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Multinational corporations and the Emerging Network Economy in Asia and the Pacific

Edited by
Juan J. Palacios

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3 Innovation offshoring: root causes of Asia's rise and policy implications

Dieter Ernst

INTRODUCTION

Much economic research on the role of Asia[1] in the global economy has focused on the impact of changes in macroeconomic parameters (for instance, financial and foreign exchange crises), but has neglected the issue of 'deeper economic integration'. The latter refers to transformations in markets for capital, goods, services, technology and labour that, to a large degree, result from changes in corporate strategies and organisation. 'Globalisation' is widely used shorthand for these transformations (Ernst 2005c). Barriers to integration continue to exist, of course, in each of these different markets, but there is no doubt that a massive integration of markets has taken place across borders that, only a short while ago, seemed to be impenetrable. And much of the action now is in Asia.

An important new development is the rise of Asia as a location for 'innovation offshoring'. Global corporations are at the forefront of these developments, experimenting with new approaches to the management of global innovation networks. But Asian governments and firms are playing an increasingly active role as promoters and new sources of innovation.

Innovation offshoring is therefore likely to accelerate. It is driven by fundamental changes in corporate innovation management in response to the globalisation of markets for technology and knowledge workers. Innovation offshoring thus creates a whole new set of challenges – and opportunities – across the Pacific Rim.

The main drivers of this change are global corporations that are increasing their overseas investment in R&D while seeking to integrate geographically dispersed innovation clusters into global networks of production, engineering, development, and research. This trend has added a new dimension to the traditional notion of global production networks (GPNs), transforming them into global innovation networks (GINs).

GINs combine the geographic relocation of innovation ('offshoring') with changes in the boundaries of the firm ('outsourcing'). Global companies 'offshore' stages of innovation to Asian affiliates to tap into the region's lower-cost pool of knowledge workers.[2] Equally important are the region's large and increasingly sophisticated markets. This has led to Asia's integration into intra-firm GINs. But global firms also 'outsource'

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some stages of innovation to specialised Asian suppliers, as part of complex inter-firm GINs.

It is time to correct earlier claims that only low-level service jobs will move offshore (Mann 2003) and that there is 'little evidence' of a major push by global companies to set up research operations in the developing world (Bhagwati 2004). Innovation offshoring goes far beyond the migration of relatively routine services like call centres, software programming, and business process support – the subject of current public debates on 'outsourcing'. Beyond adaptation, innovation offshoring in Asia now also encompasses the creation of new products and processes (Ernst 2006a).

Asia's integration into global innovation networks could facilitate knowledge diffusion and learning (Ernst 2002a, 2005c). But innovation offshoring also creates a competitive challenge of historic proportions. Asia needs to move beyond its traditional role as the primary 'global factory' for manufactures, software, and business services. It needs to develop strong national innovation systems to facilitate firm-level development of innovative capabilities.

Across the region, governments and domestic firms are all searching for strategies that would enable them to benefit from integration into GINs. China and India have clearly been at the forefront, but equally important are developments in South Korea, Taiwan, Singapore, and Malaysia.

In short, new strategies and policies are required across Asia to cope with these new opportunities and challenges. Yet, while the policy relevance of these developments is all too evident, there has been very little research on the root causes and impacts of innovation offshoring.

This chapter presents preliminary findings of research on root causes. It does not explore impacts of Asia's integration into GINs, for instance on knowledge diffusion, value added and productivity growth.[3] The analysis is based on an extensive micro study of developments in the electronics industry, which dominates East Asia's trade and foreign direct investment (FDI). The research is based on structured interviews with more than 150 companies in the United States, Asia and Europe.

The first part of the chapter reviews the foundations of Asia's rise as an important location for innovation offshoring, highlighting achievements and policies to cope with the decreasing returns to the export-led 'global factory' model. The second part analyses the forces behind the growing organisational and geographical mobility of innovation within GINs, and explores what this implies for innovation offshoring. The chapter concludes with generic policy suggestions for Asian governments to cope with the new opportunities and challenges of innovation offshoring.

FOUNDATIONS OF ASIA'S RISE

The global factory

Asia's rise as an important location for innovation offshoring owes much to the region's success as the primary 'global factory' in industries as diverse as textiles, footwear, agro-industries, electronics, steel, cars, machine tools, software and information technology (IT)-enabled business services.

