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R&D Services and Global Production Networks: A Taiwanese Perspective

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INTRODUCTION

Within the high-technology industry, sectors such as information technology (IT) are often considered to be high value-added sectors. This can, however, be quite misleading, given that this sector is vulnerable to sharp declines in price and narrowing of profit margins, with its constituent manufacturers easily being caught up in deteriorating terms of trade. This can be particularly significant if one takes into account the formation of global production networks, with the result that manufacturing muscle alone may no longer be deemed a sustainable comparative advantage. Such a perspective highlights the importance of intangible assets and their role in the knowledge-intensification of industry.

The trend towards globalization has resulted in the reshaping of the industrial competitive landscape on a global scale, with one outcome of globalization over the past few decades having been the increasing disintegration, across nations, of production capabilities, and even innovation (Feenstra, 1998). Driven by such disintegration, the outreach of multinationals takes the form not only of direct investment, but also of the outsourcing of production, and even knowledge. As a result, industrial rivalry now tends to occur amongst industrial networks comprising of a multiplicity of firms linked up through their knowledge bases. Although well-established firms in the advanced nations – brand marketers in particular – tend to occupy the driving seat in these networks, firms in countries such as Taiwan can also play an important role.

It has been documented elsewhere by the authors (Chen and Liu, 2002a) that in response to the formation of the global production network, Taiwanese firms in the IT industry have evolved from pure manufacturers towards 'integrated service providers', shouldering such functions as supply-chain management, logistics operations and after-sales services, particularly through e-commerce applications (Chen, 2002).

The current paper aims to go further by examining the role of R&D services in the global production network in an international context. In order to do so, it will be useful, as a starting point, to touch upon the trend towards R&D internationalization and even globalization. Multinationals (MNCs) were traditionally engaged in very little overseas R&D, especially when compared to their cross-border production scales. However, it is evident that technology is becoming increasingly globalized, resulting in the proliferation of offshore R&D by MNCs (Petrella, 1989; Patel and Pavitt, 1998; OECD, 1997; Guellec et. al., 2001; Chiesa, 1996). Alongside technology transfer, technology sourcing has also become an important issue in the R&D internationalization of firms (Cantwell and Santangelo, 1999; Gerybadze and Reger, 1999) and in inter-firm partnerships (Delapierre and Mytelka, 1998). Within such a process, firms can build up their sustainable competitive advantages, based on knowledge, by leveraging and aligning both their internal and external networks on an international scale. This will arguably result in the reshaping of the structure of the global innovation system and the global technology landscape. Despite this discernible trend, the substantial body of literature on R&D internationalization remains developed country-centric, with only few exceptions (for example Reddy, 2000).

We are therefore motivated to explore, from a Taiwanese perspective, the network relationships of R&D in conjunction with the global production network. More specifically, throughout the paper there is a clear focus on the international aspects of Taiwan's national innovation system. Our aim is to determine in what ways, and to what extent, the R&D facilities of MNCs in Taiwan, and the overseas R&D of Taiwan-based firms, interact with Taiwan's indigenous innovation capabilities in the broadly-defined IT industry. We also aim to determine what they mean to the global production network.

In empirical terms, the paper draws on two of our earlier research projects. The first concerns the R&D efforts of MNCs in Taiwan, whilst the second addresses the R&D deployment, within China, of Taiwan-based firms. It is worth noting that China is very significant to this study because it has become the major host country for outward investment by Taiwanese IT firms. Although not denying the importance of indigenous innovation capabilities (Wu et. al., 2002), we will argue that driven by the emergence of the global production network, R&D services have become essential to Taiwan's economic development, which means more than simply local R&D and innovation capabilities, but in fact, the ability to leverage international R&D networks.

R&D GLOBALIZATION AND THE DEVELOPING WORLD

In the studies on R&D globalization, the bottom line appears to be that although not yet truly globalized, R&D is undergoing a process of globalization (Howells, 1992) and that progress varies across sectors and economies (Casson and Singh, 1993; Dunning, 1994). More recent literature (OECD, 1997; Patel and Pavitt, 1998; Guellec et. al., 2001; Cantwell and Santangelo, 1999; Gerybadze and Reger, 1999) has also confirmed that this is an escalating trend, but despite this trend, the globalization of R&D has largely been considered as a developed country-centric phenomenon. In particular, foreign-owned affiliates accounted for around 70 per cent of the overall R&D in Ireland, whilst for the OECD countries as a whole, by 1997, over 10 per cent of R&D had come from foreign corporations. However, since the rules of the game in a knowledge-based economy are speed, innovation, networking and global reach, the cross-border operations of established firms cannot be reduced to the mere relocation of their operations by means of technology transfer and access to lower-cost material-based inputs (Niosi, 1999;

Zander, 1999). Although firms in the developed countries are generally at the apex of the international pyramid of knowledge, they may have to outsource, even from second-tier countries, in order to establish 'across the board' competitive advantages for the new era. Therefore, firms in countries such as Taiwan may also have a role to play in the international innovation networks even during the early stage of the product life cycle (Chen and Liu, 2001).

Reddy (2000), amongst others, has in fact revealed a rising trend in terms of the R&D operations of MNCs in the developing world. The factors underlying this trend, as highlighted by Reddy, are summarized in Table 1. In specific terms, MNCs are themselves faced with an increasing need to monitor and learn the new global trends and hence to engage in multi-sourcing of technology inputs, partly because of rising R&D costs, the increasing demand for R&D personnel and a shortage of R&D personnel in the industrialized countries. Conversely, some, if not a great many, of the developing countries are able to provide an abundant supply of R&D personnel or skills, especially with regard to the so-called 'non-core' R&D areas. This match of supply and demand has been facilitated by factors such as improved information and communication technologies, the flexibility of new technologies, which allows de-linking of manufacturing and R&D, and the comparative advantages of the developing host countries.

For our empirical work, we propose a framework for further analysis which, in short, is based on Dunning's (1992) eclectic paradigm, with a strong flavor of the evolutionary approach to technology (Nelson and Winter, 1984), whilst in some cases, also allowing leapfrogging competition. According to Dunning, where firms possess advantages of ownership and internalization, and host economies enjoy locational advantages,

international production may take place.

