current strategy of using Taiwan as its main operational base than UMC because the returns on that strategy have been so much greater. In fact, TSMC has had only two major foreign investments, and one of them, the Singapore JV with Philips, was due to arm-twisting by TSMC's large shareholder, Philips. UMC has had 2 ventures in Japan and two more in Singapore though two of these four ventures have ended due to decisions by UMC's partners. Clearly, UMC has been searching for a way to best TSMC by internationalizing its operations.

When one examines the two firms' activities in China, UMC's pro-China strategy stands in sharp contrast to TSMC's criticism of China's prospects. While UMC was quietly planning its 8-inch fab investment in China by 2001, TSMC continued to criticize China's policies and China's IC industry prospects from the beginning of serious interest in China as a new base of foundries brought on by the announcements of Grace and SMIC (DB 2003: 13 fn 37). TSMC continued to be critical even after TSMC received permission to build a fab in China. While UMC was so eager to set up operations in China that it did not wait for Taiwan's government to make the decision to legalize the investment of eight-inch fabs, TSMC has pursued a course of antagonizing China's

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[153] I first heard this fact about TSMC's price premium from a knowledgeable Chinese American (Interview 179) who returned to do academic and entrepreneurial work in greater China after a very successfully career in academia and Silicon Valley in the US. As a chip designer and a venture capitalist investing in fabless design houses, he is well placed to know what goes on at the foundries. His claim is also backed up by recent data on the average selling prices for wafers of the various firms. TSMC does indeed enjoy roughly a thirty percent margin over UMC with the firm charging 1420 dollars per wafer versus UMC's 1100 (UBS Warburg, "Update form SMIC Investor Lunch," February 24, 2004).

government by threats of suing China and publicly blaming China for a potential glut of capacity even after agreeing to invest there (Lin 2003b). UMC can be said to be tending towards an partially China-based operational strategy where as TSMC at best has been forced to incorporate China as a small component in its operations by the force of investor opinion in Taiwan. This split mirrors what one finds in Taiwan. Firms that do not tend to envision China as strategically important to their operations (i.e. firms without a China-based operational strategy) will not be the firms in the lead to contribute to China's technological development.

UMC's fab in Suzhou has been up and running since mid-2003. More importantly though less well known, UMC has been very active in creating an IC design base in Suzhou and Shanghai. UMC has called on the fabless firms in which it has equity-holdings, such as Faraday, as well as other long-term fabless clients, such as Realtek, from Taiwan to set up operations in Suzhou. Like the Suzhou fab itself, these firms do not consist of a bunch of transplanted Taiwanese engineers, but rather are Taiwanese managers in charge of training local engineers (Interview 155). This design cluster has been so successful that the Suzhou government has argued with the central government to give it the coveted National IC Design Center designation since their design base is much more developed than some those areas with the actual designation.[154] UMC itself has a very active R&D team in China. In fact, UMC is one of the leading firms with US utility patents from their Chinese operations. From 1997-2001, UMC's Chinese operations have received 17 patents, which may seem quite small, but puts the

[154] Conversation with Suzhou IC Base officials at Chinese Semiconductor Industry Association conference in Shanghai in March of 2003. I have personally visited all seven national bases and only Shanghai and Beijing are clearly more developed than Suzhou's cluster. Shenzhen has some sophisticated designers within several systems houses, but these design teams were there before any national designation was given and are not really part of the core idea of fostering a cluster of fabless design houses.

firm behind only two other firms in China (D. Floyd and P. Meyer 2002).[155] Through 2004, UMC was the fifth largest patent holder (see Chapter Four).

In contrast, TSMC has no US utility patents from Chinese operations. Its Chinese fab only began operating in the final quarter of 2004. The firm also has no plans to promote a design cluster near its plant.[156] Indeed, if TSMC had been serious about promoting such a cluster, it would not have situated its plant so far away from the city center where the design firms are. TSMC's plant is in Songjiang County, which is so removed from Shanghai's center that it used to be part of Jiangsu Province. The only other location TSMC considered, Kunshan, is also a bit removed from Shanghai and like Songjiang is thus far strictly a manufacturing base. Both Songjiang and Kunshan offered TSMC very lucrative packages of incentives.[157] Whatever the reason for its locational decision, TSMC has not been ambitious in its plans to develop the IC industry in China. The idea proffered by the economists from the Taiwanese think tank about TSMC coming to China just to hurt SMIC looks plausible when TSMC's actions in China are considered. TSMC may train local engineers to carry out fab activities just like its counter-parts at Hejian, Grace and SMIC, but the firm does not appear to have any deep commitment to creating a technologically deep fabrication or fab/design cluster in China.

2.3.4 Motorola

[155] I suspect that these patents might be probably from UMC's Faraday affiliate because this part of UMC has been active in the Shanghai area for a number of years.

[156] TSMC has announced plans to open a design service center, but this center is aimed to simplify the design to fabrication transition rather than the creation of entire new designs, the work of UMC-affiliated design companies (EET, March 29, 2005).

[157] Some Taiwanese businessmen reported that they heard that TSMC received up to 7 years of tax-exempt status, which far exceeds the three years authorized by the central government.

The other big WFOE (wholly foreign-owned enterprise) fab project was Motorola's fab in Tianjin. This fab was announced in 1995 (Geppert 1995: 42) although planning for it started even earlier. Given how dependent Motorola became on the China market, this investment represents something of a critical case. China should have had significant leverage in terms of market access to gain technology from Motorola, and, yet, Motorola's fab never contributed much to China's technological upgrading under Motorola's control.

Motorola needed to ensure its access to the Chinese market because Motorola had a large lead in mobile phone sales in the rapidly growing and large Chinese market whereas its share was declining rapidly everywhere else. Almost equally enticing, China was investing heavily in telecommunications infrastructure, an area in which Motorola also had products. This classic dependence of the MNC on the host government's power over market access should have given China significant leverage in being able to wrest some technological contributions from Motorola. A former Motorola executive who was extensively involved in many of the negotiations with the Chinese government over the course of the 1990s admitted that Motorola's calculation in putting the fab in China was due to its need to please its Chinese in order to keep the market open to Motorola's products. MEI was especially keen to receive semiconductor technology. To play the good MNC, Motorola decided to place a fab in China. Unfortunately for Motorola, the ministry most critical for success in telecommunications was Ministry of Post and Telecommunications (MPT), a ministry that could care less about semiconductors as it was outside of MPT's purview. Still, placing a fab in China looked good to Chinese officialdom from the point of view of contributing technology to China, especially at a time when numerous Chinese scholars of industry were denouncing Motorola's "hegemonic" control of the mobile phone market (CASS, various years). Moreover, Motorola lucked out because the reorganization of the ministries in 1998 placed MPT under control of MII (the former MEI) so the officials Motorola had most pleased could return the favor. However, this reorganization also gave MEI more leverage because if Motorola did not deliver, the unhappiest officials would also be those officials in charge of regulating the markets Motorola would most like to participate in, telecommunications. More alarmingly, the Chinese legal system being what it is, Motorola would have no legal recourse if it wished to challenge MII (Interview 236).

Despite the leverage, China never really received the level or amount of technology one would have expected. The idea that market access concerns give officialdom leverage is not incorrect, but in this particular case, other variables intervened. Motorola spent a long time training Chinese engineers in the US only to have them jump ship to other before they were sent back to Tianjin (IPC Interview). Thus, the ramping up of the production was painfully slow. Moreover, Motorola's semiconductor division has had problems for years and in the last few years had announced a fab-light strategy i.e. outsourcing more to foundries. Before going fab-light, the firm had been proclaiming that it would concentrate its Asian IC production in Tianjin and move production out of Japan, but the firm ran into political difficulties in other countries as well. A recent analysis viewed Motorola's problem as having old fabs in places where it also did not want to upset the government, such as France and Japan, by closing fabs. The only solution was selling the new fab in China because selling it would not mean closing it i.e. the fab had enough value to be kept up and running (Jelinek 2003). Thus, selling the new fab would not affect relations with that host government i.e. China.

While Motorola did have special circumstances and did in some sense try to transfer technology to Chinese hands, Motorola's difficulties were not the only intervening variable that affected the access for performance trade-off. The Chinese state could have been stricter with Motorola about ramping up the plant. From bringing in equipment in 1998/1999 to the plant's sale in 2003, the plant managed to ramp up to a trickle on the basis of not very large capacity (12000 wafers/month). The trickle of production may have been due to Motorola's internal difficulties, but the fact that the capacity of the plant's capacity was so small shows how little the Chinese government held Motorola to any performance targets. One needs only to eyeball the number of pieces of capital equipment in the fab to know the approximate level of production so this information was not something hard to uncover if MII had wished to learn about it. Instead, Motorola moved very slowly and still retained all of its privileges in China[158]. Boosting capacity had nothing to do with physical limitations of the plant itself, SMIC is busy bringing in more equipment to the same plant to triple the plant's capacity.

2.3.5 Other FIEs

There are also a number of FIEs that are not contributing much to China's technological development as they are brining over older fabs. Essentially, they are

[158] For those who wonder what if any weapons MII had at its deposal, the Ministry had two very powerful weapons; 1) it has licensing power over what foreign firms may sell cellular phones in China and has only granted licenses to 11 foreign firms 2) it still controls China's telecommunications service providers in China so it could easily influence their purchasing decisions. Of these two, obviously, the licensing power was a much more formidable cudgel to bang Motorola over the head with, but this threat was never voiced by MII as far as I have heard.

bringing the same technology as CSMC with better initial processes, but starting five years after CSMC started production. A number of these firms are essentially old six-inch fabs from Taiwan being moved to China to receive a new lease on life. Ningbo Sinomos (NSSI) and ADT are two firms that fit this type. NSSI is actually an old TSMC fab that has some connection to executives at Grace though when I asked Nasa Tsai of Grace, he vehemently denied any connection. NSSI also appears to be the same fab that Tsai was rumored to have tried to broker a deal with a research institute in Beijing to be a joint-venture partner. The deal in Beijing fell through and the fab was eventually set up in Ningbo. The attempts to situate this fab in a number of different Chinese cities were confirmed by an interlocutor working for a quasi-governmental agency in Taiwan (Interview 277). ADT was (and at least officially still is) operating in Taiwan's famous Hsinchu Science-based Industrial Park, but in reality the fab left in Hsinchu is an empty shell. Meanwhile. the firm is building a second fab in its new location of Zhuhai, the SEZ (special economic zone) next door to Macau (Interview 251). Although the buyers intended to move this fab to China even before it was legal to move six-inch fabs to China, a quasi-governmental agency in Taiwan actually helped the Taiwanese buyers with advice and research on which Chinese city to re-locate the fab according to an interlocutor at the Taiwanese quasi-government agency. On Semiconductor's fab in Sichuan also fits the model of offshoring old fabs to China though in this case the firm is American, a spin-off from Motorola.

These firms all have the same strategy of prolonging the life of trailing-edge technology by moving the equipment to China. In this respect, these fabs resemble CSMC more than SMIC. These firms still marginally meet the criteria for technological upgrading because they are more advanced than the majority of fabs in China, but given the small size of most backward fabs in China, the technology used in these six-inch FIEs may not be above the average of China if the technology is counted on a per wafer rather than a per fab basis. For example, SMIC may already have the same level capacity of ten or more small four-inch fabs (or approximately half the older fab output in China). In any case, these recent six-inch fab investments are not the center of China's developing IC industry whether measured in technological or output terms.

From the perspective of China's development, these investments offer one encouraging sign. These firms are all located outside of the large technology metropolis of Beijing, Shanghai and Shenzhen and relegated to second or third-tier (in the case of On Semi in Leshan, deep in China's interior) locations. The fact that these fabs locate outside of these centers of the IT industry suggests that China's large centers of technology have developed enough to become at least somewhat choosy about what activities they try to lure to invest in their jurisdictions.

3. Design in China: From Reverse Engineering to Innovation

A few years ago, IC design activities as done in the advanced industrial world were virtually nonexistent in China. Outside of university labs, China's major activity related to design was buying imported chips, and then reverse engineering (copying the design by copying the circuitry). By 2002 and 2003, a number of commentators not only recognized China's growing design talent, but predicted China would succeed more in design than in fabrication (DB2003; Lin-liu 2002: 16; Woetzel 2003: 52; D. Ernst

2004).[159] As with many phenomenon, there has been a lag time between the emergence of the phenomenon and the recognition of it even though the Chinese design industry really began to take off in 2000.

3.1 Metrics of Evaluation

This section presents data on the differential technology upgrading performance of firms in China. Several metrics were used to evaluate firms. First, firms were evaluated on technical criteria, such as the process technology to which they designed the ICs as measured in microns and the part of the design process they carried out themselves. Secondly, they were evaluated on whether or not they were engaging in actual design work. Much, perhaps most of the IC design work performed in China is not design work at all but simply reverse engineering. Firms engaging only in reverse engineering were not counted as contributing to upgrading.

3.1.1 Technical Metrics

For process technology, the smaller the lithography, as measured in microns, the more sophisticated the technology. Lithography widths as a measurement of technological sophistication cannot be compared across process technologies, such as bipolar versus CMOS (complimentary metallic oxide silicon), but within a given technology, they are a good measure of design sophistication. For design, one good

[159] A number of these commentators make the dubious argument that China has the engineering talent for design but not for fabrication (see Woetzel 2003). If they offered any evidence that Chinese engineers are trained in EDA tools but not in fabrication processes, I would be able to accept the argument, but no proof is offered and anecdotal evidence from recent engineering graduates I have met suggests that fabrication process training is available. In any case, the situation for fabs and fabless design houses hiring these recent graduates is the same. These employers report that the graduates have good basic electrical engineering skills but need significant training (Interviews).

measure of technological sophistication is the process technology lithography to which a chip is designed. The same principle holds as for process technology—

the smaller the lithography the more sophisticated the design. Design can also be measured down the design chain (as shown in Figure 5.1 below). Generally speaking the front-end activities are more sophisticated than the back-end activities.