Integration into GPNs provided a fascinating example of the catalytic role that linkages with foreign firms can play for industrial development (Borrus *et al.* 2000; Ernst 1997). It enabled Asian firms to access the world's leading markets, especially in the United States, and helped to compensate for the initially small size of their domestic markets. Network participation also provided access to leading-edge technology and best-practice management approaches, creating new opportunities, pressures and incentives for Asian network suppliers to upgrade their technological and management capabilities and the skill levels of workers (Ernst and Kim 2002).

Aggressive support policies by Asia's governments enabled local firms to cope with these opportunities and challenges and to improve their position in these networks. The result is one of the most impressive success stories of Third World economic development. During the first years of the new century, the region's rate of growth in gross domestic product (GDP), trade, and inward FDI has surpassed even the impressive pace it achieved during the decades of the 1980s and 1990s. Asia also has become an increasingly sophisticated market for an even wider array of goods and services.

No other industry reflects Asia's rise as well as the electronics industry. Asia's five leading exporting countries (China, South Korea, Taiwan, Singapore and Malaysia) today account for more than one-fourth of world electronics manufacturing output. These five countries occupy leading positions in global markets for digital consumer electronics, computers, and mobile devices, as well as for high-precision components, such as semiconductors and displays.

For instance, roughly 70 per cent of the output of the semiconductor industry is now based in Asia. In addition, India, which has firmly established itself as a global export production base for software and IT-enabled business services, is now emerging as the next frontier for offshore manufacturing in sectors as diverse as car components, electronic components and pharmaceuticals.

This process has culminated in China's emergence as the dominant 'global electronics factory'. Since 2004, China has been the world's largest exporter of electronic products, surpassing the United States – a dramatic increase from its position as number 10 in 2000. Noteworthy in particular is a rapid improvement in the country's export portfolio: digital consumer electronics and mobile telecommunications equipment have increased relative to commodity-type appliances and personal computers (PCs), and electronic components have now become China's second biggest electronics export item.

China's emergence as the second largest electronics importer (up from seventh in 2000) indicates the growing importance of Asia's rapidly growing and increasingly sophisticated markets for communications, computing and digital consumer equipment, and for the electronic components (especially semiconductors) required by Asia's global electronics factories. The main prize is the sheer size of China's market. In the electronics industry, China has become the main export market for the United States, Japan, Taiwan and South Korea. China is the world's largest market for telecommunications equipment (wired and wireless), as well as a test bed for advanced third-generation (3G) wireless communication systems. China is also one of the most demanding markets for computing and digital consumer equipment. As most of that equipment is produced in China, the country has become the world's third largest market for semiconductors.

Upgrading through technology diversification

Asia's role as the 'global factory' will continue to be an important source of economic growth and capability development. However, both the 1997 financial crisis and the downturn in the global electronics industry in 2000 have brutally exposed the downside of that model. A country is more vulnerable to external disturbances, the higher the share of electronics in its exports, the greater its integration into GPNs, and the more it depends on exports to the United States (Ernst 2001).

In addition, there are decreasing returns to the 'global factory' model (Ernst 2004). As the capital intensity of such investment increases, it generates less new employment. Local spillovers to domestic suppliers also decline as global contract manufacturers, such as Flextronics, provide integrated manufacturing services, increasing their share of global factory production. And much of the 'global factory' investment has remained 'footloose', leading to plant closures in established locations and relocation to new, lower-cost sites.

Furthermore, Asian firms heavily rely on American, Japanese and European firms as the dominant sources of new technology. This reflects the heavy concentration of R&D, innovative capabilities and intellectual property rights (IPRs), much of it centred on the United States.[4] For Asian firms, this has resulted in razor-thin profit margins owing to the hefty licensing fees charged by the global brand firms.

Across the region, a broad consensus has emerged that Asia's electronics industry needs to upgrade to higher value-added and technologically more demanding products, services and production stages and that this requires the development of strong innovative capabilities. To achieve this goal, Asian governments and leading electronics and software companies are seeking to develop and improve the skills, knowledge, and management techniques needed to create and commercialise successfully new products, services, equipment, processes and business models.

A remarkable achievement of these efforts is a pragmatic focus on what is feasible in view of the fact that the region continues to lag substantially behind advanced nations in the development of a broad-based science and technology system (Ernst 2005d). Instead of jumping right into 'technology leadership' strategies to compete head on with global technology leaders, the focus has been on 'technology diversification'. This arguably has laid an important foundation for the region's success in attracting innovation offshoring.