In our view, Dunning's paradigm can be useful for analyzing the offshore R&D activities of multinationals if one interprets ownership, internalization and locational advantages in the context of R&D, with these advantages being related mainly to the technological routines and trajectories of the firms and the host economies (Dosi, 1982). In short, what a firm and an economy can do, or is about to do, is linked strongly to their routines and previous bases.

Table 1 Driving forces behind MNCs' R&D internationalization

	1970s	1980s and 1990s
Corporate R&D		
Demand-side forces	Need for monitoring and learning new worldwide trends Technology transfer abroad for cost-effective production	Need for monitoring and learning new worldwide trends Need for multi-sourcing of technology inputs
Supply-side forces	Large local markets Proximity to production facilities	Improved information and communication technologies Flexibility of new technologies to allows de-linking of manufacturing and R&D Comparative advantages of host economies
External forces in business environment		Liberalization of economies worldwide Homogenization of consumer preferences worldwide Emergence of regional markets Increasing global competition Science base of new technologies
Internal forces		Rationalization of MNC's operations leading to specialization of affiliates
Internationalization of Corporate R&D		
	R&D Internationalization	R&D Globalization
Demand-side forces	To enhance market share in local market abroad Host government's 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-divisibility of R&D into core & non-core activities Changes in policy regimes, including IPR in host economies

Source: Compiled from Reddy (2000).

However, in some cases where technologies are not characterized by incremental change, leapfrogging competition may arise, which may allow the firm or economy concerned to bypass certain stages of the technological trajectory, or to jump straight into a new generation of technology. Therefore, those MNCs involved in offshore R&D may shift some part of their R&D operations to a host country according to the capabilities of the latter, whilst capitalizing on the derived benefits by exploiting their own advantages of ownership and internalization. By so doing, we may be able to explain not only why R&D is internationalized, but also what types of R&D are undertaken in the host countries. Figure 1 itemizes some of the advantages that multinationals, Taiwan and China may each possess in the Dunning context.

In our opinion, the ownership advantages of MNCs lie, in general, in their core technology and world-class brand names. With the core technology, they are able to set an agenda at the international level and influence the way that technology progresses. Their world-class brand names enable them to gain direct access to customers and marketplaces, which in turn facilitate their initiation of concepts for product development and the means of exploiting market potential elsewhere.

The internalization advantages of MNCs may include systems integration capabilities, product planning capabilities, market access advantages and information and communication networks. In particular, with systems integration capabilities and information and communication networks at their disposal, they may be able to deploy core and non-core R&D across boundaries, whilst maintaining control over the profits generated in the process. Likewise, the possession of product planning capabilities and market access advantages means that MNCs have control over the two ends of the ‘smiling curve’, and hence, have the final say

in the benefits derived from the entire value-chain they face.

With regard to Taiwan as a location for offshore R&D of MNCs, we have to refer to the way in which economic development has evolved on the island, since it is well-known as a typical example of the export-oriented industrialization paradigm. Although this goes hand in hand with the process of migration from labor-intensive sectors towards high-technology as well as capital-intensive industries, Taiwan's major sectors are characterized by their vertical disintegration and the pursuit of OEM/ODM contracts for brand marketers, without direct access to the final market. In terms of R&D, local firms may, in general, lack systems integration capabilities and the ability to take the initiative in product and technology development; however, some of the industrial players may be positioned as 'first-tier suppliers' and possess innovation capabilities in certain areas and industrial segments, which could be considered as Taiwan's main locational advantage in offshore R&D. In addition, the last decade witnessed a wave of R&D investment in China both from MNCs and from Taiwan-based firms. For this reason, Figure 1 goes a step further to analyze the case where Taiwan-based firms invest in R&D in China.

It is generally perceived that firms based in Taiwan undertake more 'D' than 'R' and that they lack systems integration capabilities. As a result, commercialization capabilities of the sub-system in certain areas may be considered as their R&D ownership advantages. However, their networking relationships with brand marketers may be considered as their internalization advantage on two counts. Firstly, although China is emerging as a major electronics manufacturing base, approximately two thirds of Chinese exports are attributable to Taiwan-based firms. Elsewhere, we have argued that the restructuring of the global electronics industry has led to the formation of the global production network, in which Taiwan-based firms have begun to shoulder functions such as coordination of cross-border supply chains and logistics,

acting as integrated service providers and hence, an essential node in the global value chain (Chen, and Liu, 2002a; Chen 2002). As a result, many of the world-class brand marketers may be 'anchored' to Taiwan's economy, especially in terms of order placement. Secondly, in the process of outreaching, Taiwan-based firms have scaled down their local operations and handed over parts, or the whole, of their manufacturing functions to offshore sites, leading in varying degrees to the de-linking of manufacturing and R&D. As long as their networking relationships with brand marketers are secure, the Taiwan-based firms remain in the driver's seat in terms of profit distribution within internal organizations, and coordination of R&D and manufacturing.