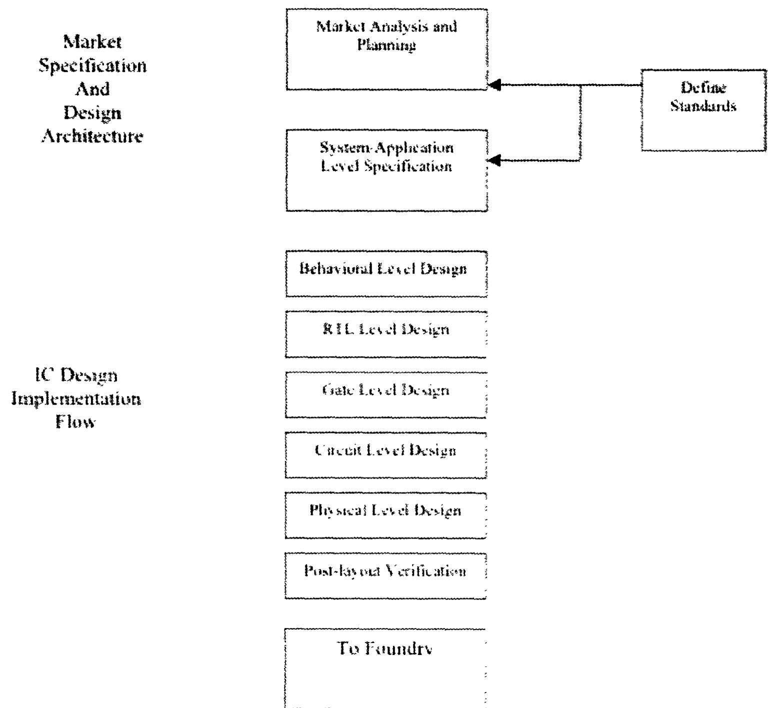
Given the technical backwardness of the IC design industry in China over the last several decades, to see improvement in the technical activities in China one should not set the bar for these metrics very high. Additionally, other metrics that are often used, such as gate count controlling for IP cores purchased or digital versus analog and mixed signal design[160], are of much more value to differentiate average from sophisticated design rather than trying to differentiate crude from average design. Furthermore, in the case of gate counts, many firms in China are reluctant to reveal their gate counts to outsiders fearing that this information will reveal too much information about their products to their competitors.

Setting the bar high to distinguish the current design activities as closer to the international technology frontier than the design activities of the recent past (1999), a good standard is CMOS[161] process technology at .8-microns. The very few design teams not engaged in reverse engineering five years ago were using .8-micron and larger process technologies (Interviews 4, 5 and 11 and visit with major local design firm in 1998). Since the mainstream design activity of five years ago was reverse engineering rather than real design at .8-micron, moving to actual IC design at .8-micron from reverse

[160] Generally speaking, digital designs are less technically complex than analog and mixed signal designs.

[161] CMOS technology is the standard used here because this technology is the most common technology of the firms interviewed as well as the most common process technology globally. Forty-four of the firms used CMOS technology.

Figure 5.1 IC Design Process Flow
Source: Adapted from Chang and Tsai 2002.



engineering still represents a movement toward the technological frontier. Likewise, layout (marked physical level design in Figure 2) skills were fairly common even five years ago, but most of the other design skills were lacking. Thus, firms that do more than layout in the IC design flow will be considered as contributing to technological upgrading.

To set up a harder test for this paper's prediction that foreign firms are contributing more to technological development than domestic firms, the bar for foreign firms will be set higher. Foreign firms must have process technology of at least .35-microns, several generations in advance of .8-microns. Furthermore, firms that appear to be at best marginally technological upgrading will be counted if they are domestic firms and disqualified if they are foreign firms. These measures make the test more robust.

There was data on CMOS process technology for 44 firms. Two firms used only bipolar or bi-CMOS technology. Four others declined to reveal their process technology. The table below presents the foreign and domestic firms and their ranges of process technologies. The process technologies of known reverse engineering outfits were recorded as the nominal process technologies they reported.

Table 5.8 Process Technologies of Foreign and Domestic Design Firms
Unit: Lithography line-widths in microns.

	FIEs (28 firms)	**Domestic (16 firms)**
Average Range of Common Design Metrics	(2 firms) .5 to .18 (13 firms)	(1 firm) .8 to .35 (6 firms)
High	.8 (1 firm)	1.5 (1 firm)
Low	.13 (5 firms)	.13 (1 firm)

Note: This table includes data from firm interviews through September 2004. The process technology profiles of firms interviewed prior to 2004 were updated during August and September of 2004.

3.1.2 Reverse Engineering

In some areas of industry, reverse engineering is an activity that may be illegal but is a crucial step in industrial learning. In these industries, reverse engineering means taking apart products to learn how they are put together. Reverse engineering and engineering activities are hard to separate and use much the same skill set.[162] Unfortunately, reverse engineering in IC design is not this type of activity. Reverse engineering means peering into another firm's chip circuitry and copying it, but copying the circuitry alone does not really lead to a more profound understanding of how the circuitry works in order to build an improved product. A better analogy would be photocopying a book in a language one does not understand. One has replicated the book, but one would not be able to write a single sentence in that language. This analogy may be somewhat extreme, but reverse engineering chips does not by itself cultivate the skills needed to do real chip design because chip design and chip reverse engineering are separate and distinct activities as a number of advanced chip designers with knowledge of China's reverse engineering tendencies pointed out (Interviews 179, 115, 252, 273). One foreign chip designer who had worked with several of the foreign design start-ups in China and was actively involved in recruiting designers reported that he soon discovered that engineers with experience in the local firms only had experience with reverse engineering. This particular experience had two implications: 1) they were not actually experienced or trained in design work and 2) they had bad habits in that they would rather fall back on ripping off competitor's chips than create their own designs. Consequently, the designer decided to avoid hiring any more designers with "experience" in the local firms and to hire only fresh university graduates who had not been tainted by years of reverse engineering (Interview 273).

[162] I would like to acknowledge the contribution of a group of scholars at IDE (Institute of Developing Economies) in Chiba, Japan to this distinction between reverse engineering in other industries and IC design. One scholar of the automotive sector in Japan and China in particular pointed out how reverse engineering was critical to building the design skill set in China's motorcycle industry. This traditional benign view of reverse engineering is also in expressed *Industrial Technology Development in Malaysia: Industry and Firm Studies* (Jomo, Felker and Rasiah 1999: 6).

Testimony by Semiconductor Industry Association's (SIA) Darryl Hatano to USTR (United States Trade Representative) also illustrates the difference between Chinese reverse engineering and reverse engineering in which the engineer peeks at a design and subsequently engages in actual design work. "Reverse engineering a chip to design an original and better product is allowed under layout design laws. However, in these [Chinese] cases, the chips were essentially photocopies of the US design, which we know because they included the US company's part number etched in a submask level and unused circuits that the US firm had place on the chip to reserve space for future product development (DB 2003: 110)."

Reverse engineering may not only hinder developing design skills, but also have technological limits. In the 1980s, circuitry was still not very dense so one could project a chip on the wall and copy the circuitry. TI engineers touring a Korean fab reported stumbling upon Korean engineers doing just that to a TI chip. Of course, the Korean firms invested heavily in R&D after learning the basics from reverse engineering (Mathews&Cho 2000), but there is a danger that reverse engineering firms may lose even that option as circuitry becomes denser. As one well known designer and former chip design professor at a major American research university near Silicon Valley explained, below between .5 and .35-microns, reverse engineering bandits can no longer even trace the light through the circuitry so it is impossible to copy someone else's chips without the mask data, which explains why fabless firms need to trust their foundries so much (Interview 179). Other engineers I discussed this matter with concurred though one designer claimed below .35-micron it was still possible though much more difficult (Interview 273). Thus, the rampant reverse engineering in China is not only illegal and undermining the practitioners' own ability to develop design skills, but also probably an activity with little time left.

The divide between the hybrid FIEs and the other firms in IC design is even wider than the divide in fabs because of the reverse engineering. After interviewing numerous designers and venture capitalist familiar with the IC design sector in China, it is clear that the local firms are focusing on reverse engineering, even the large local firms that have received financial help and state procurement.[163] The testimony of the foreign venture capitalists is particularly reliable because many of these firms are concentrating solely on what they call the "two-less strategy," meaning investing only in fabless design and wireless product design. Thus, these firms are scouring China for promising design houses in which to invest. They are particularly concerned with assessing the technology, including technology embodied in the firm's human capital, of these small fabless firms because technology is the only asset they have. By local standards, the large fabless firms are 100 million RMB (roughly 12 million USD) revenue firms, and as of 2002, there were only five such local firms. My own sample of domestic firms was intentionally biased toward larger firms because these firms are the ones with the resources to at least attempt design. By all accounts, the two–to-three person firms that form the bulk of the 400 or so design houses that MII claims exist in China are completely dependent on reverse engineering. As one designer explained, these firms have no access to capital so they really cannot afford a design team large enough to do any design (Interview 273; DB 2003: 11).

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[163] There is one large, private design firm in China, but this firm is also dependent on reverse engineering (Interviews 273, 155).

Given the illegal nature of the activity, trying to determine which firms were conducting reverse engineering as the mainstay of their activities required finding reliable sources outside the firms studied to assess firm practices. A few firms were quite open about the fact that they were only reverse engineering even though I never broached this sensitive topic directly in interviews with design operations. For most firms, interviews with upstream suppliers, such as suppliers of EDA tools, the many venture capitalists who concentrate on the technology sector and make it their business to assess firms' real technology capabilities and returnee designers who were attempting to recruit local talent provided extensive information on the extent of reverse engineering in the firms under study. I also had the opportunity to take three electrical engineering professors from elite microelectronics programs in the US to various companies to help assess their capabilities. These short visits with the engineers were not conclusive on their own, but served to point out certain companies to investigate further.

The small private firms I did visit (firms with less than ten designers) were by their own admission doing reverse engineering (Interviews 198, 254). In one of these firms, I noticed upon entering what looked suspiciously like a big blown up photo of the circuitry of presumably some other firm's chip. After discussing the firm's history for awhile, I was surprised by the manager's honesty when he admitted that the firm was only doing reverse engineering and that he knew this route was not the way to grow a sustainable enterprise but he could see no alternative for the time being given the small size of the firm and the tight capital constraints.

He was not the only forthright manager. At one of the large telecommunications systems firms in China, the manager also surprised me by admitting in the course of the interview that his firm was doing reverse engineering (Interview 186). This firm is just the type of firm that one would consider having sufficient resources to try the more risky but rewarding path of creating IP through design. However, being a SOE with soft budget constraints and the ultimate end-market being the iron rice bowl of other SOEs, the telecommunications service firms in China, which apparently do not care if the firm is violating the IP of foreign firms, there is little incentive to go the high-risk route.

Here I will measure the deleterious effects of running a reverse engineering design house on the overall contribution to China's technological upgrading by subtracting the number of reverse engineering firms from the total number of firms contributing to technological upgrading for different categories of firms. I call this metric the Industrial Environment Impact Index. If the reverse engineering firms are more numerous than the contributing firms, then the impact on the industrial environment would most likely be negative and this negative impact would be reflected in the negative sign in the resulting index.

Measuring the technological upgrading of the FIEs and local firms was done by measuring what types of design these firms did in China compared to the moving international frontier and to China's own general level of design technology. In the recent past, the Chinese level of technology was abysmally low with the vast majority of design really just reverse engineering of foreign chips. Thus, any true chip design undertaken in China could be considered to have contributed to China's technological upgrading in chip design as China's design capability was essentially nil just a few years ago. However, many of the firms interviewed actually were using relatively sophisticated designs that were much closer to the technological frontier (measured in the ability to design to narrower lithography line-widths commensurate to the narrower micron widths of the lithography technology as shown in Table 5.3) than one would have expected given the low base that these firms from which the design segment started. This accelerated catch-up to the technological frontier is almost entirely due to the transfer of skills through returnee start-ups and ECE subsidiaries with marginal contributions from either local firms or other FIEs.

3.2 The Evaluations

The overall evaluations for which firms were contributing to technological upgrading are summarized in Table 3 below. Of the six domestic firms deemed to be contributing, at least two firms were only making marginal contributions because reverse engineering constituted a large part of their activities. Only 2 of the 13 domestic firms that were not contributing were also not proven reverse engineering firm. One firm was essentially reselling an IP core it received for free from MII (Ministry of the Information Industry). The other had received technology transfer from a MNC a decade ago and had been producing the same chip for the last ten years. In contrast, only two of the 31 foreign design houses were reverse engineering. In addition, of the five foreign hybrid firms deemed not to be contributing, three would have been considered contributing if they were judged by the less strict standards of the domestic firms.

The regular foreign firms were few in number so one may question the validity of the findings for them, but the fact that fewer foreign firms were interested in establishing design operations in China is in itself telling and conforms with the prediction of behavior of the non-China-based OS of the regular FIEs. With the vast majority of IC design work still in Japan, the EU and the US, these firms are underrepresented in China's design operations. This under-representation suggests a relative lack of interest or ability to run technology activities in China, precisely the prediction made by differentiating regular FIEs as less willing or able to pursue upgrading in host countries such as China. Beyond the regular FIEs interviewed, I only located two other active design operations of regular FIEs in China and one of these had just started. There were several other "backend" facilities, but informed interview subjects had confirmed that these other facilities were simply layout shops.

The hybrids contributed by far the most in terms of training engineers in real design skills. Twelve hundred of the eighteen hundred engineers trained were trained in hybrids. The domestic firms trained almost five hundred engineers, but forty percent of these came from one firm, a firm that may be in the process of shutting down its design operations. When one looks at the negative impact of reverse engineering vis-à-vis the positive impact of the contributing firms (the Industrial Environment Impact Index), the results show the positive impact of the foreign firms and the negative impact of the domestic firms. Among the FIEs, the hybrids had a large positive impact whereas the regular FIEs, given their small numbers in China, had only a marginal positive impact. Also noteworthy is the fact that none of the regular FIEs were conducting reverse engineering as their main activity. This may reflect both their higher level of skills and the more stringent legal environments in these firms' home bases.

Table 5.9 Contributors to Upgrading by Firm Type
Source: Company interviews.

Firm Types	Contributors to Upgrading	Total IC Designers in Contributing Firms	Reverse Engineering Firms	Industrial Environment Impact Index	Total Firms
Hybrid FIEs	21	1204	2	+19	26
Regular FIEs	2	108	0	+2	5
Domestic Firms	6	488	11	-5	19

There were two cases that demonstrate the key factor is not the registry per se, but the capital source of the firm. There was one FIE with very close ties to the Chinese state both in terms of procurement and financing. This firm was counted as a local firm as it had a strong link to local finance rather than foreign finance despite its foreign registry. Similarly, one local firm had received a large amount of foreign VC-investment with the plan that the firm would soon be re-created as a foreign enterprise. For the time being, the firm was still a local firm in terms of registry, but its capital source was clearly foreign. This latter case is somewhat weaker than the FIE with strong links to the Chinese state because this local firm with foreign finance was a temporary organizational form along the way of creating a new FIE with foreign registry. The VC made it clear that this investment would not be tenable if the local firm remained local due to the common fear shared by all foreign VCs that they could not retrieve their investment from local firms.[164]

3.3 Limited Upgrading in Regular FIEs

[164] Recent reports indicate that the deal to reorganize this firm as a foreign entity has fallen through, but more information is needed to assess the impact of these purported changes.

