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Shin-Horng Chen

Pei-chang Pam Wen

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Chen Shin-Horng and Wen Pei-chang Pam

I. Introduction

The last few decades have witnessed the upsurge of East Asia as a major manufacturing base within the developing world, initially as a result of the "catching-up" of the Asian "Newly Industrializing Countries" (NICs), and more recently due to the emergence of newly developing economies within the region, and of China in particular. These developments have much to do with both indigenous innovation and the relocation of the value chain activities of multinational corporations (MNCs). Lall elaborates on these two points, arguing that the performance of countries like Taiwan and Korea may be attributed more to the former, while other less-advanced economies within the region may be gaining more momentum from the latter.[1]

However, certain news reports released in Taiwan seem to suggest an emerging structural shift in the economic geography of innovation across the Taiwan Strait. For example, Ford Taiwan announced in December 2004 that in the next few years, their corporate mandate on business operations across the Taiwan Strait would shift towards China and away from Taiwan. In November 2003, a Taiwanese newspaper reported that the head of the Sun's Research and Development (R&D) lab in Beijing had been sent to Taiwan to evaluate the feasibility of establishing an R&D branch in Taiwan. More recently, it was reported in April 2006 that the first Chinese-design car model for GM would be introduced to and made in Taiwan.[2]

All of these developments give rise to important questions concerning a shift in the balance of power across the strait in terms of R&D and innovation. Taiwan is evidently ahead of China in economic development, but is it equally true in terms of R&D and innovation? China is a latecomer, but can we project its developmental trajectory according to Taiwan's experience? Is China just a "low-cost manufacturing powerhouse"?

As a matter of fact, some researchers in the Western world have begun to address such questions as: Can China (and India) redefine the technological world order? Will China become a regional, if not global, technological power? The emergence of China, going hand in hand with the trend toward globalization, would arguably reshape the global technological landscape.

Against this background, the essay sets out to examine the economic impact of globalization and the rise of China from the perspective of Taiwanese high-technology industy, and information technology (IT) in particular. As a country with geographical and cultural proximity and close economic ties with China, and widely known for its high-technology industry, Taiwan's experience with China may help to shed light on what the rise of China economically, together with the trend toward globalization, may mean to its neighboring countries in the region and even to the world economy.

II. Globalization and Knowledge-Based Innovation

The trend toward globalization involves a process of increasing disintegration of production around the globe, and even disintegration of innovation capabilities,[3] with the result that some, if not many, of the indigenous firms and/or industrial clusters in the developing world are nowadays able to shoulder important functions that used to be undertaken by their counterparts in the developed world. For one thing, outsourcing and offshoring, not only in manual but also knowledge work, have become widely-adopted practices in quite a number of industries as a means of enabling brand marketers to remain cost-competitive, which arguably would lead to further disintegration of innovation capabilities on the global scale.

Product innovation involves an assortment of knowledge related to various stages of the value chain. Knowledge applied to manufacturing, marketing, and customer services is complementary to the knowledge used in product innovation. Vertical integration of the innovation

function in the value chain is only justified, however, if internalization is the best way to acquire the relevant knowledge, and this is not often the case. Since product innovations address the needs of customers, the type of knowledge most valuable to product innovation is that which is obtained from interacting with customers; in a word, marketing. Therefore, product innovation combined with marketing may be the optimal mix of services offered by a firm. In the traditional industries, such as footwear and apparel, Nike, Reebok, and Calvin Klein are typical examples of this innovator-marketer combination. This trend towards the emergence of innovation and marketing as the core functions of a firm is even taking place in the high-technology industries. In the IT industry, for example, integrated device makers (IDMs), including Apple, HP, Dell, and Motorola, have partitioned themselves from manufacturing, which is now delegated to contractors.

In addition, in many cases, innovations involve technical systems that are inherently large in scale, comprising a set of jointly-consumed interdependent products.[4] On the basis of the network effects and product compatibility, successful innovations for technical systems entail intensive interfaces between multiple actors with different knowledge and skills bases, referred to as "innovation networks." By implication, not only does such an innovation often result from the collective efforts of inter-related firms, but it also demonstrates that the value chain does not need to be completely internalized within individual firms. In many cases, therefore, industrial competition takes place between rival technological and production networks that contain a multiplicity of differentiated firms, rather than between vertically integrated oligopolies.