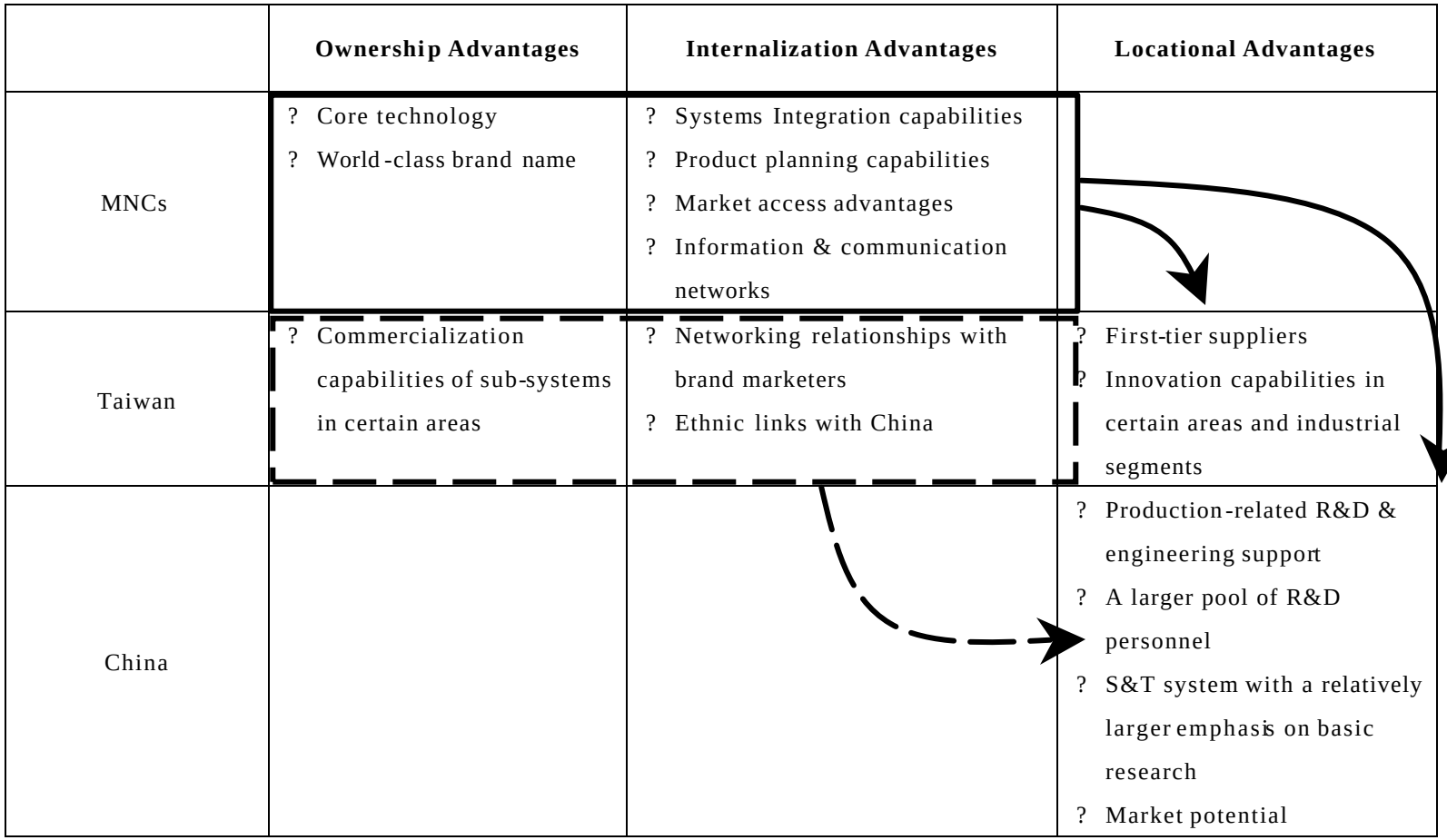


Figure 1 R&D-related advantages of MNCs, Taiwan and China in the Dunning eclectic paradigm context

An additional internalization advantage, which may be enjoyed by Taiwan, is ethnic links with China, especially as compared with MNCs. Similarities in language and culture between Taiwan and China may facilitate knowledge communication and absorption between the two parties if Taiwan-based firms undertake offshore R&D in China. It then comes down to the question of what locational advantages China may have that are capable of attracting offshore R&D. A large pool of R&D personnel and market potential may be two obvious advantages, but when discussing market potential, we have to take into account the possibility of leapfrogging development, as some proportion of the Chinese population may consume state-of-the-art products. In addition, the Chinese S&T system formerly placed relatively greater emphasis on basic research, partly because of the defense race in the cold war period. Moreover, as China is emerging as an international manufacturing base, it may be in the process of accumulating production-related R&D and engineering support, which will subsequently become a locational advantage.

The essence of the above framework is that R&D globalization may be better understood in a 'multilateral' rather than simply a 'bilateral' context. This means that R&D undertaken by the three parties in the individual locations may, to some extent, interact, resulting in complex networking relationships.

R&D UNDERTAKEN BY MNCs IN TAIWAN

Although it is well-documented that foreign direct investment (FDI) has played an important role in Taiwan's economic development, it is seldom realized that to some degree, some of the MNCs in Taiwan have also invested in R&D. Panel data for 1999 collated by the Investment Commission at the Ministry of Economic Affairs shows estimated R&D intensity of 1.94 per cent for foreign-owned subsidiaries over the period

1996-1998, whilst the electronics and electrical appliances industry achieved an intensity level of 2.36 per cent (Table 2).