The foreign-finance firms that have failed to contribute to China' technological learning in themselves are noteworthy because their failures shed light on the environment in which these firms operate. This thesis argues that regular FIEs are less likely to upgrade than hybrid FIEs. Looking over the failures to upgrade, the normal FIEs are over-represented as 3 out of 5 failed to contribute whereas only 5 out of 26 hybrid firms failed to contribute.

The two regular FIEs that failed to technological upgrading demonstrate how problematic the Chinese operations or any operations in the developing world are in the strategies of MNCs. The American firm reported that the original idea of the firm was to have joint development projects between Beijing and the US design sites. However, the company became concerned about the problem of protecting IP when coordinating these trans-Pacific design activities. The manager on-site claimed that the concerns over IP were really concerns over export controls (presumably the US interpretation of the Wassenaar Agreement) and not solely concerns over IP leakage, but this claim makes little sense given the ease with which other interviewed firms were able to coordinate design functions between the US and China and the lack of any complaints on the part of US industry interest groups about exports controls on this front. More likely, the firm itself was concerned about controlling the leakage of IP from the Chinese office to China due to the limited recourse the firm had under Chinese law to punish and seek compensation from violators of its IP. In any case, the design office in Beijing ended up conducting very little design activity due to the firm's internal firewalls as the headquarters simply would not transmit the necessary data to the Chinese operations (Interview 142). This firm had the potential to contribute much to China's technological development because the firm had a heavy emphasis and great expertise in analog designs, design skills particularly lacking outside of the Triad of the US, the EU and Japan. The sophistication of the US firm's technology and the absence of almost any design activity in its Chinese "design" office illustrate the often yawning gap between what normal MNCs can offer and do offer to developing host economies.

The Japanese design division of a systems producer did not have cumbersome firewalls between its Japanese and Chinese operations, but the local design activities were at best limited to peripheral customization of designs for local buyers of older generation product. The firm was adamant about not training the local staff to design the more recent generation of products (Interview 133). In this particular case, the firm itself cannot be said to have regarded silicon design as the core technology of the firm, but instead was an auxiliary technology supporting the firm's core technology of creating end-products and optical components. Nevertheless, the firm was careful to prevent much of this auxiliary technology slipping into Chinese hands. The firm had no plans to expand the activities of the design portion of the local operations.

These two MNCs were at best training a handful of designers in older technologies. In both cases, the design activity was at a distant remove from the firm's core technology. These characteristics contrast sharply with activities in the headquarter countries employing thousands of people and creating the core technology products of the firms.

One of the regular FIEs was a regular FIE operation subsequently sold to an ECE firm. This firm failed to contribute to China's technological learning due to special circumstances beyond the control of the ECE firm, which originally may have planned to develop a second substantial base in China. The ECE firm bought Nortel's Shanghai design center. Nortel shed this 70%-Nortel-owned asset at the same time that Nortel sold its share in a local IC fabrication plant, ASMC. The Taiwanese IDM was hoping that this asset could serve as the critical base for the firm to develop telecommunications ICs, an area in which the firm had little experience. In other words, the ECE firm at least had the conception that this China-based subsidiary would take the lead in developing a new and potentially valuable product line. Unfortunately, they did not realize how little value this asset actually had. Nortel had owned this firm in conjunction with the Shanghai government and the design subsidiary functioned much like a traditional SOE. Many of the managers were assigned by the government and the recently departed chief of operations left the now-Taiwanese subsidiary to head the Shanghai Semiconductor Industry Association, a de facto government-run organization, a sure sign that the departing chief was a government bureaucrat, a suspicion later confirmed by interview sources.

After the Taiwanese took over, they discovered that the subsidiary had very little actual capability to design telecommunications ICs or anything else for that matter. The manager brought into right this listing if not sinking ship was very frank about the low capabilities he had found within the company. Furthermore, the company's slow turnaround had driven off the new young engineers that the Taiwanese IDM had recruited. This firm failed to contribute to technological upgrading, but probably due to its historical background as a peripheral operation to a MNC rather than due to the ECE firm's own effort and strategy. Indeed, from interview accounts, it appears that the firm had entertained high hopes that this new subsidiary would be developed into a large and valuable part of the firm creating technology in a whole new and lucrative product area for the firm. The failure appears to have less to do with any lack of the ECE firm's commitment to a China-based operational strategy than the lack of commitment to such a strategy on the part of Nortel (Interviews 6 and 132).

Although the hybrid FIEs have led the way in setting up design operations in China, regular FIEs are beginning to follow suit. This author has confirmed reports of the preparation to establish design centers by Korea's Samsung and Germany's Infineon. Cirrus Logic of Austin, Texas has design activities in three Chinese cities, Shanghai, Beijing and Shenzhen. However, an examination of Cirrus Logic's recruitment page in April of 2004 suggests that the Beijing operation concentrates on testing the ICs rather than actual design work, and the most skilled works remains in Austin with all the postings requiring master's degrees and above in electrical engineering being in Austin despite the design offices Cirrus Logic maintains in Tokyo, Seoul and Taiwan as well as China. Among fabless firms, Cirrus is the largest North American firm with confirmed design operations in China. In contrast to Taiwan's extensive activities in China, none of the top 25 global fabless firms, other than the Taiwanese firms, has design operations in China.[165] The two North American design operations interviewed were both design operations of IDMs, and both Samsung and Infineon are IDMs. Other IDMs have operations in China, but these operations have nothing to do with designing the silicon. For example, Intel, the largest semiconductor firm in the world, has "design" operations in China, but these operations aim to aid telecommunications equipment firms present in

[165] There were 5 Taiwanese firms in the global top 25 fabless firms for 2003 according to IC Insights. The other 20 firms were all North American except for one Israeli firm, Zoran, which has its HQ in the US but its technical team in Israel according to Danny Breznitz of MIT.

China to be able to fit Intel chips into their product designs by providing reference design and support rather than actual chip design (Interviews 282, 320).

This preponderance of IDMs among the few non-ECE MNCs in China's design segment suggest that perhaps for these firms the barriers to setting up and running design operations in China or the developing world generally are significant enough to discourage smaller firms which do not place China or another developing host country near the center of their operational strategy. India's situation also suggests possible barriers to small firms setting up operations abroad because the design operations in India are predominantly subsidiaries of IDMs, such as Intel, TI and Cypress. The large scale of some of these operations, such as Intel's in Bangalore, help make amends for the lack of returnee start-ups in India.

3.4 The Success of Hybrid FIEs

3.4.1 Returnee Hybrids

The firms that were contributing the most to design in China were the hybrid FIEs, both Taiwanese firms and returnee start-ups. Given their generally brief histories, the returnee start-ups generally are not yet large firms. However, there is one hybrid that has become quite large. This firm, Newave, started in 1997 in Shanghai when it was very unclear that China had a future in this industry. The three founders, a Hong Kongese, a Taiwanese and a mainlander Chinese returnee, simply took a gamble that China's homegrown engineering workforce could be trained to be effective designers as well as cheap ones. The firm has grown to employ approximately 120 designers and has world-class design facilities according to two MIT electrical engineering professors who visited the facility. The business model for Newave was to design older telecomm chips in scaled .5-micron CMOS processes. For example, a typical CODEC[166] designed using switch capacitor technology is fabricated in 1.25-micron processes. By redesigning these in shrunk technologies (.5-micron), there is a cost reduction and this is the advantage of Newave. These designs employ rare and highly valued mixed signal expertise. Thus, though the design is for a rather old process technology, it is still quite cutting edge design. Since mixed signal designers are so rare, even in the US, globally very few firms have taken on such a business model (Interviews 149, 180).

While the administration of Caohejing High-tech Development Zone claims responsibility for the success of this firm, they are at loss to explain how they contributed beyond the standard provision of incentives such as tax breaks and subsidized office space (Interview 119). The firm itself reports having very little to do with the zone's officials beyond filing the requisite paperwork. In fact, the firm contributed more to its greater environment than vice versa. The firm has established a tradition of sending its experienced, Silicon Valley managers to the good Shanghai technical universities, such as Fudan, to teach classes. The managers actually jokingly complained that they do more actual teaching than some of the paid EE professors at Fudan. This activity is more than simple altruistic charity work. The firm is able to contribute to the quality of the engineering graduates of Shanghai, which is a public good, but the firm's managers are able to privatize part of this public good by using the classes as an opportunity to recruit the best and brightest young engineers to work at the firm. This connection to the local university system reminded one Silicon Valley veteran of the relationship between

[166] CODEC stands for COmpressor/DECompressor and refers to any technology for compressing and decompressing data.

designers in commercial firms and local universities and community colleges in Silicon Valley where they started to teach design classes in the 1970s.

The skills and capabilities of Newave made it valuable enough an asset that IDT, a US IDM, bought the firm for 80 million USD in 2001. The strategy is for Newave to continue to develop its lines of chips, a product line in which IDT has little to offer. Thus, Newave functions as an independent division of IDT in China. Newave in turn benefits not just from the cash but also from the IDT sales channels globally. This model is quite different from the MNCs that decided to set up some design activities in China because in this instance the MNC, IDT, found a functionally independent and sophisticated design operation in China and bought it to expand the firm's portfolio. Thus, the non-China-based strategy of IDT did not impact the growth of the capabilities of the local design activity since those activities were completely independent of IDT during the development of those capabilities. Now that the capabilities are developed and are not intimately connected to or dependent upon the capabilities of the foreign (meaning non-China) operations of IDT, this MNC has an interest in allowing this China-based asset to continue to grow and enhance its capabilities. The Newave management claims that IDT is not a barrier to Newave's growth. The main barrier to that growth is how quickly Newave can train local engineers to do sophisticated mixed signal design (Interviews 149, 180). Newave's most important contribution is to lead the way in showing that designing ICs in China is a viable strategy as the firm's three founders arrived 8 years before the wave of returnees started to show interest in China.[167]

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[167] Interview 141 has been heavily involved in the recruitment of overseas Chinese engineers and noted that the interest to return really began to pick up noticeably in 1999/2000.

Eleven other returnee start-ups have also begun serious design activities in China and design activities much more sophisticated (measured in micron-widths) than the local firms were generally doing even if one takes the reversed engineered "designs" of the local firms as real design work. This judgment is not based solely on interviews with the firms and with VCs knowledgeable of the local IC industry. A number of these firms have already been recognized as technologically strong even innovative by industry media, analysts and competitors.

Verisilicon is copying the Taiwanese created model of a fabless design house that serves foundries and their clients by providing technologies to help fabless firms design their products. This model is called the design service or ASIC foundry model.[168] The two main Taiwanese foundries have several of these firms with Faraday being the main supplier to UMC's fabless clientele and Goya and Global Unichip being the main design service firms for TSMC. Faraday has been in Shanghai for several years, probably in hopes of winning contracts from the fabs in the area, but Verisilicon has won the key orders as it supports both SMIC and Grace.

Comlent is a firm that wants to design the RF (radio frequency) chips for mobile handsets. RF design is very complex and is a rare skill found mainly in North America and Europe (Fuller 2005), but the firm is busy ramping up its capabilities in RF design in Shanghai by brining experienced RF designers to train local engineers (Clendenin 2003). This firm has enough promise that it has attracted personal investment from what one PRC newspaper dubbed "The Stock King of Taiwan's IC Industry," Cai Ming-Jie, CEO

[168] Design service firms and ASIC foundries are not exactly the same but there is overlap between the two activities and the terms are often used interchangeably.

of Mediatek and Faraday, two large Taiwanese design houses (Ding, ESJB, June 28, 2003).

Another firm, Vimicro, has become the first Chinese firm to be allowed to enter the Mobile Industry Processor Interface (MIPI), an international alliance for mobile technologies. This alliance has only one firm from Taiwan, Mediatek, despite Taiwan being the second largest IC design producer after the US.[169] More impressively, Vimicro has a joint R&D facility with Microsoft to develop multimedia technologies with Vimicro researching the multimedia chips. Another firm, AAC, is concentrating on analog technologies, which as mentioned earlier is an area of design lacking in China and even Taiwan.

3.4.2 Location of Sophistication Design Activities

The question remains as to whether these firms were dependent on sophisticated design done outside of China while doing the routine, EDA (electronic design automation) tool-pushing design work in China. If all of the sophisticated design was done outside of China, then these firms could not really be said to have a China-based operational strategy. Routine design has a large presence in China and given the cheaper labor costs, it makes eminent sense to place this routine work in China. However, the division of labor is not so simple. Technologically advanced fabless firms, such as Broadcom of the US, keep their routine and innovative design functions in-house and, thus far, in the home country. Similarly, these eleven returnee design houses are not

[169] From MIPI's website at www.mipi.org though it should be noted that one other member, Anyka, has a significant presence in China.

dividing their functions so neatly between recognized centers of innovation, such as Silicon Valley, and recognized centers of sweat, such as China. Rather than taking China's place in the global technological ladder as given, these firms share Newave's strategy of trying to build technological competencies in China.

There are significant pull reasons to set up such operations in China given the cheap and plentiful supply of engineers (see table below) that give this strategy a strong economic justification (D. Ernst 2004:1). These pull factors can not account for the fact that these firms are investing in the development in China of the type of sophisticated technical skills found in places such as Silicon Valley. Rather, the most cost effective way to take immediate advantage of the cheap engineering resources of China would be to employ these engineers to do tool-pushing after a minimum amount of training in the use of these EDA tools, which is basically the model used by the Japanese firm discussed above.

Not one of these returnee design houses is doing such a rigid division of routine design in China and advanced design abroad. Seven of these firms have no design teams abroad at all (Interviews 124, 140, 159, 252) and the three other returnee firms (Interviews 135, 184, 189, 253) had significant advanced design work (relative to the firm's spectrum of design activities) in China. These eleven firms all shared the same basic strategy of Newave. They wanted to enhance employee skills through extensive training. This strategy also makes economic sense as these firms can then take advantage of the substantial wage gap with the centers of innovation to pad the profit margins in order to make up for the initial training costs. These firms recognize that the key to this strategy is to retain employees just as Newave has, and they recognize the key

Table 5.10

Source: D. Ernst 2004, "Internationalization of Innovation: Why is Chip Design Moving to Asia," *East-West Center Working Papers*, No. 64.