Technology diversification, defined as the expansion of a company's or a product's technology base into a broader range of technology areas, focuses on applied research and the development of products that draw on component and process technologies that are not necessarily new to the world or difficult to acquire (Granstrand 1998). This enables Asian firms to build on their existing strengths in manufacturing, process development and prototype development. They also can leverage their experience in providing knowledge-intensive support services required to raise money and to manage supply chains and customer relations, knowledge exchange and the development of human resources. Most importantly, technology diversification allows Asian firms to use their accumulated capabilities to implement, assimilate and improve foreign technologies, as technology diversification often requires the exchange of knowledge with foreign parties.

Achievements

The results of these efforts are impressive. Asian governments and leading electronics and software companies have mobilised substantial investments to improve infrastructure (especially for broadband communication) and to support leading-edge R&D programs in a few high-priority areas. South Korea, Singapore, Hong Kong and Taiwan, together with small Nordic countries in Europe, lead the world in broadband access and speed. A few regions in China and India that are attracting innovation offshoring are rapidly catching up (Fonow 2006).

In addition, gross domestic expenditures on R&D have substantially increased in Asia's five leading electronics exporting countries, with China and Singapore experiencing the fastest rise. This has led to a substantial growth in the output of scientific papers, in citation ratios of these papers, and in the number of patents invented in Asia granted by the US Patent and Trademark Office (Wong 2006; Hicks 2005).

As a result, new innovation clusters have emerged for broadband technology and applications in South Korea and Singapore; for mobile communications and digital consumer devices in South Korea, Taiwan and China; and for software engineering and embedded software development in India.

The concerted efforts by Asia's governments and leading companies to support research programs and alternative standards offer an intriguing example. In telecommunications, for example, South Korea's four leading players (Samsung, SK Telecom, KT, and LG) are all engaged in serious efforts to become major platform and content developers for complex technology systems, especially in mobile communications. These efforts can build on considerable capabilities, accumulated in public research labs, like the Electronics and Telecommunications Research Institute, as well as in R&D labs of the *chaebol*[5] to develop complex technology systems like switching systems and communication systems that are based on the code-division multiple access (CDMA) standard developed by Qualcomm.

Another important example is China's development of an alternative 3G digital wireless standard, called time-division synchronous code-division multiple access (TD-SCDMA), which the International Telecommunications Union approved in August 2000.[6] Datang Telecom, a Chinese state-owned enterprise, and the Research Institute of the Ministry of Information Industry developed the TD-SCDMA standard with technical assistance from Siemens.

To accelerate the implementation of this strategy, Datang formed a series of collaborative agreements with global industry leaders to develop China-based R&D. There is a joint venture with Nokia, Texas Instruments (TI), the Korean LG group, and Taiwanese original design manufacturers (ODMs), a joint venture with Philips and Samsung, and a licensing agreement with STMicroelectronics. These will provide the Chinese company with access to critical design building blocks. Such linkages illustrate the important role that such programs play in attracting innovation offshoring.

Skills and capabilities

Asia's greatest attraction for innovation offshoring results from substantial improvements in the region's talent pool. Building on existing strengths in volume manufacturing, Asian firms have developed a broad range of specialised skills and capabilities. These include quality control, and the management of resources, supply chains and customer relations.

But to remain in the GPNs, Asian firms had to move up into product development, and increasingly into system and integrated circuit design (Ernst 2005a). Proximity to Asia's vast electronics manufacturing base has been an important asset, because product development focuses on manufacturability and the production of commercial samples. Asian firms also made substantial progress in developing the specialised skills required for complex R&D projects.

Most importantly, as noted by the National Science Board (2004: chapter 1, overview, p. 8), Asia's leading electronics exporting countries:

> ... [have substantially expanded] their higher education systems and the high-technology sectors of their economies in an effort to develop internationally competitive centres of excellence. In the past, these ... countries have been the main source of internationally mobile scientific and technical talent, but recently some of them have developed programs designed to retain their highly trained personnel and to even attract people from abroad.

For instance, China now graduates almost four times as many engineers as the United States. South Korea – with one-sixth of the population and one-twentieth of the GDP – graduates nearly the same number of engineers as the United States (National Science Board 2004: Appendix 2–33). China is experiencing explosive growth in Ph.D.-level degrees in science and engineering (S&E), the critical indicator of a country's research capabilities. A recent report prepared for the National Bureau of Economic Research (Freeman 2005) shows that between 1995 and 2003, first-year entrants in S&E Ph.D. programs in China increased six-fold, from 8,139 to 48,740. The report concludes:

> At this rate China will produce more S&E doctorates than the United States by 2010! (Freeman 2005: 4)