Table 2 R&D intensity of foreign-owned subsidiaries in Taiwan, 1979-1998

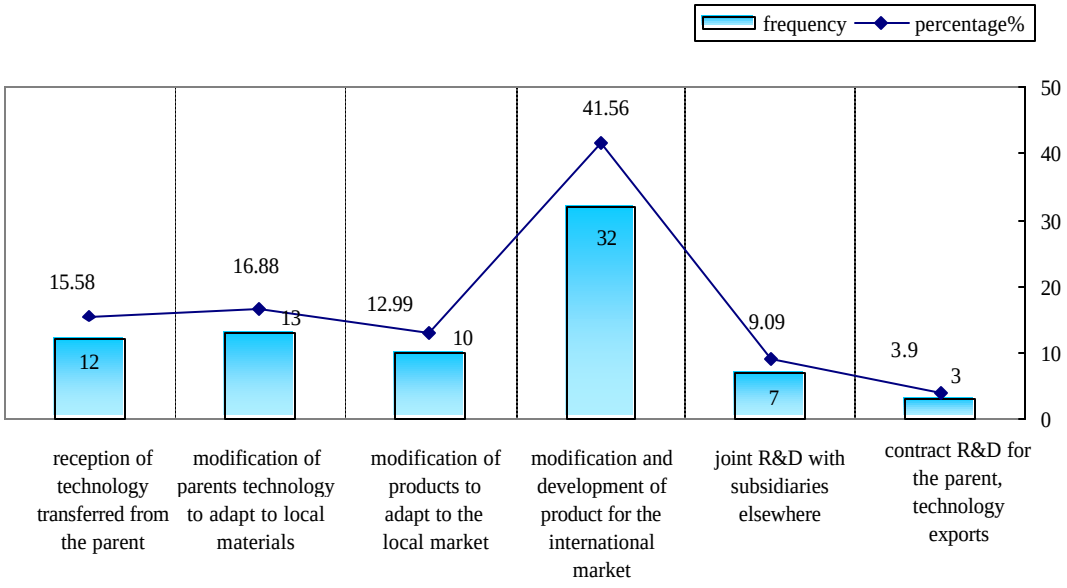
	Overall Industries			
	Numbers of Firms (1)	R&D Expenditures (NT$ million) (2)	Sales (NT$ million) (3)	R&D Intensity (2)/(3) x 100
1979	858	646	302,119	0.21
1980	830	680	352,944	0.19
1981	795	1,195	391,486	0.31
1982	819	1,744	392,416	0.44
1983	847	1,032	361,662	0.29
1984	956	2,713	552,402	0.49
1985	837	3,085	421,188	0.73
1986	890	4,443	500,230	0.89
1987	974	5,723	600,673	0.95
1988	1,079	5,464	699,237	0.78
1989	1,132	7,101	880,761	0.81
1990	1,391	12,625	984,791	1.28
1991	1,947	23,198	1,191,129	1.95
1992	2,089	16,510	1,596,983	1.03
1993	1,939	14,934	1,713,660	0.87
1994	2,026	43,074	1,812,995	2.38
1995	1,900	29,136	2,485,987	1.17
1996	1,270	28,160	1,904,129	1.48
1997	1,657	61,254	2,260,105	2.71
1998	1,439	29,365	1,800,605	1.63
1979-80	844	663	327,532	0.20
1981-85	851	1,954	423,831	0.45
1986-90	1,093	7,071	733,138	0.94
1991-95	1,980	25,370	1,760,151	1.48
1996-98	1,455	39,593	1,988,280	1.94

Source: Complied from Investment Commission, Ministry of Economic Affairs

Taking advantage of the panel data, elsewhere we have conducted statistical analyses to explore the factors determining local R&D by MNCs' subsidiaries in the electronics industry (Chen and Liu, 2002b). Employing Tobit analysis to test the factors determining the R&D intensity of the foreign-owned subsidiaries, we find, amongst other things, that foreign-owned subsidiaries with higher R&D intensity are characterized by higher average wages and a higher degree of localization in terms of sourcing of both production materials and capital goods. To interpret this finding, one can refer to Westney's (1990)

arguments that MNCs' offshore R&D units are given higher hierarchical mandates if their ties with the local scientific and technical community are gaining strength (and probably, therefore, greater R&D intensity). To put this another way, Reddy (2000) championed the concept of 'first-tier supplier advantage' as a locational advantage for attracting MNCs' R&D units, 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.

By controlling the variable representing local sourcing of materials, we also find that in Taiwan, foreign-owned electronics firms with higher export propensity tend to be more R&D intensive. As is widely known, the electronics industry in Taiwan is internationally competitive and export-oriented, with local players in many of the sub-sectors enjoying first-tier supplier status. By analogy, their MNC counterparts in Taiwan may have to act in the same way in order to exploit Taiwan's advantages. In a questionnaire survey of MNCs' R&D activities in Taiwan, conducted by the authors (Liu et. al., 2002), R&D performers were asked to identify their highest level R&D activities in Taiwan. The predominant level appeared to be the modification and development of products for the international market. By sharp contrast, only a small proportion of the respondents reported that their subsidiaries were mandated to conduct joint R&D with their sister subsidiaries elsewhere, and to conduct contract R&D and/or technology exports for the parents (See Figure 2).



Source: Liu, Chen, and Lin (2002)

Figure 2 The Highest Levels of MNCs' R&D Activities in Taiwan

In terms of Westney's (1990) categorization of MNCs' offshore R&D units – namely technology transfer units, indigenous technology units, global technology units and corporate technology units – our findings may imply that quite a number of MNCs' subsidiaries in Taiwan are given a regional or even international mandate in R&D. This is indeed consistent with the evidence, presented above, that foreign- owned electronics firms in Taiwan with a greater propensity for exports tend to be more R&D intensive. In addition, the firms surveyed were required to highlight the factors characterizing Taiwan's strengths and weaknesses in R&D operations (as summarized in Figure3).