Annual Cost of Employing a Chip Design Engineer* (US-$), 2002

Location	Annual Cost
Silicon Valley	300,000
Canada	150,000
Ireland	75,000
Taiwan	<60,000
South Korea	<65,000
China	28,000 (Shanghai) 24,000 (Suzhou)
India	30,000

*= including salary, benefits, equipment, office space and other infrastructure.
Sources: PMC-Sierra Inc, Burnaby, Canada (for Silicon Valley, Canada, Ireland, India); plus interviews (Taiwan, South Korea, China)

to retention is to offer adequate compensation through stock bonuses[170] on top of wages and through providing further opportunities for the engineers to enhance their skills.

In theory, stock bonuses are not allowed under Chinese law as Chinese citizens have not been allowed to own foreign stock. This law was recently changed to allow ownership of foreign stocks. The fact of the matter is that FIEs have been giving their PRC employees stock options and bonuses for quite some time without running into any difficulties. In fact, the previous illegality of these options actually gives the firms increased leverage over employees because these options were exercised through foreign accounts that the companies rather than individual Chinese employees managed. Thus, if

[170] Depending on the firm, these are stock bonuses or stock options. Regardless of which type, both were illegal for foreign firms to reward employees until recently.

the employees leave without the consent of the employer, these accounts were forfeited and the employees had no recourse to the law because what they have done was illegal.

A further examination of the three returnee start-ups with foreign design operations reveals a shift over time towards more operations in China. One firm that designs CMOS image sensors for digital cameras originally had a large design operation in the US alongside its Chinese operation with plans to shift the work towards China (Interview 189). However, an ex-employee still on good terms with the firm reported that within a year of the first interview a substantial shift of the resources to China had taken place with the Silicon Valley operations basically turning into a sales office (Interview 254). Another firm designing the RF chips for mobile phones has planned all along to move the handful of engineers and the CTO, all originally form the PRC, back to the PRC from Silicon Valley to join the local design force of 20 plus engineers (Interview 253). An inspection of the firm's recruitment page on April 19, 2004, confirms that the firm is hiring technical staff solely for its Shanghai operations. The firm is also hiring for a few positions in Taiwan, but these positions are for liaisons with their foundry and packaging partners and their Taiwanese mobile handset-producing customers rather than design positions.[171]

The third firm is designing baseband ICs for handsets. This firm has the largest group of engineers in the US at 30, compared to more than 300 engineers in its Shanghai headquarters (Interview 135, 184), but the firm claims to be doing much of the required design work and embedded software in China and views the core of operations in China.

[171] As discussed in Chapter Three, design firms and product firms often have to work together to achieve the designing in of the chips to the end products. This particular segment has yet to be fully digitized.

A look at the firm's recruiting page on April 16, 2004 confirms these claims as the firm is recruiting for nine positions in the US, but has openings for 26 types of positions in China and many of these positions are for more than person. More significantly, the Chinese positions are not just for routine design work as the firms seeks engineers with rare skills, such as RF circuit design, and seeks to fill several positions with technical PhDs. RF circuit design is at the heart of the wireless technologies that firms such as this one are trying to develop (Fuller 2005).

3.4.3 Taiwanese ECE Hybrids

The Taiwanese firms that have contributed to China's technological development in contrast to the non-ECE MNC firms, which are mostly defined by their absence, have tried to utilize China's human resources as part of their core strategy. Among ECE firms, VIA has gone the furthest in incorporating China-based design operations as part of its base of operations as measured by the Chinese engineers employed in VIA's core activity, IC design. Several years ago, this author thought that VIA's Chinese processor market answer to Intel's Intel Inside campaign, the *zhongguo zhi xin* campaign ("China's chip" though this pun also sounds like "the heart of China"), was unintentionally ironic. The firm had its processor design in Texas and was having difficulty remaining in the processor business. Furthermore, the processor business was a sideline of VIA's mainstream PC chipset business located in Taiwan and the firm had no real technology activities in China. VIA has since proven how sincere its advertising campaign really was by ramping up to a workforce of 500 designers between its Beijing and Shanghai offices and has plans to expand to 2000 within two years (Woetzel 2003: 55). One report predicated VIA would have a larger workforce in China than in Taiwan by the end of 2004 ("VIA Tech to Have More Employees in Mainland than Taiwan," TENS April 29, 2002). To put some perspective on these numbers, 500 engineers is equivalent to almost one percent of the total US IC design workforce (with a high estimate of 50,000) (D. Clarke 2004) and 500 engineers would be a quarter of VIA's total workforce in 2001 and 2000 engineers would be equivalent to the whole 2001 workforce, both engineers and other staff (Plunkett 2002). 500 engineers would be at least ten percent of India's total design workforce of 5000 (Clarke 2004) and between three and seven percent of China's design engineers depending on the estimate.[172]

This author confirmed that 6 (Mediatek, Realtek, Faraday, VIA, ALI and Holtek) of the top ten fabless design houses in Taiwan in 2002 had design operations in China by 2002 and the other large Taiwanese firms may have Chinese design operations though tracking them down is difficult because they often change their names upon setting up shop in China. Both fabless design firms and Taiwanese IDMs with design operations in China had ambitious plans to expand their engineering bases, but more importantly, their design teams in place were already working in conjunction with design teams in Taiwan and elsewhere to co-design chips. In other words, these teams were part of the firm's core R&D operations rather than shunted off to do peripheral work (Interviews 61, 121,150, 155, 172, 173, 174, 190).

One dramatic example of the increasing centrality of Chinese operations to ECE firms' operational strategy in IC design is Firm T. Firm T was the creation of a major Taiwanese fabless design firm. That firm bought a CDMA mobile handset chip design

[172] Hsieh (2004) cites Applied Materials estimate that China's IC design industry has grown from 1200 engineers in 1998 to 15,000 in 2003 and Clarke (2004) cites 7000 in 2003 using iSuppli's estimate.

division from an American IDM to create Firm T. However, after purchasing the division, the Taiwanese firm did not leave the whole design staff in the US as Taiwan's VIA did when it bought the Centaur processor division of IDT. Nor did the mother firm move the operations to the headquarters in Taiwan. Rather, the mother firm decided to bypass Taiwan completely and co-develop Firm T's products in the original US base and in a city in Greater Shanghai area. The firm sent 20 to 30 engineers from China to be trained in the US operations. Now, there are 65 engineers in China and 100 in the US. The manager of the Chinese operations was blunt about his intent to move more design work to China because of the large wage gap with the US, but the US operations will continue to be based in San Diego, the cluster of CDMA design in the US due to the presence of Qualcomm and Nokia's CDMA design operations. While the US operations are not going to disappear, this Taiwanese firm decided to forgo Taiwan completely to build a large Chinese operations rather than transferring the new technology to Taiwan to be absorbed and learned at headquarters. The ramp up to 65 engineers in China took only a year and a half after the initial purchase of the US division by Firm T's mother company (Interviews 291, 292).

Measured by the number of designers as well as the design content, some of these firms have large design bases in China. At least four hybrid firms had ramped up to over 100 engineers. To put this in the historical context of the development of Taiwan, the second largest center of design activity after the US, Faraday, a top-ten Taiwanese fabless design firm, had only 40 employees in 1996 and then grew to 100 in 1997. ALI, a current Taiwan top five and global top thirty design firm, had only 200 employees in 1997. VIA, which would quickly grow to become a global top ten fabless firm, had only

180 total employees in 1997 (ICE 1998). Using 1997 provides a telling comparison because Taiwan's industry was already well developed by that point with 15% of the global market (A. Lu 2003: 3) so one would expect its firms to be global players even at that point in time. Since the employment figures were for total employees, a share of these employees were not design staff so some of the firms with over 100 designers in China may actually have larger design staffs than their Taiwanese counterparts had 6 years earlier.

China's total design workforce has exploded over the last seven years. In 1998, China had 1200 designers and as of 2003 China has 15,000 designers according to Applied Materials' estimates (C. Hsieh 2004: 2). The growth has been spectacular even if the lower estimates of current designers by iSuppli, 7000 designers (Clarke 2004), are used. While this figure is much smaller than the US figure of 40,000 to 50,000 designers (Clarke 2004), the US dominates the world design industry with approximately 70% of fabless design production.[173] Byron Wu of iSuppli predicts that with the growth of fabless design in China, greater China (mainland China's fabless industry plus the already developed Taiwanese fabless industry) will overtake North America in total size by 2008 and much of this growth will be from China rather than the already large Taiwanese fabless industry (B. Wu 2003). Moreover, the experienced returnees have snowballed into a critical mass with over 200 experienced electrical engineers (defined by interlocutor as engineers with over 10 years of experience) having returned to the Shanghai area alone. This influx of talent has allowed China to start to set up branches of the major professional associations that are active among ethnic Chinese in the American

[173]B. Wu (2003: 21) claims 7000.

high-technology sector, such as Shanghai's branch of CASPA (Chinese American Semiconductor Professionals Association) (Interview 252, 269).

3.3 The Local Firms

There were six local Chinese firms that were doing real design work. Two of these firms are major telecommunications equipment firms based in Guangdong Province. As rumored, both firms were designing chips for their equipment. However, the claims made by many in China that these firms were creating the core silicon technology needed in the telecommunications equipment they produced are exaggerated. Interviews with the firms' microelectronics departments themselves revealed that these firms were designing peripheral chips while still buying the core chips from foreign firms such as TI and Agere (Interviews 102, 169). One of the suppliers of key chips also revealed that these firms were buying the key technology from them and other foreign firms (Interview 226). Still another interlocutor, who happened to be a big booster of China's IC sector as well as well l-known academic and entrepreneur in Shanghai, pointed out that the firm considered to be the more advanced in its design was really doing the architecture but not the actual circuit design. Often, the architectural level of design is considered the more complex and innovative task, but in this case, the circuit design itself was the more technically difficult task and the firm was outsourcing that task (Interview 122). These two firms were doing design work, but it was rather peripheral and marginal, shining only in comparison to reverse engineering. Finally, one of these firms is rumored to be in the process of closing down its design operations according to insiders (Interview 308).

Another local design house that may have contributed to China's technological upgrading was a rare combination, a returnee start-up that received investment from local private entrepreneurs (the only such fabless company the author came across in China). This firm was attempting to sell relatively technologically simple RF chips for consumer electronics goods. If the firm is truly developing RF chips in China, the firm is contributing a rare skill set to China's engineering pool, but there is one major reason to be wary of this firm's claims. The firm's investor is none other than the one large private fabless design house in China, which itself is notorious for reverse engineering. There is the distinct possibility that the start-up funded by this firm may follow the same strategy.

Even if this firm actually succeeds in developing its own RF technology in China, the institutional constraints under which this firm operates may not be solely domestic. The firm has already expressed the desire to seek foreign VC funding for its second round of funding and has already been in touch with some foreign VCs (Interview 290). Indeed, originally, one VC tried to arrange for this firm to be a subsidiary of Comlent, in effect becoming invested indirectly by foreign VC funds (Interview 262). Thus, the possibility remains that the firm has already adjusted its behavior in line with the expectations of foreign capital. Rather than taking the reverse engineering route, the firm, realizing that it has to have some technological capabilities to receive foreign VC funds, may be developing those capabilities with the initial seed money from the local private firm.

For the local firms, the firms that have not been able to access the state financial system have had no recourse except to pursue the reverse engineering strategy due to lack of funds to invest in time-consuming and expensive design work. At best, these firms have competed on offering the cheapest knock-offs to the local private market firms, a business that hardly offers healthy profit margins to develop capabilities to escape this poverty trap. Only one of the top ten local firms is a private firm that has been able to generate enough reverse engineering revenues to grow. The other large local firms are all connected to the state. These firms receive financing from the state, but perhaps more critically, they gain access to state patronage. The one local firm that escaped from the inequities of this system by linking up with foreign venture capitalists and foreign technologists reported that it had tried to compete with the state-linked firms in the IC card market (IC cards are cards with chips that carry adjustable information used for such things as telephone cards and transportation cards in China) but had to resort to supplying a state-linked firm with chips because it could not get into the state's procurement channels (Interview 285). The margins were very low since it could not sell directly to the state and it decided to try to develop alternative businesses. Without the infusion of foreign technology and capital, this firm would probably have failed or remained a very small operation, the fate of most private design firms in China.

Due to the application of IC cards for use as transportation and telephone cards and even as a form of insurance card in China (transportation, telephony and social service being controlled by the state), these cards are mainly used in state-run services and thus have become the state's major way to channel government procurement to favored local IC design houses. MII has even implemented the Golden Card Project, which promotes the use of such cards in various services industries with procurement of these cards channeled to the local favorites.

The other main avenue of procurement is for firms designing chips for telecommunications infrastructure equipment. As the telecommunications service providers are all state-run, this area has become another path for government procurement to the IC design segment though less by design than default. The local telecommunications equipment firms are favored in the awarding of contracts, but this favoritism appears to have no direct link to the design activities going on in the telecommunications equipment vendors. They do not appear to receive or lose government contracts on the basis of the level of their own IC content in their equipment. In other words, the promotion of IC design was only indirectly promoted by this state procurement and perhaps was not even a goal of the telecommunications chip procurement. As of 2001, the local firms were still the largest because the ECE firms were not counted as Chinese firms and the relative youth of the returnee start-ups. Of the top ten, only two were returnee start-ups, Trident and Newave, and only one was a private local firm. The other seven were state-owned and all of these firms sold IC cards or were themselves part of telecommunication equipment vendors that were the design firm's main customer.

State procurement in itself is not a poor policy if granting these economic rents generates technological learning, but there is no evidence that the firms receiving procurement have done anything but continue to reverse engineer foreign products. One foreign-trained manager looking for design talent found designers from these firms to have no real design expertise at all. He went on to say that if he sourced from a fab to which one of the design houses was associated, he would make sure to mislabel his layouts. By mislabeling the layouts of the designs, he would ensure that if the fab passed on his layouts to the design houses they would be have great difficulty deciphering what the functions of the actual layout really was, such difficulty that the reverse engineering firm would be better off blowing up pictures of the circuitry (the standard practice of reverse engineering firms that have no connections to fabs). Having worked for a number of fabless firms in China, the same interlocutor reported that the government officials were easily fooled into believing almost anything is high-technology because they have a limited understanding of IC design. Thus, the 863 Plan, a major S&T initiative under MOST to encourage innovation in China, has funneled small amounts of money to support research to both foreign and domestic firms, but these officials will support just about anything you tell them is high-tech (Interview 273). A number of other interlocutors agreed that MOST and MII did not have the capabilities to discern which firms were undertaking innovation. Thus, the funds from these ministries were readily available to undeserving firms (Interviews 302, 305, 307, 310).