We also have to take into account the nature of knowledge-based innovation in order to better undertand the changing dynamics of the evolution of the international innovation landscape. Various kinds of knowledge differ in their degree of codification,[5] path-dependence,[6] and complexity. As a result, certain kinds of knowledge-based innovation will allow for the possibility of leapfrogging, as opposed to incremental changes, as well as an international division of labor. For example, with regard to the degree of codification, knowledge can be broadly classified into articulated (explicit) and tacit (implicit) knowledge. One of the benefits of information technology is that articulated knowledge is easily and widely transferable.[7] In addition, codification of knowledge may also facilitate the possibility of modularization. Conversely, tacit knowledge is socially or organizationally embedded

and cannot be easily transfered through formal channels of information but may be transfered by means of networking.[8] Thanks to codification and modularization of certain types of knowledge, IT has made it possible for R&D to be conducted in an internationally coordinated way, giving rise to a global R&D network of firms. This seems particularly true for software-related R&D, which has become more receptive to modularization.

More importantly, where a technology is less path-dependent, the firm or industry concerned may have a better chance to bypass certain stages of the technological trajectory, or to jump straight into a new generation of technology, or even to surpass the previously dominant firm to become a new leader (as in Schumpeter's widely known "creative destruction") because of disruptive technological innovation. A typical example at issue is the new industrial standard, TD-SCDMA, for third-generation mobile communications (3G), which, despite the low mobile phone penetration rate on the Chinese mainland, has been proposed by China and accepted by the International Telecommunications Union (ITU). Another example lies in the area of software, because new learners can enter directly and learn the new version (or generation) of software without the need to go through previous versions.

In our opinion, for a country to leapfrog, several conditions must be met. Firstly, the country needs to have a sound science base and/or vigorous creativity, or more broadly distinct intangible assets, based on which the country may be able to make breakthoughs in emerging technologies. Secondly, some proportion of the country's population should be able to and also wish to consume state-of-the-art products so that market demand in the country may serve to drive new technological innovation. The third, though not necessary, condition is that the relevant industry in the country should be well-equipped with capabilities along the value chain, based on which new technological innovation at the indigenous initiative level can be commercialized.

The above discussions tend to imply that given the possiblity of leapfrogging, one cannot project China's developmental path based merely on the previous trajectory of Taiwan's own experience.

III. Taiwanese IT Industry's Pathway to Innovation and Industrial Migration

As a small country, some aspects of Taiwan's performance in technological innovation are impressive. According to surveys by prestigious international organizations, such as WEF and IMD, Taiwan has often enjoyed impressive international rankings on several fronts of technological innovation as well as economic performance. In particular, in terms of U.S. patents granted, Taiwan has ranked fourth for six years in a row (1999–2004), second only to the U.S., Japan, and Germany. In this regard, the electrical and electronic machinery, equipment, and supplies sector outnumbers all other product fields, registering an increase from 2,013 to 7,644 in the second half of the 1990s. Similarly, Taiwan claimed 1,669 patents granted in Japan in 2002, ranking only behind Japan, the U.S., and Germany. All these taken together may imply that Taiwan's industries, the IT sector in particular, have moved from foreign technology to indigenous innovation.[9] However, in sharp contrast, Taiwan has been faced with a huge and increasing deficit in technological trade. In other words, Taiwan's achievement in international patenting is not proportional to its trade balance in technology.

The so-called "innovation paradox" portrayed above may be attributed to some characteristic features of Taiwan's industrial and S&T system. First of all, Taiwanese high-tech firms are generally characterized by vertical disintegration and are deeply involved in OEM contacts for brand marketers; thus, individual firms specialize in a specific industrial and technological segment and may tend to focus their R&D efforts on incremental technological change in relation to a specific technological trajectory, leading to the rapid proliferation of patents. Secondly, following closely from this, Taiwan's export-oriented high-tech firms tend to pursue technological innovation on the pathway led by the architectural design created by leading brand marketers. As a result, the more their production volume expands, the more royalties they pay to the brand marketers. Thirdly, while excellent in quantitative terms, Taiwan's international patents are generally not so impressive in qualitative terms. For example, the U.S. utilities patents held by Taiwanese usually prove to be quite low in terms of their "science linkages" by international standards. Over the period 1995–1999, Taiwan's utilities patents granted in the U.S. registered a science linkage index of 0.18, which was far below the international average of 1.97. In particular, the indexes for two of Taiwan's mainstream high-tech

fields (computers and peripherals, and semiconductors and electronics) were merely around 0.26 and 0.22 respectively, and again far below the international average (1.37 and 1.21 respectively).[10] By referring to these indexes, it can be argued that Taiwan's U.S. patents are generally not so knowledge-intensive, let alone influential and valuable, as the so-called international industrial standards. Fourthly, the service industry currently accounts for more than 70 percent of Taiwan's GDP, but suffers a huge deficit in trade in services, especially in terms of the mode of commercial presence.[11] This may in part contribute to the size of Taiwan's trade balances in technology, especially in regard to international franchises in services.