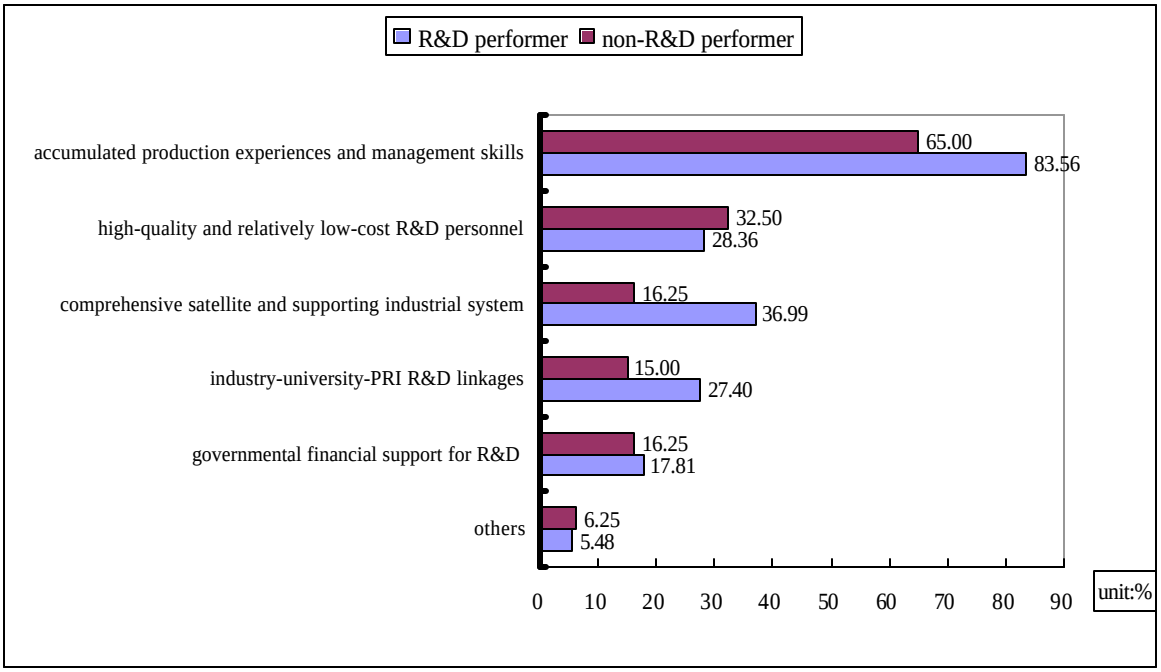


Figure 3 Taiwan's strengths in R&D operations

From the standpoint of R&D performers, there are generally considered to be three major factors which bring about local R&D: (i) accumulated production experiences and managerial skills; (ii) high-quality and relatively low-cost R&D personnel; and (iii) a comprehensive satellite and supporting industrial system. Government provision of financial support for R&D, and for R&D linkages between industry, universities and public research institutes (PRIs) appears to be less significant in bringing about local R&D. Non-R&D performers collectively place much greater emphasis on accumulated production experience, managerial skills and relatively low-cost but high-quality R&D personnel as Taiwan's strengths in R&D operations, whilst tending to downplay the remaining specified factors and indeed, were somewhat indifferent towards them.

It is fair to say that the factors specified in our questionnaire as Taiwan's strengths in R&D operations related mainly to the supply side, as well as being network-related. The

reason for this was that in terms of domestic market and government procurements, in our opinion, Taiwan is small in scale. In addition, as Reddy (2000: 36) argued, amongst other motives, those that were technology-related were observed to have become more important than market-related motives for R&D globalization. Indeed, both groups of respondents were greatly aware of Taiwan's advantages of accumulated production experience and managerial skills, and relatively low-cost but high-quality R&D personnel. Of some interest is the finding that R&D performers appear to be more appreciative of the comprehensive satellite and supporting industrial system than non-R&D performers. This may be because some, if not a great many, of the industrial sectors in Taiwan have comprehensive satellite and supporting industrial systems which enable major MNCs in the same sectors to exploit Taiwan's 'first-tier' supplier advantage, as discussed above.

In terms of Taiwan's weaknesses in R&D operations, both R&D performers and non-R&D performers share the same views, in order of importance (as summarized in Figure 4). The lack of international vision and language capabilities amongst R&D personnel stands out as Taiwan's first and foremost weakness. Secondary weaknesses are the insufficient supply of R&D personnel and the unsound science base for advanced research.

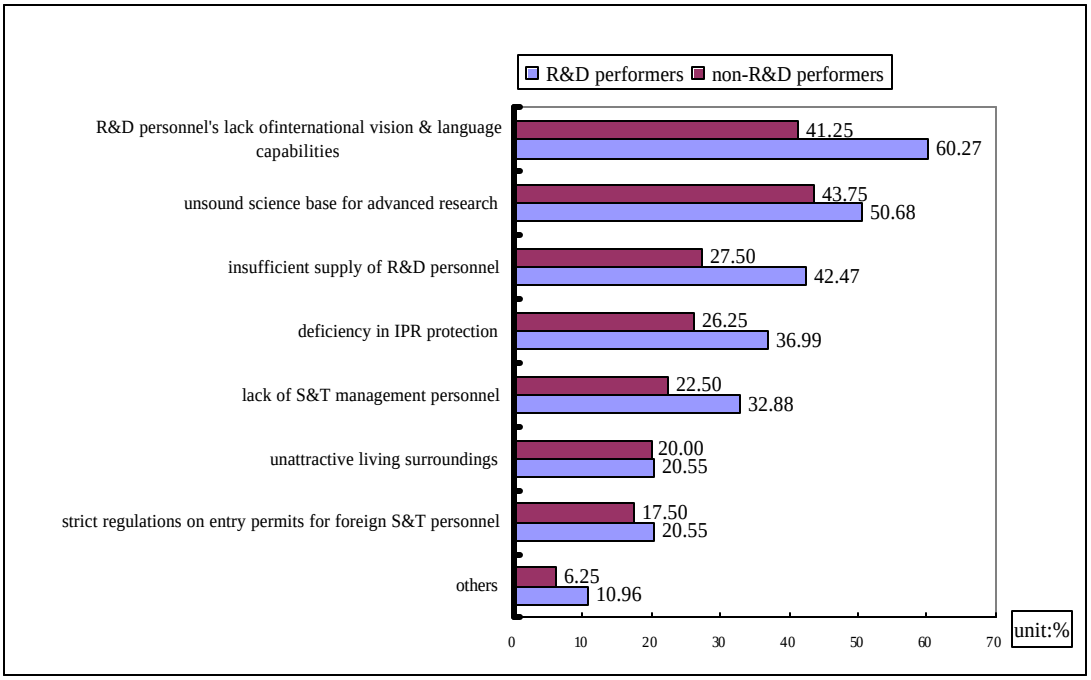


Figure 4 Taiwan's weaknesses in R&D operations

These three factors are all supply side-related, but the lack of international vision and language capabilities of R&D personnel, and the unsound science base for advanced research, may have a substantial negative influence on the R&D operations to be undertaken in Taiwan. In addition, when foreign-owned subsidiaries considered Taiwan's science insufficiently sound for advanced research, it was not at all surprising that they downplayed Taiwan's industry/university/PRI R&D linkages. Conversely, factors such as intellectual property rights (IPR) protection, and the lack of S&T management personnel scored relatively low. Moreover, a few respondents pointed to the lack of systems integration capabilities as a major constraint for R&D in Taiwan.