The support for domestic firms through procurement dwarfs the S&T research funds available to design firms, but distribution of state procurement similarly lacks a mechanism to weed out those firms that do not generate any technology. Indeed, there is no evidence that there is even any attempt to measure their performance beyond the fact that the design firms deliver the ICs ordered. As part of the 909 Project, the state gave support to seven design houses including SSMEC (Guowei) in Shenzhen and HuaDa in Beijing (DYBG 2002, No. 11:5).[174] One firm, Huada, has been at the center of state IC design plans since its founding as China Integrated Circuit Design Center in 1986. The fact that the same firms have been receiving state support since the 909 Project and others

[174] Some of these seven firms were established under the 909 Project and others were established during the 8th Five Year Plan or even earlier.

have benefited from sate telecommunications procurement (Shanghai Belling and Datang Microelectronics) despite no major technological accomplishment to show for it suggests that the criterion is politically rather than economic or technological. The other newer state-linked firms appear to benefit from local state support, such as Zhao Ri in Beijing and Fudan in Shanghai, on the grounds of being local enterprises rather than any technological accomplishments. All of these firms are actually SOEs, but as we shall see below, the state procurement now extends to other firms that have been able to enter the state's favor.

The state procurement extends to orders from state-owned enterprises for some new state-linked firms. Beijing Municipality appears to be the main source of this type of support. Through municipality-owned SOEs, such as Beijing Oriental Electronics, the city has recently promoted two design houses that are nominally not state enterprises. One is BLX, a design house with ties to Institute of Computer Technology in the Chinese Academy of Science, and the other is actually a FIE that has turned sour under the state's benevolence.

BLX is the type of firm that would be called *minying* (privately managed) as it is not officially a SOE and is at least nominally managerially separated from CAS or any other state organ. Many other technology companies are often placed into this category, including Legend and Huawei. However, *minying* is a term with no legal standing. Moreover, the assumption that *minying* firms have no connection to the state is false. Like Legend and Huawei, BLX is championed by the state though here the state is primarily the municipal government rather than the central government. In this case, it is hard to differentiate where CAS' influence as a national influence ends and the influence of Beijing Municipality begins, as the interested parties are all located in the capital, which also happens to have an important and large regional government.

Whatever its exact ownership category, BLX is reliant on orders from state-owned firms and these orders have no economic justification. BLX is trying to make server processors. The first generation, 32-bit Godson-1, were based on the MIPS instruction set, but were not strictly compatible because they avoided using key instructions that would have run afoul of MIPS patents. The Godson-2 is 64-bit 500-MhZ processor for servers that supposedly do not use the MIPS instruction set. However, these processors are actually using quite old technology and are more costly the Intel's most current processors. In the marketplace, these chips would go unsold, but in Beijing's politically determined marketplace, Dawning and Legend, firms with ties to CAS, purchase them for their servers, which in turn on purchased by the agencies of the state. As one VC manager remarked when asked about this firm and Arca, a firm discussed below, "I can buy cheaper from Intel and Motorola so why buy from [these guys]?" He also noted that the higher priced local CPUs were performance-wise far behind the international lead vendors. The same investor noted that new firms, "…need government support but not too much government support." He went on to explain that for these two firms, the government procurement is the main market and this venture capitalist did not see how this support would do much other than undermine the incentives to innovate in an economic efficient manner (Interview 262). There is no evidence that these firms have been able to expand their markets beyond the state procurement of servers. These firms have thus not passed the basic test of commercial viability because they have no products even attempting to compete in the marketplace.[175]

The other firm that shows the expanding patronage for IC design by the Chinese state is Arca. This firm is also the prime example of how nominally foreign firms can also become linked to state finance and thus have their incentives to create technology undermined. Returnees from the US founded Arca and the firm had a core of experienced engineers returning from the US to do the design work. At least one VC run by an experienced entrepreneur and well-known electrical engineering professor thought very highly of Arca's potential and was considering investing in the firm. Then, he became disillusioned as he found that the founders became too enmeshed in the state's propaganda about its supposed high technology triumphs. As he put it, the founders of the firm began spending too much time making speeches to bureaucrats in Beijing about how great their technology was and neglected the actual work of creating the technology (Interview 179). A source close to the firm reported the firm's technology was very backward compared to international competitors in CPUs (central processing units) (Interview 243) and the customers of the firm reflect this backwardness. Rather than being able to compete in open commercial markets, the firm has relied on purchases by local state enterprises, such as Beijing Oriental Electronics. Thus, this firm fails on the basic test of creating a commercially viable product just as BLX failed.

One could argue that these various efforts to provide state procurement to Chinese design houses just need time to reach fruition. While BLX and Arca are relatively new, the history of procurement and other funds to support favored IC firms has a much longer

[175] There are recent rumors that BLX has lost its state patronage.

history. Unfortunately, even Huada, which as almost 20 years of state support backing it, has little to show for its efforts and still relies on government largesse. The other firms that received support from at least the 909 Project onward also do not have original technology products competing in the marketplace after at least eight years of state support. Clearly, continued state support is not predicated on the individual firm's performance in creating competitive technology products. Consequently, the firms perform accordingly poorly in upgrading their technological capabilities, living down to the low expectations set for them.

4. From Puppeteers to Stage Managers: Assessing the Extent of Change in the Chinese State's IC Industrial Policymaking

Dewey Ballantine's study of China's IC policy argues that the state has shifted industrial policy from one based on using Chinese state-owned firms to one that mimics Taiwan's IC industry in using private enterprises with a passive minority investment from the state to develop the industry. There are certain facets of the current argument that fit with this argument. SMIC certainly does not resemble the firm created out of the 909 Project, HHNEC, because it is private even while also receiving tax breaks and some loans from the state. Central and local governments have provided support for SMIC as a way to boost the development of the IC industry in China. However, there are also many continuities with the past that suggest there is not suggest a clean break with the previous attempts to use state enterprises to drive industrial development. Local experimentation and competition has opened space for the FIEs to operate in this sector, but these opportunities do not mean the abandonment of the dream of state-driven success in silicon. Furthermore, the Chinese state began to accommodate WFOEs in ICs much earlier than Dewey Ballantine recognizes. Motorola's wholly owned fab was being prepared since 1995 and in 1984 the first wholly foreign owned assembly and test plant was set up in Shenzhen.

The state loans to SMIC and Grace are not the only signs of shifts away from state-owned firms as the core of China's industrial policy. An examination of internal reports from MOST presents some signs that the government may want to distance itself from state-sponsored firms in the IC industry. MOST officials reviewing the failures of the 909 Project have proposed a model of "the government provides the stage, the firms sing the arias [*zhengfu datai, qiye changxi*]" instead of the state-owned enterprises taking the lead. Their interpretation of the perceived success of a disparate group of countries (Taiwan, the Soviet Union and India) sees the need for government policy to provide a platform of incentives and investment measures to "innovate [new] organizations, managerial systems and operational models (DYBG 2002, No. 11: 8)." Their calls for a new approach to funding the industry makes clear how great a departure the platform model is from previous state-owned efforts.

The MOST officials even grasp some of the potential of modularity in that they conceive of concentrating in one narrow area of operation first, but they then see this as the opportunity to create a base from which to expand into upstream and downstream functions. While the wording concerning the subject of this expansions is vague (is it the industry or the individual firm), the mention of two firms that have this potential strongly suggests that the officials have in mind a slow emergence of a vertically integrated giant rather than the emergence of a segmented but complete industrial value chain as has emerged in Taiwan (DYBG 2002, No. 11: 9). Instead of direct financial support, the officials advocate support for financial measures to provide for the raising of private and foreign funds through capital markets. Indeed, the officials view capital markets as the tonic to ameliorate the overinvestment in and inefficient use of industrial capacity brought about by state investment in competitive industries.

Most surprising given MOST's institutional interest, the researchers call for state support to firms with R&D and production capabilities and not to MOST research institutes and higher education institutions because they are far removed from the demands of the marketplace (DYBG 2002, No. 11: 9) or as they put it, "They emphasize scientific research, ignore products. They emphasize scientific papers and ignore patents." They envision placing the government research institutes into large firms and then supporting the firms with state funds for R&D. While this strategy does not throw their MOST comrades out on the street, it certainly lowers the scope of bureaucratic influence of MOST assuming that the firms themselves are not under MOST control. This assumption is a solid one given the general movement to remove firms from ministerial control and the fact that the MOST officials mention large firms rather than firms controlled by MOST. In China's IC industry, none of the large domestic firms are under MOST's direct or indirect control.

Another MOST report echoes the call for a government-provided public service platform, but combines this proposal with one of trying to limit the influence of foreign firms in the industry by removing their preferential policies and recognizing IP through utilization rather than creation (a ploy to avoid paying for foreign IP) (DYBG 2002 No. 14: 9). Finally, a third report which examines SMIC and correctly recognizes it as a new and very international way to build a semiconductor industry in China, still calls for the government to provide strategic guidance, which follows a call to mimic the incentives and guarantees provided to the IC industries in Japan and Korea (DYBG 2002, No.12: 7). Even for reformers, the desire for the government to remain in firm control is strong.

Discussions with MIII officials involved in policy formulation for the semiconductor sector also show some shift in policy. These officials conceded without prompting that their past large-scale projects, namely the 908 and 909 Projects, failed because of a lack of understanding of the end-markets in which these technologies would have to compete. These officials recognized that the used of state-managed projects would not resolve the problem of the lack of knowledge of the markets, but they also insisted that these projects had contributed to the technological development of China while presenting little evidence of this supposed contribution (Interview 74, 78).

On the other hand, MII does not seem to have dropped support for large-scale investments in semiconductors. While ASMC's 8-inch fab construction could have been driven by local Shanghaiese officials, one former Shanghai Science and Technology Commission official who still operates within a state-sponsored technology organization in Shanghai, insisted that the push behind the recent wave of state-owned fab-building was due to the influence of Beijing in the Huahong Group, the group which controls Huahong NEC, Shanghai Belling and, indirectly via Shanghai Belling, ASMC. This interlocutor claimed that the local government was not very interested in building the fab planned by Shanghai Belling and now being completed by Huahong NEC, but was forced to do so because of central government influence within the Huahong Group (Interview 268). This claim has some factual evidence because the Huahong Group has been split between the Shanghai government and MII with MII controlling 60% of the shares (Naughton 1999: 13 fn11). Furthermore, Shanghai Municipality has already done well by recruiting SMIC, Grace and TSMC to the municipality so Shanghai does not have a clear incentive to support the building of more state-owned fabs. Building more state-owned fabs might actually hurt the fabs already in place because they could add stress to the critical supplies of electricity and clean water that these fabs need to run. One foundry manager reported that Shanghai Pudong's supplies of water and electricity were better than Taiwan's, but that once SMIC and Grace each had two full fabs running on top of Huahong NEC, the supplies might be stretched by further fab-building without requisite investment in the necessary infrastructure (Interview 20).

Another piece of evidence that lends credence to the charge that MII has not abandoned state-owned firms as the core of semiconductor industrial policy is the forced adoption of Shanghai Belling's eight-inch fab project by HHNEC. Shanghai Belling had aspired to build an 8-inch fab just as HHNEC did and ASMC was doing. Belling wisely realized that a foreign partner would be needed as a technology source, especially as the firm decided that it would try to pursue a niche technology route in order to avoid competition with established foundries. The problem was Shanghai Belling wanted to maintain majority control (Interview 260). Consequently, no foreign partner was found. However, MII did not want this project dropped so they forced Shanghai Belling to drop the plan and hand it over to a reluctant HHNEC, which had its hands full with managing the one foundry it already had (Interview 289). This fab project then was able to find a partner, Jazz Semiconductor.

Much more important than any major shift in national policy towards allowing private and foreign firms to play a larger role in China's IC industry have been the moves of local state actors. Shanghai encouraged the investments of SMIC and Grace in 2001. In contrast, when I talked to the firm in charge of Beijing's main fab project in the Northern Semiconductor Base in late 2001, the Beijing Municipal Government had given the funds to start this base (approximately 850 million USD) to a local SOE, Shougang, to build a Shougang majority-owned 8-inch fab under the control of Shougang's SGHT (Shougang Hi-tech Corporation), a new corporate entity created for this project (Interview 32). However, the fab was unable able to find suitable partners with only several quite small Chinese-American design houses, Alpha&Omega and Joshua, interested in investing in the project. This fab project, dubbed Huaxia, was never able to start due to the lack of foreign technological partners.

In the meantime, SMIC had moved in equipment and was about to start production in its first Shanghai fab. In 2002, Beijing started to discuss with SMIC about the possibility of SMIC setting up a fab in Beijing. These talks led to the rug being pulled out from under the Huaxia fab project as the Beijing government took back 650 million dollars from Shougang's own project and routed it to the SMIC project prior to August of 2002. This left the managers who were trying to set up the Huaxia fab with only 200 million USD to invest, far too little to buy equipment, even used equipment, for an 8-inch fab (Interview 191). Shougang still benefits because Shougang is the large, minority, passive stakeholder in SMIC's Beijing fabs, which are grouped together as a SMIC subsidiary, BJSMC, but due to the need to keep up with Shanghai's rapid progress, Beijing sacrificed control in exchange for rapid progress led and majority-owned by a FIE.

The fab project also undermined the idea of having the Northern Microelectronics Base in Badachu in the western parts of Beijing near Shougang's steel operations. This location was the planned location for the Huaxia fab and the location of SGNEC's older six-inch fab. SMIC reportedly did not like this site so they insisted on moving to the Beijing Economic Technology and Development Zone in Yizhuang, which is also functionally a high-technology development zone (HTDZ) (DB 2003 Appendix 1: 16).[176] This zone had been trying to attract a fab for some time and had been involved in the talks between Grace and other Chinese government institutes involved in plans to set up the old six-inch fab sold by TSMC. That fab eventually settled in Ningbo across Hangzhou Bay from Shanghai. The Yizhuang zone is much more appealing than Badachu simply by virtue of its close proximity to Beijing's city center. Given the support of the Beijing government for the SMIC project, wherever the firm had settled in Beijing they would have enjoyed preferential tax treatment so such incentives are unlikely to have been a factor in the move. The move to Yizhuang underlined the shift from control by Badachu-based Shougang to the FIE, SMIC.