All these reasons behind Taiwan's innovation paradox have to do with some of the characteristic features of Taiwan's IT industry. From its inception, the development of Taiwan's IT industry was driven by a strategy of vertical disintegration, which in turn facilitated the formation of local and cross-border linkages as the momentum for industrial expansion. One aspect of globalization over the last few decades has been the increasing disintegration of capabilities in production, and even innovation, across nations.[12] Driven by this disintegration, the outreach of MNCs has taken the form of not only direct investment, but has also increasingly involved the outsourcing of production and even knowledge. As a result, boundaries between firms have become blurred on an international scale,[13] which has eroded the basis for the formation of traditional oligopolies. Instead, industrial rivalry now tends to occur amongst industrial networks that are comprised of a multiplicity of firms linked by different knowledge bases. Although the driving seat is occupied mainly by well-established firms in the advanced nations of the world, firms in countries such as Taiwan also have a role to play.

In fact, ever since the 1980s, the IT industry has increasingly become the paramount engine of economic growth in Taiwan. On a world-wide scale, Taiwan currently ranks as the fourth largest producer of information hardware, the fourth in the case of IC, and the third in the optical electronics area. As to the communications sector, despite a less impressive world-wide ranking, Taiwan has recently experienced an explosive growth in mobile communications. With particular regard to the information hardware industry, a number of Taiwanese-made products have enjoyed a significant global market share. What underlies this are the well-regarded production and design capabilities of

the Taiwanese IT producers, which in turn have made Taiwan a major source of contract work for prominent international IT companies.

Taiwan's characteristic local industrial clusters and their role in the growth of the PC industry in the economy have been well scrutinized,[14] but local agglomeration alone can no longer adequately account for the dynamics of Taiwan's PC industry, because while global production networks have come to the fore, the way in which the global PC industry is organized has changed. An important milestone in the development of Taiwan's PC industry in this regard was the outreach achieved by local firms, beginning in the late 1980s. Their outward investment was initially directed towards Southeast Asia, but more recently towards China and elsewhere in the world. The offshore production of Taiwan-based PC firms right now significantly outweighs their domestic production.

With the PC industry's drive to reduce production costs, lead-time to market, and inventory costs came a profound change in the manufacturing system and inter-firm competition. It became commonplace for components to be sourced from a global network of suppliers and for final assembly to be done within the end-market.[15] Specifically, major brand marketers moved to adopt outsourcing and order-based production, which greatly rationalized their global supply chain, and hence altered their contractual relationships with Taiwan's firms.

Such contractual arrangements with global leaders in the PC industry have prompted Taiwan's IT firms to upgrade their position within the global production system. Taiwan's firms began to shoulder the essential functions of coordinating the global supply chain for their OEM customers. For example, under its new business model, HP outsourced every element of the value chain except marketing to Taiwanese subcontractors, and imposed a "98-3" operational formula on subcontractors, requiring them to collect 98% of the components and parts needed for product within three days of the order and to ship the product within six days of receipt of the order. In doing so, a number of brand marketers completely handed over inventory costs to these subcontractors, who were also required to produce and deliver subsystem products on tight schedules and in tune with the vagaries of market demand. The Taiwanese firms had to ensure that everything was synchronized up and down the supply chain. In order to do this, they had to participate in cross-border supply-chain management, logistics operations, and after-sales services. In addition, to coordinate all of

these, they had to form a fast-response global production and logistics network.[16]

As part of this process, recent years have witnessed a new phase of cross-Strait industrial interaction. The newly emerging geographical concentration of investment in the Long River Delta by Taiwan-based firms, notably in the broadly-defined IT industry, suggests that Taiwan's outward investment in China is becoming more technology-intensive and capital-intensive. Indeed, in recent years, the electronics and electrical appliances industry has accounted for approximately 40% of Taiwan's annual outward investment in China. More importantly, China has become an increasingly important offshore production site for Taiwan-based PC firms, having significantly outweighed the latter's domestic production since 2002.