THE CROSS-STRAIT R&D DEPLOYMENT OF TAIWAN-BASED FIRMS

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 suggests that Taiwanese outward investment to China is becoming more technology- and capital-intensive; indeed, in recent years, the electronics and electrical appliances industry has accounted for approximately 40 per cent of Taiwan's annual outward investment to China. There has also been some cross-strait policy convergence in the attraction of offshore R&D by MNCs as well as the promotion of technological upgrading, which implies a trend towards cross-strait co-opetition in R&D and technology. The trend towards deployment of R&D in China by MNCs is becoming discernible; indeed, one suburb of Beijing, Zhong Guancum, is reported as an emerging example of foreign R&D clustering in the developing world (Reddy, 2000; UN, 2001). A study by Chinese scholars revealed that up to July 1999, about thirty-four foreign-owned R&D facilities were located in China, with eighteen of them being in Beijing (Transnational Corporation Research Center, 2001). The lion's share is taken up by the information technology, communications and electrical machinery industries, with their presence in China being attributed mainly to factors such as the huge potential of the Chinese market, availability of local R&D personnel, collocation of R&D and regional (or Chinese) headquarters, and state policy.

In addition, it is evident that the China operations of Taiwan-based firms have gone beyond manufacturing, increasingly moving into R&D. In a separate research project, a questionnaire survey was undertaken to determine the R&D of Taiwan-based IT firms in China (Chen et. al., 2002). The results showed that 47.56 per cent of respondents had conducted R&D activities in China, implying that China had become the major target for these Taiwanese firms' offshore R&D in quantitative, though not necessarily qualitative terms.

Based on firm-level interviews conducted on both sides of the Taiwan Strait, it was

possible to identify certain patterns of cross-strait R&D deployment by some of the Taiwan-based IT firms (summarized in Table 3). In essence, the cross-strait production network is evolving alongside its global counterpart and hence is becoming more complex. In manufacturing, there are now new types of division of labor, going beyond horizontal and vertical division. Based on information obtained from the structured interviews we were able to identify five types of R&D portfolio across the Taiwan Strait. First, where Taiwan-based firms' production lines were concentrated in China as well as other countries, product development was undertaken in Taiwan, while manufacturing-related R&D and engineering support was performed in China. This often entailed the de-linking of R&D and manufacturing. Second, some Taiwanese firms outsource their software development services from China. Third, there is a tendency for some Taiwanese firms to perform basic research in China, which often entails collaboration with local universities and/or research institutes. Fourth, some Taiwanese firms perform upstream (core) R&D in Taiwan whilst their subsidiaries in China carry out downstream (non-core) R&D. Finally, there are also cases where Taiwanese firms performed R&D in China as part of their collaborative ties with the MNCs. For example, one interviewee mentioned that the company's R&D activities were divided into five stages; namely engineering sample (ES), engineering valuation test (EVT), design valuation test (DVT), production valuation test (PVT), and mass production valuation test (MVT), with the first two stages being conducted in Taiwan whilst the remainder (all manufacturing-process-related) were undertaken in China.

Table 3 Cross-Strait R&D Deployment by Taiwan-based Firms

		Taiwan	China
Product	Type	Peripherals	System-related
	Market	International market	Domestic market
	Life Cycle	Development stage	Mature stage
Attributes of R&D or Technology	Software & Hardware	Hardware	Software
	R&D Process	Product & process R&D	Basic research? verification and fine-tuning of process

Part of this survey enlists information on firms' R&D activities in China. For the purpose of this paper, the respondents were first asked to identify the major technology sources of their subsidiaries in China. Figure 5 presents the distribution of the answers to this question.

'Support from the parent' stands out as the predominant technology source of Taiwan-based firms' subsidiaries in China; almost 80 per cent of the respondents ranked it as highly important. Secondary to this was 'local subsidiaries' own R&D efforts'. These two were followed, by quite a substantial margin, by such sources as 'joint efforts with local research institutes' and 'joint efforts with local firms'. It is therefore arguable that the Taiwan-based firms' subsidiaries, although heavily technologically reliant on their parent companies, are also engaged in local R&D which cannot be regarded as negligible.

The respondents were also asked to assess the relative significance of a few R&D activities on both sides of the Taiwan Strait; the results are summarized in Figure 6. Basically, in each type of R&D activity, Taiwan significantly outweighs China. By counting the proportion of respondents who ranked Taiwan as 'highly important' and 'secondarily important', we can argue that Taiwan remains the major focus in these firms' cross-strait R&D operations, particularly in terms of the development of new products, modification of products, and new process technology. Of equal importance is the finding

that quite a large proportion of respondents expressed the indifference of both Taiwan and China towards machinery design, duplication of machinery and environment-related R&D. Part of the finding is consistent with the results gathered from the firm-level interviews and presented in Table 3. In fact, as some of the Taiwanese IT firms have scaled down or even hollowed out their manufacturing operations in Taiwan and shifted them towards China, and elsewhere, it may become necessary for them to rely increasingly on their Chinese subsidiaries to undertake manufacturing-related R&D.