Support for design activities also shows a mix of policies supporting either state-led or private-led development. With the exception of Arca, the procurement support for design houses is aimed solely at the SOE design houses (if BLX is considered a SOE).

[176] Officially, only part of the Beijing Economic and Technology Development Zone (BDA) is a HTDZ (High Technology Development Zone), the part known as Yizhuang and under the rubric of Beijing's Zhongguancun Science Park, but as reported in DB (2003: Appendix 1, p. 16), the incentives of this HTDZ are applied to all of BDA. This practice is quite common throughout China and is another way incentives spread beyond their planned boundaries. At least some of the time, this expansion of incentives is done by illegal collusion between investors and local officials in which the firms are registered in the relevant zone but are in fact located outside of the zone, a fact known by the local officials who register the firms.

Even the one large domestic private firm does not have a share of this procurement support. On the other hand, small grants under Torch and the 863 Plan, two S&T initiatives, provide support to all types of firms deemed high-tech. Finally, the seven nationally designated IC Design Parks welcome investment by foreign design houses and provide tax benefits and subsidized services, such as EDA tools, to all comers. At least one of the national design centers still revealed an ill concealed technonationalist streak. One of the officials in charge policy development of this park, which was avidly courting Taiwanese investment, denounced the reliance on Taiwanese investment and declared that China would never progress technologically if it continued to rely on investment by Taiwanese or other overseas Chinese not to mention real foreigners (Interview 87).

In general, the IC industry may be the one sector under study in this work in which the old dichotomy between state-owned and consequently state-favored and private and consequently discriminated against or at least neglected by the government still holds for the domestic firms. Given the large scale of investment in IC fabs, until quite recently, there would have been few private firms with the financial wherewithal to invest in the sector by themselves. In contrast, the state sponsored a number of SOE IC fabs. Thus, path dependency of scale makes it more likely that the next projects would be centered around the existing SOEs with existing fabs rather than to target private firms with no fabs regardless of their links to the Chinese state. In design scale is not very important so there is less built-in scale path dependency. Thus, Arca and the arguably privately-managed (*minying*) BLX[177] have been able to enter new procurement channels

[177] A number of companies that have merged form state research institutes have taken on the privately managed (*minying*) or even private (*siying*) mantles, such as Legend, which came out of CAS, and Huawei, which came out of a military research institute in Xian. BLX is as *minying* as these two firms though all of them have quite strong links to the state, through their mother institutes and other channels.

of the state. As for the one large private firm, as the exception to the rule, it has managed to reverse engineer many commercial products for the local electronics industry (probably learned form the original Taiwanese JV the design house in Hangzhou from which it emerged) so it has developed a business model that is both viable and not geared toward maintaining relations with state actors to keep the orders of IC cards for state agencies rolling in. The other private firms have suffered in capital-deprivation from the state's neglect.

The overall policy direction is two-fold: openness to FIE investment and policy inducements applicable to all firms while at the same time expanding state-owned enterprises continue to receive support from the central government. The central government's State Council Circular No. 18 in 2000 effectively cut the VAT from 17% to 3% for IC fabricated or designed in China although this policy will be challenged by the US in the WTO court. These incentives were available to both foreign and domestic firms. Indeed, at least half of the VAT subsidies went to FIEs (JJGC July 19, 2004: 33). Local governments are even more interested in foreign investment in this sector as a way to develop quickly and without the need of large investment of local state funds.

Nevertheless, the central government's desire to back state-owned projects cast a technonationalist shadow over the more technoglobalist policy incentives, such as the VAT, and local initiatives. Even MII recognizes that interaction with private and foreign interests can be beneficial, but the old statist proclivities die hard. In the wake of dropping the VAT incentives in the face of a US lawsuit in WTO court, China has redoubled its industrial policymaking efforts rather than abandoning them. Early reports of the new policies have the state planning to spend as much as 10 billion RMB (approximately 1.25 billion USD) to support domestic industry through 2010 (JJGC, July 17, 2002; ASWJ, November 26, 2004: A7; Fuller 2004). Central and local government actors have learned new technoglobalist methods to develop the IC industry, but technonationalism still lurks as the guilty conscience of the central government prodding and cajoling it to support Chinese state-owned projects even in the face of successful FIE investment.

Chapter Six
Conclusion:
The Sustainability of China's Peculiar Path and the Scope for the Global Hybrid Model of Development in the Developing World

How sustainable is the China's peculiar path to technological upgrading? This chapter will answer this question by looking at the extent of institutional embeddedness of China's IT activities. There is much evidence that China now has the institutions necessary to encourage activities that will utilize the accumulated technical resources. In other words, there is evidence that the technological upgrading is institutionally embedded. When we talk of technical resources, we primarily mean the accumulated human capital.[178] Institutions to encourage the continued use of this human capital are necessary to ensure that these resources continue to contribute to economy over time.

Demonstrating that China has such institutions begs the question of the sustainability of the institutions. Here, the question of alternative institutional paths is as important as the viability of the institutions themselves. The reason these alternatives are so critical is that the current path China has taken is default one rather than desired course. China's political elite has not given up its techno-nationalist dreams even as it has tolerated technoglobalist successes of the hybrid-led development. The logic of

[178] From the previous empirical chapters, we have shown that the activities of firms in China have created a large increase in the quality and quantity of technical knowledge among China's engineering (i.e. an increase in China's human capital). This technical knowledge does not reside in individuals alone. Some of the technical knowledge conceivably is knowledge lodged in a particular firm or other institution rather than an individual. Nevertheless, the history of innovation in IT strongly suggests that most of the knowledge is captured by individuals. This explains why environments where the knowledge workers circulate, such as Taiwan and Silicon Valley, have shown much stronger performance in the diffusion and creation of knowledge in recent decades than those where the knowledge workers are locked into a particular firm, such as Japan or arguably pre-1990 Route 128. To quote Angel's (2000: 125) study of Silicon Valley, "The technological dynamism and forms of flexible manufacturing observed in Silicon Valley are predicated upon fluid employment relations and various efficiencies in job search and inter-firm worker mobility that facilitate the rapid deployment of specialized knowledge, skills, and experience among firms in the local labor market." If most of the knowledge did not reside in the workers' heads, then all of this labor mobility would have be for naught (see also Fosfuri 2001).

central-local relations opened the space for these technoglobalist successes, but they became the main driver of technological upgrading only because the state's techno-nationalist projects failed. On top of the ideological problem China's foreign-driven strategy presents to China's leadership, there is the structural issue of China's financial institutions limiting the potential of China's private entrepreneurs. The malfunctioning of the formal state financial system forces entrepreneurs to adopt the foreign route if they wish to succeed. The irony of course is the short-term political costs of thoroughly reforming the financial sector prevent China from realizing what would be a major gain in the eyes of techno-nationalists, the creation of a set of dynamic domestic technology firms. The hybrid-driven model has emerged as the default option only because China's domestic political institutions (including the state banking system) have thwarted the dreams of state bureaucrats and private entrepreneurs alike.

This chapter will examine the institutions for continued use of the accumulated technical resources, the possibilities for alternatives to the hybrid-model and the policy implications for other nations of China's peculiar path of hybrid-driven development.

1. Institutional Embeddedness

The final test of the embeddedness of the technological upgrading (see Chapter One Section Three) is the ability of the local environment to retain technical resources for continued use even if the firm undertaking the upgrading leaves. What guarantees the continued use of these accumulated technical resources is an institutional framework supportive of luring in foreign firms or encouraging new firm creation. First, I will discuss the specific supportive frameworks for IC fabrication, design and IT hardware

R&D. Then, I will describe the primary institution that support continued used of the accumulated technical resources across the IT sector, foreign venture capital.

1.1 Sector-specific Institutions

For fabrication, China's main institutional hurdle in the past was the controlled investment environment for foreign ventures. Local competition has dissolved the remaining serious hurdles to investment by FIEs. These hurdles may have been as much perception as reality as Motorola was allowed to invest in a WFOE fabrication facility in 1995 and Motorola's plan had been on the table since the early 1990s. On the other hand, during the 909 Project's selection of an appropriate partner for Huahong, foreign firms assumed that this project would be the only post-Motorola chance to enter the Chinese semiconductor industry.[179] Since 1998, the flood of foreign investment has proven these fears wrong. The number of new areas where new fabs have begun operation is growing with Nanjing, Suzhou, Ningbo, Hangzhou and Beijing's BDA joining Tianjin, Shanghai, Wuxi and Beijing's Badachu as areas with foreign-owned fabs. Other Taiwanese firms are joining the movement to China, such as Powerchip, which recently announced the relocation of one of its 8-inch fabs to China. Even the interior has begun to seize some

[179] This author volunteered for USITO (United States Information Technology Office) in the summer of 1998. A number of American IC firms complained vociferously that US technology controls had kept an American firm from winning the right to participate in 909 as Huahong's JV partner. These firms were quite upset because 909 seemed the only plausible right of future participation in China's IC industry for most of these firms. However, it is unclear if they thought it was the last chance to participate or the last chance to participate in a JV funded primarily by the Chinese state. In other words, these firms were looking for an investment option that gained favor with the Chinese state without too much of a burden on their own bottom line and they may have regarded 909 as the last chance to do this. There is no evidence that the Chinese state would have blocked a WFOE from investing in semiconductor fabrication so barring misperceptions on the part of American companies regarding the regulatory environment (highly implausible given Motorola's fab and the information provided by USITO and other US business organizations in Beijing), the only logical explanation is that American firms wanted to invest on the cheap via 909. They simply discounted investing alone as a desirable option when claiming 909 was the last chance.

opportunities. On Semi, a Motorola spin-off, has a six-inch fab in Leshan, Sichuan. Behind this geographic spread are central and local government openness to these new foreign-invested projects and recognition by the foreign firms of the feasibility of such operations. Existing investment incentives in combination with the competition between localities has opened up the investment environment at the same time that established firms are busy training the requisite human capital. Despite foreign complaints about government support for domestic industry, some of the policy support for fabrication has granted foreign fabs equal treatment with local firms as long as the FIEs are producing in China. In fact, foreign firms received at least half of the tax rebates of State Council Circular No. 18 in practice.[180]

"Soft" sociological institutions have formed alongside of the rules and policies of the political institutions, to support each segment of the IT industry. These soft institutions are actionable industry information and industrial clusters. The industry information comes in two forms. Foreign firms with successful operations in China provide templates or models for potential investors that reduce the uncertainty of investing in China. There is also the information feedback from investors to local and central authorities on how to meet the demands of the IT industry.

In IC fabrication, the establishment of running fabs by SMIC, Grace and UMC (Hejian) and TSMC has served as a demonstration effect that running sophisticated fabs in China is possible. These ventures provide a template that helps to overcome those

[180] Despite the vociferous complaints of the Semiconductor Industry Association of the US, the level of rebates was quite small, at most around 25 million US dollars or less than one third of one percent of China's domestic semiconductor production (Fuller 2004). Nevertheless, foreign firms have garnered half of these subsidies (JJGC, July 19, 2004, p. 33). China agreed to drop the Circular No. 18 policies when faced with a pending WTO judgment declaring these tax rebates in violation of TRIM (trade-related investment measures). However, the state is busy preparing new policies to replace the old ones. These new policies may involve a substantial amount of money, running into the hundreds of millions or even billions of US dollars (Fuller 2004; CJ July 20, 2004: 98-99; ASWJ, November 26, 2004: A7).

fears by foreign investors of entering into an alien environment. The fabs have also provided a template of infrastructure provision for the state authorities to emulate as the latter begin to realize the demanding infrastructural needs of IC fabrication, especially a constant uninterrupted supply of electricity and very clean water.

Similarly, the success of IDT Newave and Vimicro in IC design demonstrated that China was a viable location for IC design. MNCs are also well aware of their competitors' activities in China and the movements of R&D operations to China were visible to competing firms. The demonstrable increase in real R&D activities since the late 1990s as noted by Walsh can in part be attributed to such templates (Interviews). There is not the same type of public goods provision models for IC design and R&D as there is for IC fabrication.

There is also the formation of industrial clusters that afford the external economies of scope through co-location, such as a large common pool of engineering talent to recruit from and the concentration of supplier services. The greater Shanghai area (inclusive of Hangzhou, Suzhou and arguably Ningbo and Wuxi as well) has six 8-inch fabs up and running and at least two more that will begin production this year alongside of a number of six-inch fabs. Powerchip is also planning to move an 8-inch fab to Shanghai. The capital equipment makers of the advanced world, such as Applied Materials and Lam Research, have recognized this cluster effect by setting up their main China offices in the heart of Shanghai's silicon industry, Zhangjiang Park. The other potential cluster is in Beijing-Tianjin where the big base of SMIC is right alongside of the highway that leads to TEDA (Tianjin Economic Development Area) where SMIC's fab purchased from Motorola is located.

Clusters exist for IC design and other R&D activities as well. The Beijing-Tianjin area has become a cluster of wireless R&D with similar clusters in Shenzhen, Shanghai and Hangzhou. In IC design, Shanghai and Beijing followed by Shenzhen and Hangzhou have substantial clusters of designers.

What is not clear is the future potential of these industry clusters as *innovation clusters*. These clusters enjoy the effects of co-location in terms of a pool of engineering labor to recruit form and an infrastructure of suppliers, but it is less clear that any of these clusters enjoy any other substantial advantages from locating in an established cluster of innovation. I have not uncovered evidence that suggest firms in one industry cluster generally outperform those in other parts of China due to the type of advantages that innovation districts confer, such as rapid generation and flow of industry knowledge. Simply put, the co-location of production in China is at an early stage so it is premature to confer the status of innovation cluster on these newly formed clusters of production. What can be said is that there are enough firms of a given segment in certain places in China that the new entrants in these areas will not have to create an industrial infrastructure from scratch, the difficult task that faced Newave when it was founded in Shanghai in 1997.