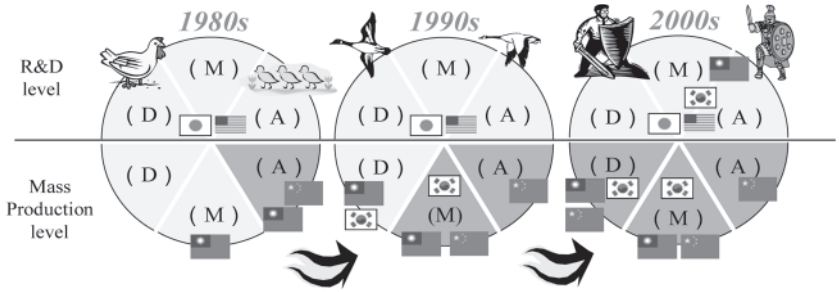
Along with this process, there is an evolution of the industrial landscape in the global IT industry, or more specifically the PC and IC sub-sectors, as illustrated by Figure 1. In the 1980s when the industry was dominated by vertically integrated firms in advanced economies like the United States and Japan, their outward investment in Taiwan triggered the entry of Taiwan into the value chain at the mass-production level. In particular, the local firms were able to take up the vacuum caused by the withdrawal of foreign firms during the mid-1980s, which then laid the foundation for the formation of the local industrial clusters. The 1990s witnessed the emergence of such economies as Taiwan and South Korea as the major players in subcontract work for brand marketers in the advanced economies, partly because of the rising popularity of outsourcing. Along with this development, OEM, which used to be the major business of the IT firms in Taiwan and South Korea, has gradually given way to ODM and, to a lesser degree, to production under brand names, thus facilitating their involvement in the design value chain at the mass-production level. Meanwhile, China's "open door" policy and the outreach of Taiwan's IT firms fuelled China's rising significance in the assembly and manufacturing of IT products. Ever since the turn of the new millennium, the evolution has gone further to realize the involvement in R&D of the IT firms in both Taiwan and South Korea. In the meantime, China's coverage of the value chain at the mass-production level has become more comprehensive. There are even signs that China is increasingly playing a non-negotiable role in R&D, a point we shall return to later.

In fact, elsewhere, based upon the result of a survey, we have shown that China has become the major target for Taiwanese IT firms' off-

shore R&D, certainly in quantative, though not necessarily qualitative, terms.[17] Based upon firm-level interviews conducted on both sides of the Taiwan Strait, it became possible to identify certain patterns of cross-Strait R&D deployment by some of the Taiwan-based IT firms. First of all, while the Taiwan-based firms' production lines are concentrated in China (as well as some other countries), product development is undertaken in Taiwan, and manufacturing-related R&D and engineering support are performed in China. This often entails the de-linking of R&D and manufacturing. Secondly, some Taiwanese firms outsource their software development services to China, partly because of the leapfrogging potential of software. The third type of portfolio involves a tendency for some Taiwanese firms to perform (mostly problem-solving) basic research in China to take advantage of the strength of the local science base, which often entails collaboration with universities and/or research institutes. The fourth type has some Taiwanese firms performing their upstream (core) R&D (or R&D for products at the development stage) within Taiwan, while their subsidiaries in China carry out downstream (non-core) R&D (or R&D for products at the mature stage). Finally, there are also those cases in which Taiwanese firms perform R&D in China for the domestic market, while in Taiwan for the international market. In essence, it appears that the cross-Strait production and innovation network is evolving alongside its global counterpart and hence is becoming more complex.

On balance, global production networks in the IT industry have come to the fore. Characteristic features of the global production networks include cross-border modularized production and speedy patchy production, instead of production under one roof and mass production as before (see Figure 1). Therefore, from the standpoint of Taiwan's IT producers, the triangular linkages involving Taiwan (Hsinchu), China (the Long River Delta), and the U.S.A. (Silicon Valley) may mean much more to their prosperity than does the local industrial cluster in Taiwan.

The IC sector can be considered another driver of Taiwan's success in the IT industry. The global IC industry is currently dominated by firms from the U.S., Japan, Korea, and Taiwan, with their worldwide rankings shown in this order. Of interest is the fact that the industry in Taiwan differs from that in the other three in several significant ways. Unlike Korea, which specializes in the production of dynamic random access memory (DRAM), Taiwan produces a much wider variety of IC chips, and dominates in foundry services, capturing around 70% of



	R&D level	Mass production level
Design(D)	Design method / CAD / IP	Layout, Prototype, Theoretic test, etc.
Manufacturing(M)	Development of new process, new equipment, new materials	Front-end: Fab, mother-board, etc.
Assembly(A)	Application of new packaging, modular, materials, etc.	Back-end: Packaging, Assembly, etc.

Source: Nikkei Micro Device, quoted in MIC ITIS Project August 2002.