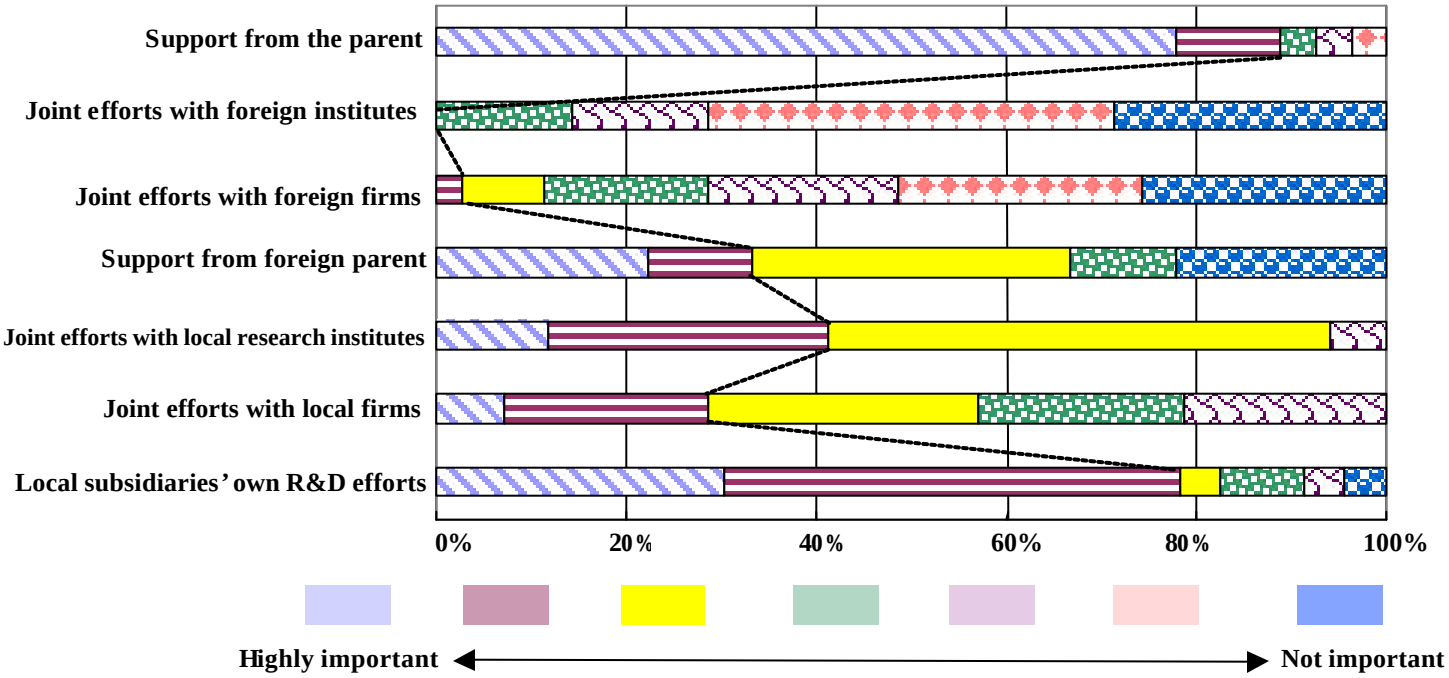


Figure 5 Technology sources of Taiwanese IT firms' subsidiaries in China

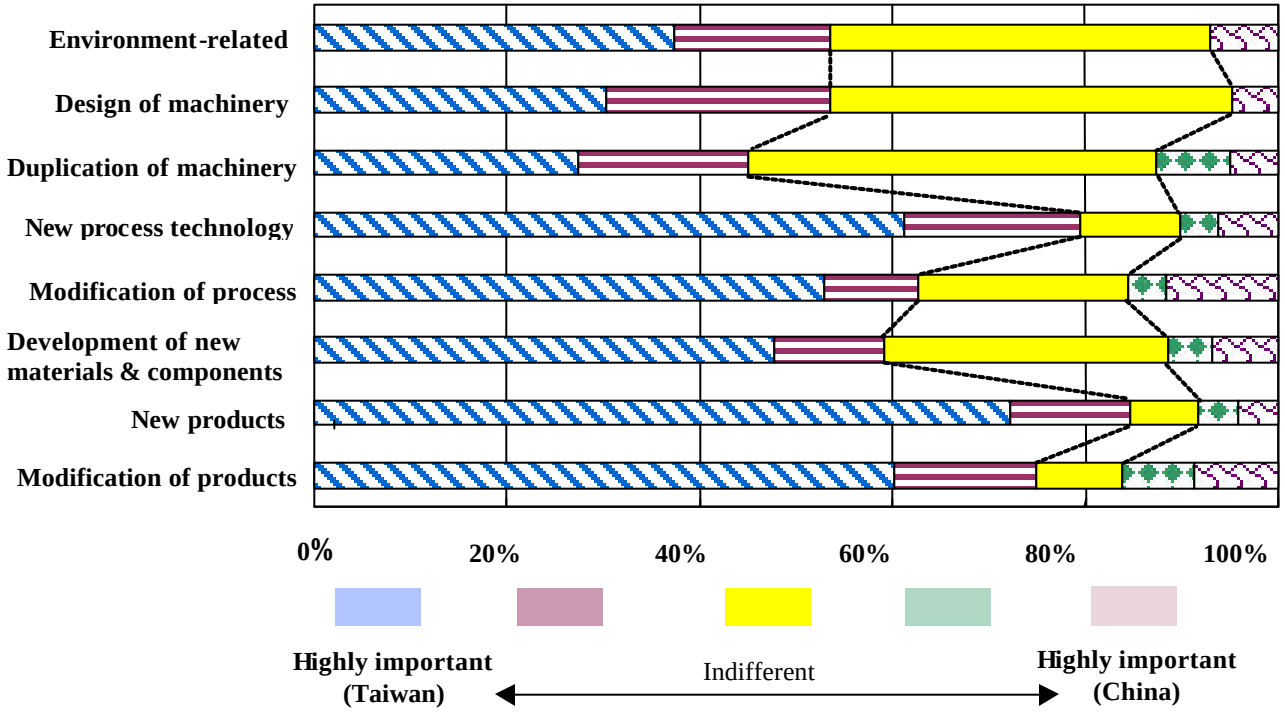


Figure 6 Relative significance of cross-strait R&D by Taiwan's electronics firms

This seems more likely in the case where the de-linking of R&D and manufacturing is feasible (Reddy, 2000). In addition, global production networks in the IT industry have come to resemble a 'just-in-time' system on a global scale which entails the modularization of production across different sites and borders (Chen and Liu, 2002). As a result, concurrent development may become the norm in the industry for the introduction of new products into the marketplace, and this will be facilitated by the application of information and communication technologies. For example, Mitac, a leading PC producer based in Taiwan, has set up a 'collaborative product commerce' (CPC) mechanism for online joint product design. This incorporates an intra-link which enables its subsidiaries and partners to use the same design tools for joint product design and development, ranging from product definition to product R&D and product modularization, and not only helps to reduce the R&D cycle time for Mitac and its partners, but is also essential in the coordination of the production, assembly, delivery and repair and maintenance activities that follow (Chen, 2002). In light of this, it is not surprising to see that the Taiwan-based IT firms have, to a large extent, mandated their Chinese subsidiaries to undertake certain elements of their R&D.