There is one partial exception to the lack of innovation clusters. The extensive links between universities and firms that is common in clusters of innovation, particularly Silicon Valley, is also beginning to form in Shanghai and Beijing in the area of IC design. As mentioned in Chapter Five, some firms in Shanghai are beginning to send their leaders out to universities to teach in order to provide practical design education to the university students in a manner reminiscent of similar practices in Silicon Valley. In

Beijing unlike Shanghai, I did not come across firms sending managers to teach in local universities, but there were a number of university research centers that had joint research projects with firms though this research was for product creation rather than advanced basic research. The research collaboration between universities and the firms is not as strong yet, but this gap may also be due to the weakness of research capabilities of the universities and/or the technological learning stage the firms generally find themselves in. These firms are not trying to create the new technologies, but instead they are learning to master the latest generation of technology so they can get ahead in the commercialization of the next generation of products. Thus, they are not generally interested in advance research as of yet. The universities on the other hand are not generally capable of much advanced research at this stage either. In this sense, the industry looks again much like Taiwan of a few years ago. Even today Taiwan's universities are not doing much cutting-edge research and the link between design firms and universities on research remains weak.

1.2 Foreign Venture Capital

Beyond the soft sociological institutions discussed, the critical institution needed to generate new firms is venture capital willing to back China technology ventures. Domestic venture capital suffers from connections to soft budget state finance so foreign venture capital is the main way to fund technology entrepreneurship. The foreign registration of the hybrids allows foreign venture funds easy invest and exit opportunities. A large number of important VC firms from the US, such as Intel Capital, IDG, WI Harper and Draper Fisher Jurvetson, are investing in Chinese start-ups from offices in

Hong Kong or the mainland itself. The Taiwanese and Hong Kongese VCs, such as Investar and Acer Venture Capital, are very active as well. Foreign VCs had already invested over 5 billion USD in China, and foreign and JV firms combined for over six billion in investment as of 2003 (see Table 5.10). Given that some of the foreign VCs operating in China do not disclose the amount of their capital investment and that these firms were not counted in the amount invested, the real investment in China is larger by perhaps several hundred million assuming the non-reporting firms invest the average amount of the reporting firms. In early 2004, the Carlyle Group announced plans to invest over one billion US dollars in China over the following eighteen months. By the first half of 2004, foreign investment had clearly taken the lead in provision of venture funds in China with 85.44 percent of all venture money coming from foreign firms (*Dongfang Zaobao*, July 28, 2004).

The VC firms active in China, like their counterparts in the US and Taiwan, are very interested in investing in fabless design firms, and 57% of all VC investment in China has gone to the IT industry (Zero2ipo 2003). The legal environment has become more transparent and predictable for these investments through the new regulations announced in 2003 to clarify and streamline the process of foreign VCs setting up investment operations in China (Kuzmik and Tan 2004). Moreover, the local governments understand that VCs are critical to encouraging innovation. They are actively welcoming foreign VCs to their locales. In several instances, local officials have even asked me for advice on how to lure more foreign VCs to their locales. With great interest from the foreign venture capitalists and government officials alike, the foreign venture finance needed to create new ventures is in place in China.

Table 6.1 China's Venture Capital Cumulative Investments 2003

Source: http://www.zero2ipo.com.

Type of VCs	Number of Firms	Number of Firms With Capital Amount Disclosed	Total Amount of Capital (million US$)	Total Amount of Capital Available for Investment in Mainland China (million US$)	Average Amount of Capital Available for Investment in Mainland China (million US$)
Domestic VCs	269	149	4,177	4,109	28
Foreign VCs	38	36	101,795	5,967	166
Joint-Venture VCs	18	15	540	420	28
Total	325	200	106,512	10,495	52

With a large amount of domestic investment in domestic venture capital firms, one might think that domestic venture capital would be able to take over the role of funding entrepreneurial finance. Taking over this role from foreign venture capital would spell the end of the hybrid-driven model as the entrepreneurial finance would be domestic rather than foreign. Unfortunately, the domestic venture capital firms generally suffer from the same soft budget constraints of other firms directly or indirectly tied to the state (White *et al* forthcoming).

In 1985, China established its first venture capital firm. From that time until the late 1990s, explicitly government-managed funds dominated the domestic venture capital industry.[181] While the late 1990s heralded the supposed beginning of CVCs (corporate venture capital) alongside of the previous government venture capital firms, the majority of the CVCs are supported by funds from local governments and their performance has

[181] The National Research Center of Science and Technology for Development under the State Science and Technology Commission (the forerunner of MoST) started in 1984 to conduct research on 'New Technology and China's Countermeasures." The research center suggested developing venture capital at this time. The following year, SSTC and the Ministry of Finance jointly founded China's first venture capital firm, China New technology Venture Investment Corporation (White, Gao and Zhang forthcoming: 31).

ranged from lackluster to disastrous. The three CVCs among the top twenty VCs in terms of Chinese investment (the other 17 were foreign venture capital firms) (White *et al*: 39) were all local state-organs backed by the governments of Shanghai, Shenzhen and Guangdong Province respectively. The creation of corporate entities was supposed to foster better performance compared to the GVCs where government organs or SOEs owned and managed the funds. However, the actual differences between most CVCs and the GVCs were not large. Whereas the government directly owned the GVCs, for the CVCs, the major shareholders of the CVCs if not always SOEs were still government-backed firms. In other words, the links to the state still existed with the advent of the CVCs.

The actual performance of the state-backed CVCs also was poor. Two of the three largest government-backed CVCs, Shanghai Venture Capital and Shenzhen Venture Capital have essentially left the field of entrepreneurial finance (Interviews 323, 86, 116, 260, 261). Shenzhen Venture Capital took most of its assets and ploughed them into China's volatile stock markets. The result was disastrous as the firm destroyed 80% of the value of its funds, losing approximately 200 million USD out of 250 million USD in funds. The management team was fired, but the problem was the management team had no incentive to perform in the first place. They were simply given the government's money and told to invest with none of the returns going to the management team of local bureaucrats. With neither the skills nor the incentives to make asset-enhancing investments, the team decided to gamble in the stock market (Interview 323).

Since being founded in 1999, Shanghai Venture Capital Company has essentially outsourced its funds to investment management firms. Shanghai Venture Capital quickly realized that without incentives or ownership, these investment management firms would simply abuse the funds so the VC now requires the investment management firms to have a majority ownership stake. Yet, these reforms are less impressive upon close inspection. The transition to majority ownership by management is not complete and the investment management firms are all directly tied to Shanghai Municipality bureaus or research units. Thus, these investment management firms themselves suffer from the same soft budget constraints that other Chinese government-linked businesses do. The investment management firm charged with investing in IT firms has abandoned this mission to invest in Shanghai's real estate market. The investment considerations are driven by local concerns about building up a complete industrial chain in Shanghai rather than profit-maximization.[182] The firms in which Shanghai's state VCs have invested are firms targeting state procurement rather than viable commercial enterprises (Interviews 268, 260, 261).

The one domestic CVC that foreign venture capitalists regard as competent and that has successfully led the funding of commercial enterprises is Legend Capital. However, much of Legend Capital's success suggests this firm is the exception that proves the rule. Legend Capital manages funds for Legend Holdings and some foreign investors. However, by the initial agreement with Legend Holdings, the management team of Legend Capital owns the firm and only makes money by managing the invested funds for a profit. This firm is not actually part of Legend Holdings and has no safety net to fall back on if it fails to invest the funds properly. More tellingly, Legend Capital has mimicked the foreign VC strategy to a tee, seeking only to invest in foreign firms with

[182] Furthermore, if Chapter Three is correct, co-location of the entire industrial chain is irrelevant to Shanghai's goal of industrial development.

commercial rather than political business strategies. In a sense, Legend Capital is an institution based on round-tripping investment (Chinese outward investment that returns to China). Legend Capital invests in offshore companies, which then take the invested funds and invest in technology activities in China.

Unfortunately, none of the other VCs founded by domestic firms not directly linked to the state, such as the VCs funded by Ancai and Wanxiang, have exhibited the success or the foreign-invested strategy of Legend Capital. These other firms have not yet successfully invested in a firm showing demonstrable commercial success whereas Legend Capital has done so. Domestic and foreign VCs alike acknowledge that Legend stands out among the domestic VCs for successful commercial investments (Interviews 208, 323,275, 262, 265).

Legend Capital's investments for its first fund were primarily foreign-invested firms. Six of the nine invested firms in which Legend Capital was the lead investor were hybrid FIEs. Of the three from which Legend has already successfully exited, two are hybrid FIEs and one has been bought by a SOE. For Legend Capital's second fund where four foreign investors joined Legend Holding in providing the investment money, only two of the eleven invested firms can be construed as local, potentially state-linked firms.[183] As the second fund dwarfs the first fund in size (75 versus 35 million USD) and the investment in any firm were capped at 5 million USD in the second fund, the large majority of the funds are flowing to FIEs. These FIEs are all China-based firms.[184] With

[183] These two are Suzhou Xingheng, a lithium battery firm with technology from China Academy of Sciences, and Zhejiang Guangyuan, which has invested in TV broadcasting operations of Railcom, a SOE.
[184] Legend has invested in one FIE, Berkana, that is not China-based, but Legend was not the lead investor for this firm. Berkana in fact has no operations outside the US and Korea and is a Silicon Valley-based start-up that Howard Yang of Newave and Montage (see Chapter Five) introduced to Legend Capital. As Legend Capital has no offices outside of China, this investment was its only investment in a firm not based in China.

more of the targeted firms and investment funds flowing to FIEs over time, Legend Capital's own self-articulated strategy of investing in foreign-registered, China-based firms appears to be reaching to fruition.

Table 6.2 Legend Capital's Successfully Completed Investments
Source: Legend Capital.

Company	**Business Strategy**	**Legend's Exit**
Sinocom	Beijing's largest software outsourcing firm (export-oriented)	The firm listed on Hong Kong's main board in 2004.
Joyo.com	Mimic Amazon's bookselling on the Internet strategy for China.	Amazon bought the firm for 75 million USD in 2004.
CNC (China Netcom)	Broadband service operator.	Bought by China Netcom (SOE) in 2003.

With few successful domestically managed funds, another option might be to have foreign managers manage local funds. Unfortunately, this innovation has been tried and has failed because of the conflict between the political goals of the owners of the majority of domestic funds (China's local governments) and the profit-maximizing goals of the foreign VCs. When Jiangsu Province (the province bordering Shanghai to the west and north) decided to avoid the errors of other state managed funds by bringing in a foreign VC to manage its funds, even other state-run funds praised this strategy as a smart one. Jiangsu Province hired Fuxing (Fortune), a Taiwanese venture firm, to manage its 300 million RMB (approximately 36 million USD) in funds in 2003. Fuxing itself was quite excited as it saw this as a potential way to garner a number of similar deals from other state funds if the Jiangsu fund was properly managed.

Problems soon emerged. Jiangsu Province placed many restrictions on where and how the funds could be invested because of the political incentive structure in place for the provincial leadership. The provincial leadership viewed these funds as another mechanism to boost the short-term growth in Jiangsu and, consequently, help their political careers given the heavy weight local economic performance plays in evaluating the performance of local leaders (NFZM, November 3, 2003). Fuxing regarded these demands as not only in violation of the original agreement to allow Fuxing to manage the fund, but also as severely constraining the ability to make sound, profit-making investments. Consequently, Fuxing gave up managing the fund in 2004 and Jiangsu has not been able to find a replacement (Interviews 323, 262, 261).

From the fifteen VC funds (9 foreign and 7 domestic ones) I interviewed in China, one can see the overall patterns. The 9 foreign ones, with one exception, have increased the size of their investments in China since their inception and have focused on commercial technology enterprises. The one exception was really more of a corporatized angel investor because a wealthy Hong Kong businessman founded the firm with his own private funds. The founder decided to pull back on investing in China and concentrate on Silicon Valley. By that firm's own executives' estimation, the firm suffered from a lack of the requisite skills given that a wealthy tycoon rather than an experienced venture capitalist led it. Thus, this firm was ill equipped to act as a lead on investments, which it tried to do in China, and was better suited to tag along behind experienced VCs, its strategy in the US (Interviews 99; 179; 253). In contrast, among the domestic VCs, Legend Capital was the only firm that eschewed investing in state-connected firms concentrating on state patronage. The other six domestic VCs either concentrated on state favored firms or were simply not investing in entrepreneurial ventures at all.

The failures of most domestic VCs to fund commercially viable firms suggests that domestic venture funds will not soon displace foreign venture capitalists as in funding China's technology entrepreneurship. However, we must still ask ourselves whether there are other alternatives to the hybrid-led development.

2. Domestic Alternatives to Hybrid-led Development?

There are two main potential domestic alternatives to hybrid-led development. One would be the reform of the state banking system into a financial system with much greater efficiency in the allocation of credit. The other would be the rise of a private domestic banking system alongside of the state one that would push the state system to reform or at least displace foreign venture funds by providing domestic sources of capital for technology entrepreneurs. Neither of these alternatives are likely to come to pass in the near to medium term.

The state financial system essentially keeps China's domestic savings from flowing to dynamic entrepreneurs who currently create the foreign-invested China-based firms. Sustaining the state financial system is the well-documented political imperative to support asset-destroying firms in order to avoid the short-term economic pain and concomitant large political costs of pulling the plug on such firms. These problems are exacerbated by the many different government organizations that have access to funds in the state banking system without any responsibility for them (OECD 2002; Tenev *et al* 2002; Lardy 2002; Wu Jing-lian 2004; Li Jian-ge 2004). This asset destruction is supported by the massive savings that the Chinese people shovel into the state banking system for the lack of alternative legal investment options.

While some had hoped that centralization of funds would improve the system by preventing various state agencies from misusing funds[185], the evidence suggests that to the extent that the centralization embarked upon in the later years of the Jiang Zemin era succeeded in wresting control of funds from local governments, it did not actually ameliorate the efficient use of funds. Rather, the central government had its own political pet projects upon which it lavished state funds in an equally inefficient manner (V. Shih 2004). Furthermore, one Chinese academic who has served as an advisor to local governments in the dynamic Pearl and Yangtze River Deltas confirmed that local governments still have many informal mechanisms to bring pressure to bear on local bank branches to lend to locally favored projects despite the strenuous attempts to reign in credit in the past year (March 2005 informal interview; discussion with Victor Shih).