Figure 1: The Evolution of the Global IT Production and Innovation Networks.

the global market share. Additionally, in contrast to the vertically integrated conglomerates that dominate the industry in Korea and Japan, Taiwan's IC industry consists of many small firms specializing in a narrow range of the value chain, such as IC design, mask production, foundry service, packing, and testing. In a sense, Taiwan's IC industry is organized as an industrial network with a strong connection to Silicon Valley, the worldwide center of the IC market and IC technology.

Significantly, the development of Taiwan's IC industry has been driven by organizational innovation, with foundry services created as a market niche to specialize in production for external customers. By disintegrating the IC value chain, the emergence of foundry services in Taiwan facilitated the proliferation of small- and medium-sized firms engaged in other market segments, such as IC design, testing, and packaging, which gave rise to a balanced and vertically disintegrated industrial structure. In particular, fabless IC design houses proliferated in Taiwan in part because access to external fabrication capacity lowered the barriers to entering the IC design market. In addition, the concentration of IC and computer-related firms in the Hsin-Chu Science-Based Industrial Park generated agglomeration effects that

allowed those firms to exploit the benefits of proximity and outsourcing. Therefore, even though they specialize in one segment of the value chain or another, IC firms in Taiwan are networked by social and business connections.

Moreover, Taiwan's IC industry is closely connected with the industry center in Silicon Valley. Taiwan's strength lies in its foundry services, which depend on substantial investment in fabrication capacity. The U.S. IC firms, on the other hand, tend to concentrate on R&D, design, and marketing functions, which are backed up by access to Taiwan's foundry service capacity. In fact, more than half of Taiwan's foundry capacity in 2000 was used to serve U.S. customers, and most of the top ten fabless makers in the U.S. have been clients of Taiwan's foundries. TSMC, the world's largest foundry service provider, shares its resources and information with its customers, considering them partners. This sharing of resources and information not only facilitates the development of close long-run relationships with customers, but also helps reduce the uncertainty on both sides over technology development.

Another facet of the connection between the IC industry in Taiwan and in the U.S. is the intensive interchange between specialists in both economies. Underlying this exchange are Taiwanese and Chinese expatriates, who have played important roles in establishing the trans-Pacific social and business networks that have proved crucial in connecting Taiwan's production system with advanced market knowledge and technology.[18] Apart from the ethnic social network, the fact that the IC industrial systems in both Taiwan and Silicon Valley are decentralized and network based facilitates the interchange. This type of industrial system encourages the pursuit of multiple technical opportunities, heavy reliance on outsourcing, and interorganizational knowledge flows.[19] The similarity in industrial structure makes networking between Silicon Valley and Hsinchu Science-Based Park, the centre of Taiwan's IC industry, much easier and more intensive.

IV. A Structural Shift of Innovation across the Taiwan Strait?

Despite the success story described above, there seems to be a trend towards a structural shift of innovation across the Taiwan Strait, which may not be favorable to Taiwan. For one thing, the outreach of Taiwanese IT firms towards China has brought about a concern over the hollowing-out of manufacturing in Taiwan. In fact, thanks in part to the

Taiwanese IT firms' outreach, China has surpassed Taiwan and more recently the U.S., becoming the top IT producer in the world. Moreover, there is increasing concern that Taiwan's IT sector has in fact been facing an era of "razor-thin profits." There is even evidence to suggest that Taiwan's IT industry is facing a bottleneck, which is characterized by the slow growth of value added, deteriorating value-added ratios, and a decrease in the industrial linkage effect, which may have something to do with the trend toward globalization and the industrial development model of the Taiwanese IT industry.[20]

More importantly, alongside the trend of R&D globalization, China has demonstrated its potential to become a regional hub for foreign direct investment in science and technology, and more specifically a focal location of MNCs' offshore R&D facilities in the region. The R&D activities of MNCs were initially geared to the developed countries, but the emphasis has more recently shifted towards the developing world.[21] For example, while two-thirds of the R&D engaged in overseas in 2000 by U.S.-based MNCs ($13.2 billion of $19.8 billion) took place in six countries, namely, the United Kingdom, Germany, Canada, Japan, France, and Sweden, certain emerging markets, mainly in Asia, have played an increasing role in U.S.-owned overseas R&D.[22] In particular, such countries as India[23] and China[24] have become high-profile host countries for MNCs' offshore R&D facilities, albeit in their late developmental stage.[25] According to a survey regarding the host countries of MNCs' offshore R&D facilties, China's ranking (in terms of the percentage of the surveyed firms with offshore R&D in a particular country) is as high as third for 2004, second only to the U.S. and U.K. The same survey also reveals that for the period 2005–2009, China would top all of the countries, becoming the hot spot of the MNCs' offshore R&D facilities worldwide.