CONCLUSIONS

Gone are the days when the developed countries dominated manufacturing activities, so too are the days when R&D was a developed country-centric phenomenon. This arises not within a historical vacuum, but has something to do with the increasingly obvious trend towards the disintegration of manufacturing and innovation capabilities on an international scale. The IT industry illustrates these points vividly and the areas in which countries like Taiwan are substantially involved. In order to encapsulate these

developments, not only has this paper put forward a conceptual framework, it has also presented evidence regarding the interactive R&D flows involving brand marketers, Taiwan-based firms, and their subsidiaries in China. In summary, it can be determined through conceptualization and evidence that based on the heritage of industrialization, Taiwan is able to capitalize on its first-tier supplier advantage to attract MNCs to set up their offshore R&D facilities. In particular, we find that foreign-owned subsidiaries with greater levels of R&D intensity are characterized by a higher propensity for exports and a higher degree of localization, in terms of both the sourcing of production materials and capital goods. In addition, quite a number of MNCs' subsidiaries in Taiwan are indeed given a regional or even international mandate in R&D. What's more, it is also evident that quite a number of the Taiwan-based IT firms have given R&D mandates to their subsidiaries in China. In terms of the patterns of their cross-strait R&D portfolios, R&D in Taiwan tends to focus more on product development and new process technology, whilst in China it is more on manufacturing-related R&D.

To conclude this paper we would like to go further, using the 'smiling curve' to put forward a 'holistic' view of the cross-border innovative network in the IT hardware industry, as presented in Figure 7. The traditional view of the division of labor between the developed and developing countries tends to incorporate the dichotomy between the 'high-end' and 'low-end' of products and functions; however, we cast doubt on such a linear and core/periphery dichotomy with regard to R&D internationalization across the Taiwan Strait. As discussed above, the cross-strait IT production network is evolving alongside its global counterpart and hence is becoming more complex. There are now new types of division of labor, going beyond horizontal and vertical division in manufacturing, including: (i) technology: upstream vs. downstream; (ii) product:

peripherals vs. system-related products; and (iii) market: the international market vs. the Chinese market.

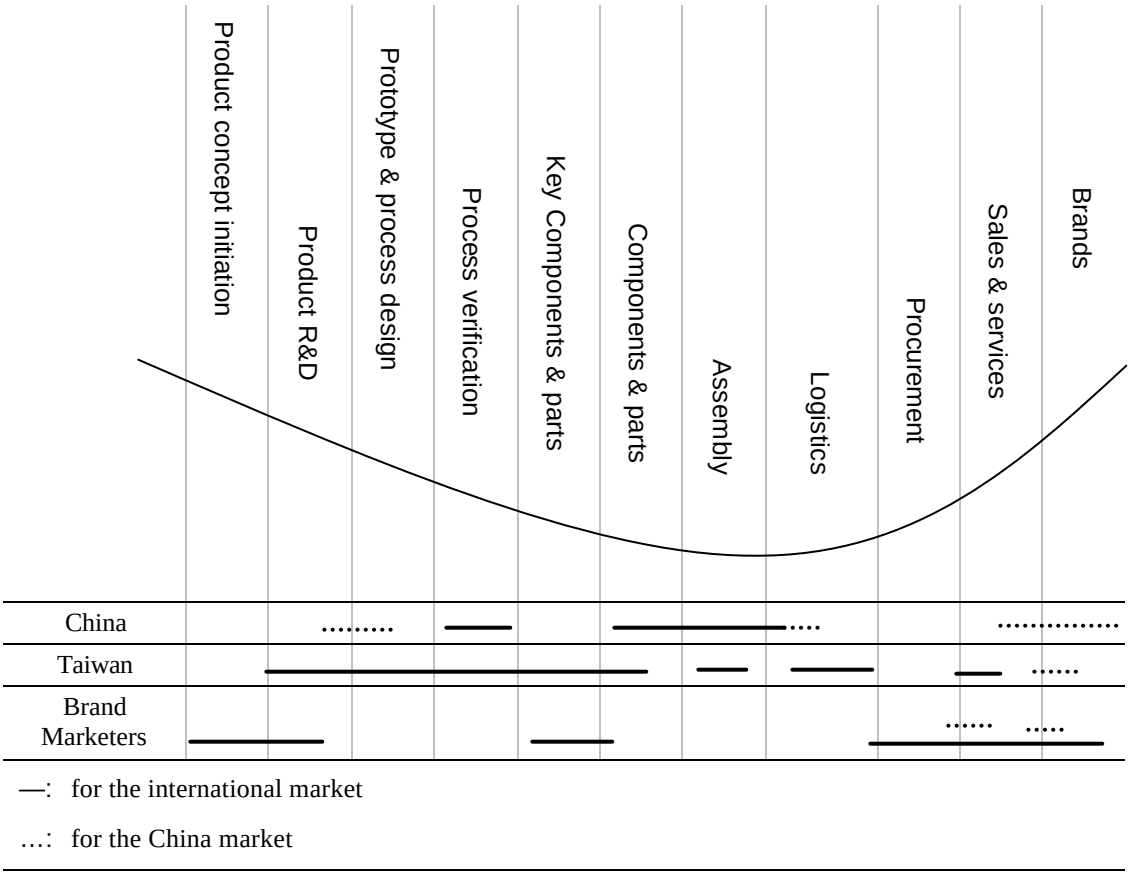


Figure 7 Cross-border innovative network in the IT hardware industry

Within this process, the operations of Taiwan-based firms in China show a rising trend towards localization, moving from the sourcing of parts and components towards verification of manufacturing processes, engineering support and even software development. Moreover, on the other end of the 'smiling curve', firms, regardless of their nationality, may be attracted by China's huge market potential to gain a market foothold through the widening of their value chains. This in turn may call for all firms concerned to strengthen their R&D commitment in China. On balance, when analyzing the trend

towards R&D internationalization, the role played by countries such as Taiwan and China can no longer be downplayed.

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