With political motivations aligned against change and China's prodigious savers docilely channeling most of their funds into the state banking due to the lack of viable legal alternatives, one could expect little to change in state-run financial system. State-favored firms would continue to consume assets and worthy entrepreneurs without the right connections would still be left out in the cold. There appears to be a potential crack in the system. The potential fissure recognized by one of China's foremost economists, Wu Jing-lian, and many others is the entrance of foreign banks (mandated by China's WTO accession agreement) into the domestic market in 2006 that ends the monopoly of the state banks on deposits. As Wu Jing-lian (CJ, August 5, 2004: 40), echoing many others, puts it, "The only reason China's low efficiency growth is maintained, under the

[185] See for example, Melloan (1998) and Hajari (1998).

context of high savings, is due to the state monopoly on the banking system and the control of the exchange rate. The minute either of these conditions no longer holds, the financial system's every kind of failing and their resulting black holes of capital will manifest themselves." With foreign banks entry into the domestic banking system, Chinese funds could go directly to Chinese bank accounts in foreign-owned banks and then be lent back to Chinese entrepreneurs instead of round tripping out and back into China. Even if the foreign banks decided to lend only to those firms that pursued a hybrid strategy in order to ensure their ability to retrieve their returns, the pressure placed on the domestic state banks to pursue profits instead of politics could cause the state banking system to bite the bullet and reform. Of course, the implosion of the state banking system would also be a distinct possibility in the wake of the entry of foreign banks.

Neither of these routes to reform is likely to happen because there is an important caveat to these WTO-driven reform scenarios. These scenarios assume that the foreign banks will actually be allowed to operate in the liberalized coastal areas designated in China's 2001 WTO accession agreement. This is not likely to happen for several reasons. First and foremost, China's leaders do hear and heed the warnings of Wu Jing-lian and others. Wu after all is a member of the Development Research Center, the think tank attached to China's highest executive organ, the State Council. With such dire warnings, the leadership is not likely to allow the foreign banks to operate freely since it may bring down China's financial house of cards. On top of this, foreign banks have found regulations curtailing their operations even in those areas of China's banking system supposedly already open to foreigners, such as banking in foreign currencies.

Most likely, the Chinese government wishes to comply with the letter of the WTO without actually implementing truly effective liberalization. In any case, the regulatory burden on foreign firms has been so heavy that even prior to further liberalization, foreign banks are withdrawing from the already nominally liberalized foreign currency banking market (EIU *Country Finance China* 2003: 16-17; Fan Jian-jun 2004). The foreign banks' share of this market in China has halved from 15 % in 2001 to 7.4% in 2002 and the total assets foreign banks own in China have fallen from 2% of the assets held by the banking sector in 2001 to 1.1% in 2003 (Fan Jian-jun 2004).

Another economist of the State Council's Development Research Center, Fan Jian-jun, expands on these regulatory arguments about why the big bad wolves of foreign banking, as he dubs them in the title of his report, are not really that scary after all. He argues that excessive regulations make the competitive advantages of the foreign banks ineffective. Instead of pushing their domestic competitors to reform or perish, the foreign banks themselves will find that China is an inhospitable clime (*shui tu bu fu*) for their type of operations. These regulations are even more burdensome for foreign banks than domestic ones because the foreign banks have to comply with the 1994 Foreign Financial Institutions Management Regulations in addition to all domestic regulations. He does not say that these excessive regulations probably keep foreign banks out by design rather than by accident, but all the political incentives point in that direction.

One of the most critical regulations is the control of interest rates by the state. The state has been controlling the interest terms of loans, and the interest caps make it difficult for foreign banks to use their superior ability to monitor risk to their advantage because they are constrained from charging risky borrowers more interest. Thus, they will have to severely restrict their scope to the few creditworthy and safe borrowers in China. In terms of banking deposits, the regulations on interest rates will also restrict the ability of foreign banks to offer a variety of deposit mechanisms and interest rates to attract different types of savers. The ability of foreign banks to offer a wide variety of investment products for depositors is precisely another inherent strength of the foreign banks. Thus, the regulations on interest rates cut the competitive legs out from under the foreign banks.

Fan also points out that the foreign banks have no guarantor whereas the domestic state banks have the state always willing to bail them out. Thus, the state banks will be able to offer overly attractive terms that make no economic sense. Instead of all the domestic savers and borrowers moving to foreign banks, the foreign banks will be unable to attract nearly anyone to lend to or borrow from them given their market-dictated but less attractive terms. In light of what was said above about controls on interest rates, this argument on guarantees makes no sense unless one considers the effective rather than nominal interest rates. Firms can borrow from state banks knowing that they will not have to pay them back with the state supporting the whole system whereas borrowers from foreign banks presumably borrow assuming that they will have to pay back the face value of the interest. Thus, foreign banks will not attract borrowers because they offer effectively higher interest rates and will not attract depositors because they do not have the backing of the state. If there were no capital controls, foreign banks could easily bring in money to reassure local depositors that bank runs would be stopped. With the continuation of capital controls (there are no international agreements to end China's capital controls and even the IMF has begun to think they are necessary for the near-to-mid-term—see Prasad *et al* 2005 IMF Policy Discussion Paper) for the foreseeable future, foreign banks cannot take money out of China at will. The result is that foreign banks would have to bring in money in advance of any bank run and keeping this money in China waiting around for such an event would be prohibitively expensive given all the excessive regulation. If they do it, they will have one more cost dampening their competitiveness. If they do not do it, their credibility among local savers will be weak.

Under these conditions, the foreign banks could not even effectively serve the underserved private entrepreneurs neglected by the state banking system. With few depositors and the burden of regulation of interest rates, it would be hard for foreign banks to lend extensively to the many private entrepreneurs who are underserved in the current system. To serve many of them, the foreign banks would have to bring in money from abroad, something they would be reluctant to do given China's capital controls. With the interest regulations, the foreign banks would be reluctant to serve any but the least risky for an additional reason beyond risk management under a capped interest rate. The private firms underserved by the state have not had the opportunity to build up a large amount of tangible assets precisely because they have severe capital constraints. Firms with few tangible assets are always considered higher risk because they can practice strategic default on creditors i.e. borrowers can credibly threaten to default because the creditors will get close to nothing if they do.[186] Thus, the very neglect by the state banking system results in the lack of accumulation of tangible assets by private firms. This lack of tangible assets in turn affects their ability to obtain credit in the context of caps on interest rates because no one wants to lend to what are perceived to be

[186] I would like to thank Tony Marciano of the Sloan School of Business for this insight.

high-risk borrowers at low rates of interest. In effect, what the state banking system has done is make all neglected firms look higher risk than they actually are.

What about the possibility of the private, relatively efficient domestic financial institutions displacing the formal state network? The likelihood of this happening barring a major overhaul of the state banking system is unlikely. Competitive foreign banks are hard pressed to compete against the state banking system as shown above, but domestic firms not tied to the state would face an even harder situation in trying to build up a banking business in competition with state-financed banks. The few nominally privately managed banks, such as Minsheng, are effectively linked to the state.[187]

There are informal finance mechanisms in China, but they are generally local and small-scale in nature so they do not generally fund major industrial enterprises. Furthermore, they are not in the business of funding technology-intensive enterprises or other high risk, low tangible asset businesses (K. Tsai 2002; IFC 2000). In this respect, China is not very different from Taiwan where informal finance flourished, but did not make investments in technology-intensive firms (Amsden and Chu 2003; Mathews and Cho 2000; Fuller 2002).

Could informal domestic financial mechanisms displace foreign VCs in funding entrepreneurial finance? Empirically, there is little evidence that domestic technology firms of whatever variety have access to much informal finance. Of the 80 domestic firms interviewed, only two that relied on informal financial mechanisms gathered enough capital to pursue serious technological activities. In each case, the founders of these firms received funds from friends. While there is nothing wrong with using one's personal contacts as a source of funds, it does suggest that the institutionalization of

[187] Correspondence with Victor Shih, April 2005.

informal finance is very limited. Without such institutionalization, those with capital are limited to lending to their circle of acquaintances and this limits the scope of investment and entrepreneurial activity. Up to the present, it appears unlikely that such personal connections will be able to offer the scope and quantity of investment that the foreign VCs offer. At best, they will be a supplement to the foreign VCs.

3. The Broader Applicability of the Global Hybrid Model

Even though the evidence above suggests that China will sustain its hybrid-led model of development for some time to come, does China's peculiar path to development offer a model to be emulated by other developing countries? While one should always be conscious of the dangers of what Peter Evans (Evans 2004) calls "institutional monocropping," the practice of imposing idealized standard blueprints on the Global South, one should also try to learn what successful practices in one developing country might have to offer to others. The global hybrid model offers large potential benefits for two sets of countries: those countries with existing transnational technological communities and those with potential for such communities.

Before examining these two sets of countries in detail, one other criterion must be established. Those developing countries that have been able to find a successful developmental policy that eschews reliance on foreign capital are unlikely to benefit from adopting a hybrid-led model. All else being equal, retaining all the returns on domestic investment at home (i.e. few payments of economic rents to foreign sources of capital) is beneficial to healthy sustainable development. Japan in the 1950s and 1960s or Taiwan until the present time represent superior models of development to China's global hybrid-model because they captured virtually all the economic rents from their domestic investment and growth. Capturing these rents allowed them to plow even more funds back into developing the economy. Yet, as discussed in Chapter Two, most developing countries do not seem to have the institutional capacities to marshal and invest domestic capital as Japan, Korea and Taiwan did in their respective heydays. For many in this much larger group of developing countries, trying to mimic Japan or Taiwan would probably cause as many developmental problems as it solved (M. Khan 2000). Moreover, it would cause them to miss the potential institutional upside of foreign investment.

India is the developing country with the largest transnational technology communities other than China. One could object that at least India does not need to mimic China's reliance on foreign finance due to its healthy domestic financial sector. Indeed, a number of scholars have pointed out that India's financial sector (Khanna and Huang 2003; Huang 2003) and its legal system (discussions with Martin Kenney and Adam Segal) are more conducive to fostering domestic technology activities than China's. However, my own interviews with foreign venture capitalists (Interview 265; 272) with some exposure to India and the work of Kenney and Dossani (2002) suggest that even India's institutional infrastructure for entrepreneurship in terms of finance and law is incomplete. Thus, foreign VCs still play a significant role in the industry and represent as much as two-thirds of the total venture investment in India (Kenney and Dossani 2002). While the large presence of foreign VCs in India suggests that India has not been closed to such investments, even in India's high-technology sector, the "regulation raj" has made it somewhat difficult to foreign firms to invest (J. Johnson

2005). Thus, India could arguably benefit from further opening to foreign investment in conjunction with the renewed interest of expatriate Indian technologists in setting up businesses back home. Indeed, the Indian government has precisely been attempting to open up further to foreign investment to spur development (J. Johnson 2005).

India is not alone in having a large expatriate technology community. Russia graduates as many engineers per year as India and many of them are making their way abroad. I have encountered them not only in US centers of innovation, but even in Taiwan's technology cluster, Hsinchu. Institutionally, post-socialist Russia is regarded as falling far from the ideal of financial transparency and corporate governance.[188] Even those who defend Russia as performing far better than its many international critics claim, concede that a few oligarchs with political connections dominate Russia's business world (Shleifer and Treisman 2004). Given this institutional background, it is not hard to see that Russia too might be able to benefit from local and expatriate Russian entrepreneurs setting up technology firms that draw upon the financial institutions of the advanced countries rather than the home country.

There are more developing countries training large populations of technologists than just India, Russia and China and they are not necessarily the countries that usually come to mind when thinking about technology talent. Mexico and Poland are both in the global top ten in terms of training engineers (AeA 2005). Even Armenia has a cluster of talented computer scientists and electrical engineers that has begun to draw investment from Silicon Valley (Grimes, WSJ April 2, 2004). Whether or not these countries have large communities of technologists already abroad, they have the potential to create such

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[188] See for example the recent concerns about the continued influence of the oligarchs in Russia's economy, Neil Buckley "With his eye on keeping control, Putin misses a moment for economic reform," *Financial Times*, April 15, 2005.

communities given their existing pool of technological talent. The existence of transnational technology communities is of course only half the equation. The other half is the use of foreign financial institutions. If these countries have relatively inefficient financial sectors, then using foreign financial institutions in combination with entrepreneurs of the particular country's transnational technology network offers great opportunities for development.

One could even speculate that perhaps technologists from the former Soviet block could create something akin to the ethnic Chinese transnational community. For the ethnic Chinese technology community encompasses groups hailing from distinctive and separate countries, but they also have a shared ethnicity. Likewise, Russian or Slavic language speakers more broadly hailing from the former Soviet bloc may be able to form a similar transnational community despite their different national identities. The potential geographic scope of impact would not then be limited to just Russia or Poland or Armenia alone and would aggregate the power of technologists hailing from disparate parts of the former Soviet bloc.

The global hybrid model can also be fruitfully applied to countries that have not yet produced large communities of technologists but have some potential to better utilize the technologists they have produced. The hybrid-led path offers insights about how to treat such technologists as a national resource. For example, there is the cautionary tale of Singapore. Historically, Singapore has supported sending students abroad to earn advanced science and engineering degrees, but has also insisted that they return to Singapore on completion of their degrees. This policy has prevented Singapore from taking advantage of the ethnic Chinese transnational community despite the country being ethnic Chinese-dominated and very friendly to foreign-investment (BGS 2001).

As a bellwether for policy in Southeast Asia, Singapore's example has been followed by other ASEAN members, such as Thailand. Thailand currently also has a policy of bringing back scientists and engineers upon completion of their degrees[189] and the financial system is wracked with inefficiencies (Doner and Ramsay 2000; Rock 2000). Thus, it has ample opportunity to benefit from using foreign finance and to encourage a transnational technology community to develop if the government changes its policy towards students abroad.

Southeast Asia is not alone in mismanaging its talent because of fears of a brain drain. Indeed, the continued fears of many developing countries[190] about potential brain drains to the developing world, echoing fears expressed by China, Taiwan and Korea earlier, may be misguided. These brain drains can be transformed into brain trusts that bring technology from abroad back into the local economy. Even countries without large populations of engineers, such as Thailand, can still benefit from better utilization of the engineering talent they do have.

Admittedly, the hybrid-led route still leaves some parts of the developing world out in the cold. Obviously, those many developing countries with a very low level of educational attainment unfortunately will have few opportunities to take advantage of the hybrid-led model of development. This acknowledgement of the limits of the hybrid-led strategy does not negate the fact that many nations could benefit from changing policies to allow hybrids opportunities to contribute to their economic development.

[189] I would like to thank Apiwat Ratanawaraha for pointing out the existence of these Thai government policies regarding technologists.

[190] For these concerns in Latin America, see Solimano and Pollack 2004.

The task of development has never been easy. Globalization as currently constructed probably adds to those difficulties. The critics of the Washington Consensus are correct in not wanting to entrust development to MNCs, but even in this globalized world, there are new ties that can bind nominally foreign firms to the development projects of various host countries. Even as globalization constrains some of the old developmental paths, new opportunities have arisen in the form of the hybrid FIEs. We should seize these opportunities.

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