In fact, several studies have documented a significantly rising trend of MNCs' R&D in China from the early 1990s onward.[26] High-profile examples at issue include quite a number of MNCs in the IT sector, such as IBM, Microsoft, Motorola, Intel, Nokia, etc. Data gathered by the U.S. government reveals that U.S.-based MNCs spent US $506 million on R&D in China in 2000, which was second to just Singapore and Israel in Asia (excluding Japan). Both Lieberman[27] and Moris[28] based on data gathered by the Department of Commerce, go further to show a dramatic increase in U.S.-based firms' R&D investment in China, with the ratio of R&D expenditure to gross products rising from 1.7% in 1998 to 8.1% in 1999, and further to 9.2% in 2000, significantly

increasing its rank as a host of U.S.-owned overseas R&D from 30th in 1994 to 11th in 2000.

In particular, Walsh has reported that R&D by high-tech MNCs in China seems to have evolved in three distinct stages.[29] The initial stage is described by as "exploratory and strategic partnerships" (early to mid-1990s), motivated by the primary purpose of entering the Chinese market by forming strategic alliances with local firms. As a result, the MNC's R&D at this stage can be characterized as "show R&D activity." From the mid to late1990s came the stage termed "expansion of R&D," witnessing the proliferation of MNCs' R&D facilities in China. This was mainly driven by the local IT market boom, by China's imminent accession to the WTO, and by the governmental policy encouraging China to "Go West." The third stage, from the late 1990s onward and termed a "consolidation of R&D," is marked by a more considered, strategic approach to R&D investment by MNC in China. According to Walsh, driven by increasing pressures on high-tech industry and growing global competition for international R&D, a number of MNCs are now shifting their R&D in China toward more advanced R&D activities, while consolidating their overall number of research-related programs.

It should also be noted that, to a degree, some of the MNCs in Taiwan have also invested in R&D. From the dataset provided by the Investment Commission at the MOEA, we can calculate that R&D intensity (R&D/sales) for foreign-owned subsidiaries in Taiwan's manufacturing sector has increased from 1.52% in 2002 to 1.94% in 2003; this perhaps indicates that Taiwan's mandate has significantly improved in terms of MNCs' regional or global innovation networks.

Elsewhere, the authors have been able to identify, with statistical robustness, those foreign R&D subsidiaries with a higher R&D intensity in Taiwan.[30] We find that those foreign-owned firms in Taiwan with a higher export propensity tend to be more R&D intensive. As an economy characterized by international competitiveness and export-orientation, Taiwan may be able to act as a host for some MNCs in order to capitalize on its comparative advantages to serve the international market.

Foreign-owned subsidiaries with higher R&D intensity are also characterized by a greater degree of localization in terms of their sourcing of both production materials and capital goods. To interpret this finding, one can refer to Westney's arguments that MNCs' offshore R&D units are given higher hierarchical mandates if their ties with the

local scientific and technological community are gaining strength (and probably, therefore, greater R&D intensity).[31] To put this another way, for countries such as Taiwan, "first-tier supplier advantage" can be regarded as a locational advantage capable of attracting the offshore R&D units of MNCs, which may imply that foreign-owned subsidiaries with a higher degree of localization may need to devote more effort to R&D in order to effectively interact with their local suppliers.

On top of that, the government in Taiwan has orchestrated a plan to encourage MNCs to establish R&D centers on the island. Since its implementation in 2002, this has met with some success. Currently, there are in Taiwan some 30 MNCs' R&D facilities established or promised by 27 different firms. Prominent cases include HP, IBM, Dell, Motorola, Microsoft, and Dupont. Of note is the fact that these R&D centers are mainly related to the current strength of Taiwan's industrial development, with the lion's share being focused on the broadly-defined information technology (IT) area and exhibiting a strong intention to collaborate with local firms.

Referring to a few cases of MNCs with offshore R&D facilities on both sides of the Strait, however, we find that those foreign R&D centers in Taiwan tend to be mandated as product development centers, while their counterparts in China tend to function as research labs.[32] This may have something to do with the features of Taiwan's NIS in terms of the IT industry.[33] From the perspective of the evolutionary approach to technology[34] what a firm and an economy can do—or is about to do—is linked strongly to their routines and previous bases.[35] As we discussed elsewhere,[36] it can be argued that the mainstream of Taiwan's industrial technological innovation currently lies in the central part of the "smiling curve," which ranges from incremental technological changes to defensive patents. In addition, it is generally perceived that the IT community in Taiwan undertakes more "D" than "R." The MNCs may therefore feel more comfortable in capitalizing on the strengths of Taiwan's national innovation system by establishing product development centers.

In contrast, while China is behind Taiwan on the ladder of economic development, there exists in China the possibility of leapfrogging development, which may allow a firm to bypass certain stages of the technological trajectory, or jump straight into a new generation of technology. Apart from having a large pool of R&D personnel and market potential, China's science and technology system formerly placed relatively greater emphasis on basic research, partly because of the

arms race during the Cold War period. In addition, China's economic development has come to the stage where some proportion of the Chinese population may be able to consume state-of-the-art products. This may equip China with leapfrogging potential on the demand side. Therefore, it makes sense for some of the MNCs to set up research labs in China and to conduct more advanced R&D activities,[37] although the bulk of foreign R&D in China may be related to adaptive R&D.[38]

Based upon an intensive case study, we have put forward a holistic view of possible R&D portfolios of a few flagship MNCs across the Taiwan Strait,[39] as shown in Figure 2. In essence, based on the heritage of industrialization, Taiwan has been able to capitalize on its first-tier supplier advantage as a means of attracting a few MNCs to set up their offshore R&D facilities on the island. As a result, those MNCs tend to conduct certain types of R&D in Taiwan, ranging from medium-term product/process applied development, to short-term innovation and prototype development, to significant adaptation and improvement to existing technologies. In contrast, to quite an extent, while the bulk of foreign R&D in China may be related to adaptive R&D,[40] some (if not many) of the MNCs are conducting strategic R&D in China, such as "blue sky" or basic research and medium-term product/process research.

It then comes down to the question of what such an R&D portfolio across the Strait means to the prospects of Taiwan and China respectively. To answer this question, one can refer to the well-established argument in economic geography that location does not necessarily make sense if linkages do not exist.[41] Research is the upstream part of the R&D process, while Development belongs to the downstream part. Some might hence get an impression that Research conducted by the MNCs may mean more to the host country than Development does. Such an impression can be oversimplified. Instead, we would like to argue that "D" conducted by the MNCs in Taiwan often entails close interactions with indigenous firms and hence could bring benefits to the local economy in an immediate and direct way. In contrast, with regard to "R" conducted by the MNCs in China, it has to take time—not to mention the risk involved—for results from the "R" to bear commercial fruit. However, where the "R" involves emerging technologies and/or industries, it is possible that R&D conducted in China can redefine the technological order across the Taiwan Strait, if not the world. This will become more likely if R&D conducted by MNCs in China eventually go through the commercialization process

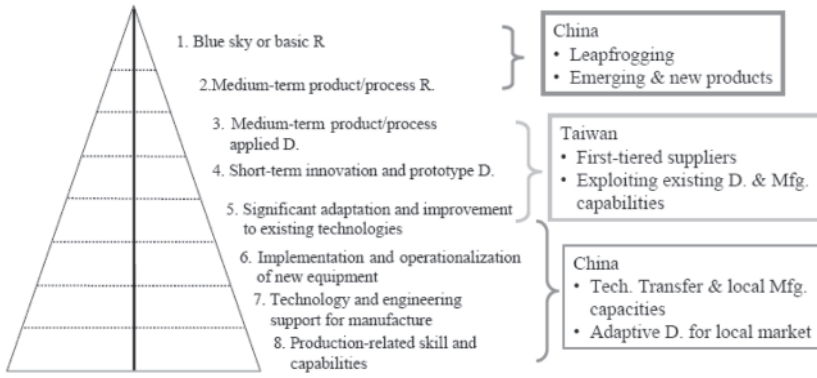


Figure 2: Possible R&D Portfolio of Flagship MNCs across the Taiwan Strait

by working together with China's indigenous value chain, giving rise to leapfrogging development in China.

In fact, China's progress in leapfrogging is not just about achievements in attracting MNCs' R&D facilities, but also concerns industrial standards and global outreach in terms of outward investment and mergers and acquisitions. Taking industrial standards as an example, it has been placed at the top of the policy agenda in China to acquire autonomous intellectual property rights by establishing its own industrial standards. Typical examples at issue include TD-SCDMA for 3G, digital TV, and Linux-based operational systems. In all these cases, China intends to explore its leapfrogging potential to eventually compete with the global leaders. It is too early to judge whether or not China will succeed in generating an influential industrial standard with commercial success, especially outside China. However, it is fair to say that through policy exercises in developing industrial standards, China has managed to substantially restructure its innovation system in a few specific sectors. For example, since TD-SCDMA has been recognized by the International Telecommunications Union as one of the industrial standards for 3G, China has managed to receive endorsement from global flagship firms like Siemens, Nortel, TI, and Philips. Together with these flagship firms, a wide spectrum of the value chain for mobile communications has already taken root in China.

V. Conclusions

Taiwanese IT firms have traditionally entered a particular product market as "fast followers" during the growth stage, with a key success

factor being the capacity to combine low-cost production in Taiwan with a rapid response to changes in markets and technology. Nowadays, however, it is far too simplistic to state that Taiwan's success in the IT industry is attributable to manufacturing muscle alone, as is the thesis on Taiwan's local industrial clustering.

On the one hand, there are grounds to suggest that Taiwan's IT sector has moved from foreign technology to indigenous innovation.[42] On the other hand, Taiwan's IT industry has gone global and become an essential part of the global production and innovation network. The latter, in particular, has much to do with the trend towards globalization and the rapid emergence of China. As a result, Taiwan's IT industry is facing a bottleneck. It is fair to say that the Taiwanese IT industry is not without R&D and innovation, but the current development model in many respects lacks value creation. In addition, the outreach of Taiwanese IT firms towards China has brought about a concern over the hollowing-out of manufacturing in Taiwan.

More importantly, the emergence of China is, in some aspects, characterized by leapfrogging, which may entail a structural shift of innovation across the Taiwan Strait. Clayton Christensen has argued that such countries as China and India may bring about "the great disruption," and "technologies emerging from these countries may have profound but unpredictable implications for the rich world's markets."[43] On the technological side, this article has shown that by taking advantage of its leapfrogging potential, China outperforms Taiwan in attracting MNCs' offshore R&D facilities, which tend to be given a higher R&D mandate. This may eventually lead to a structural shift of innovation across the Taiwan Strait.

Quite often leapfrogging is not considered relevant to Taiwan because of the seemingly plausible argument that Taiwan's domestic market is not big enough. Such an argument, however, may not hold if one takes into account an often ignored feature of industrial technological innovation. For some industries and service sectors, the outputs generated by innovative efforts can be replicated with negligible costs, implying an "out-of-proportion" phenomenon of the initial development costs in relation to replication costs for innovation. In such a case, as long as Taiwan's domestic market is large enough to allow an innovator to recover its initial development costs, leapfrogging remains possible for Taiwan. This is particularly true for sectors where innovative outputs are intangible in nature. A typical example concerns Hou Hsiao-Hsien, a famous native movie director, whose films (which are

deeply rooted in Taiwan's soil) have successfully penetrated the international market. On balance, it is necessary and feasible for Taiwan to explore its leapfrogging potential in certain niche areas, in pursuit of industrial technological innovation and national competitiveness. In this regard, the home market should serve as an "innovaion trigger," instead of a "reservoir," in case of oversupply in the international market. ◉

Notes

1. Lall 2003.
2. LaCrosse.
3. Feenstra 1998.
4. Windrum 1999.
5. Cantwell and Santangelo 1999.
6. Nelson and Winter 1982; Dosi 1982.
7. OECD 1996.
8. Cantwell and Satangelo 1999).
9. Wu, et al., 2002.
10. Lin 2001.
11. Hsueh and Tu 2004.
12. Feenstra 1998.
13. Delapierre and Mytelka 1998.
14. Hobday 1995; Kawakami 1996; Kraemer et al. 1996.
15. Angel and Engstrom 1995; Borrus and Borrus 1997.
16. Chen and Liu 2003.
17. Chen 2004.
18. Saxenian 1997; Kim and Tunzelmann 1998.
19. Sanxenian 1997.
20. Chen, Liu and Lin 2005.
21. Reddy 2000.
22. NSF 2004.
23. Reddy 2000.
24. Xue and Wang 2001; Chen 2005; Walsh 2003; UNCTAD 2005.
25. UNCTAD 2005.
26. Xue and Wang 2001; Chen et al. 2002; Walsh 2003.
27. Lieberman 2004.
28. Moris 2004.
29. Walsh 2003.
30. Liu and Chen 2005.
31. Westney 1990.

32. Chen 2006.
33. Chen 2004; 2005.
34. Nelson and Winter 1982.
35. Dosi 1982.
36. Chen et al. 2005.
37. Chen 2005.
38. Walsh 2003.
39. Chen 2005.
40. Walsh 2003.
41. For example, Castells 2000.
42. Wu, et al. 2003.
43. Clayton Christensen 2001.

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