Such rapid expansion will undoubtedly come at the cost of a declining quality of graduate education, at least outside a handful of élite universities. A recent McKinsey report (Farrell *et al.* 2005) argues that, if all negative factors are factored in, only 25 per cent of India's engineering graduates are suitable for work at global corporations, while the current share in China is only 10 per cent.[7]

But there are signs that the quality problem is being addressed aggressively. The McKinsey report shows that the current supply of suitable engineers in low-wage countries represents as much as three-quarters of the suitable engineering talent pool in higher-wage countries. This share is substantially higher than the 44 per cent share of low-wage countries in the total supply of suitable young professionals in higher-income countries. Furthermore, the supply of suitable young engineers is expected to grow much faster in low-wage countries than in higher-wage countries. McKinsey projects that by 2008, low-wage countries will supply the same number of suitable young engineers as high-wage countries.

Highly skilled knowledge workers are much cheaper in Asia (outside Japan) than in the United States. For instance, the cost of employing a chip design engineer in Asia is typically between 10 and 20 per cent of the cost in Silicon Valley (Ernst 2005a).[8] As coordinating cross-continental design teams is likely to add substantial costs, industry experts estimate the net advantage to be between 30 and 50 per cent. Cost savings of such magnitude obviously are quite significant for companies that are under constant pressure to improve their return on investment, and provide an important incentive for innovation offshoring.

Asia's growing exposure to innovation offshoring

Cost savings are certainly important for large global corporations that are acting as pacesetters for an increase in the offshoring of innovation to Asia. A recent survey of the world's largest R&D spenders (UNCTAD 2005) shows that the world's leading R&D spenders intend to increase both their intra-firm and inter-firm GINs in Asia.[9] And large global electronics firms report the most aggressive plans to expand Asia's role in both forms of innovation offshoring.

By 2004 China had become the third most important location for overseas R&D affiliates, after the United States and the United Kingdom, followed by India (sixth) and Singapore (ninth). More than half of the responding firms have at least one R&D facility in China, India or Singapore.

Leading global corporations also intend to expand their offshore outsourcing of R&D to Asian firms. China is now the third most important location – behind the United States and the United Kingdom, but ahead of Germany and France. India is ranked equal to Japan.

The UNCTAD survey projects that the pace of R&D internationalisation will accelerate – as many as 67 per cent of the respondents stated that the share of foreign R&D will increase; only 2 per cent indicated the opposite. In this new wave of R&D internationalisation, large US corporations are likely to play a critical role as they are planning to expand their reliance on R&D internationalisation. Furthermore, Japanese and South Korean firms are keen to move beyond their current low levels of R&D internationalisation.

Finally, Asia is expected to receive much of the future R&D internationalisation, with China being a more attractive location for future foreign R&D than even the United States and India. Leading global corporations also intend to expand their offshore outsourcing of R&D to Asian firms.

THE NEW MOBILITY OF INNOVATION

Only a decade ago, research on the geographical distribution of patents demonstrated that innovative activities of the world's largest firms were among the least internationalised of their functions (Patel and Pavitt 1991). This gave rise to the proposition that innovation, in contrast to most other stages of the value chain, is highly immobile: it remains tied to specific locations, despite a rapid geographic dispersion of markets, finance and production (e.g. Archibugi and Michie 1995).

Attempts to explain such spatial stickiness of innovation have highlighted the dense exchange of knowledge (much of it tacit) between the users and producers of the resultant new technologies. Research has thus focused on the *dynamics* of spatial agglomeration within localised innovation clusters (e.g. Feldman 1999; Porter and Solvell 1998; Jaffe *et al.* 2000).

Global innovation networks

There is no question that the demanding requirements of managing complex innovation projects tend to concentrate innovation in the home country. However, research on globalisation has clearly established that the centre of gravity has shifted beyond the national economy (e.g. Dunning 1998). International linkages proliferate as markets for capital, goods, services, technology and knowledge workers are integrated across borders (Ernst 2005c). While integration is far from perfect, especially in the latter two markets, it is nevertheless transforming the geography of innovation (Ernst 2002a).

Once globalisation extends beyond markets for goods and finance into markets for technology and knowledge workers, fundamental changes have occurred in corporate innovation management. A gradual opening and networking of corporate innovation systems is giving rise to GINs that cut across firm boundaries and national borders. Global corporations, primarily from the United States, are increasing their overseas investment in R&D while seeking to integrate geographically dispersed innovation clusters into global networks of production, engineering, development, and research. This trend has added a new dimension to the traditional notion of GPNs, transforming them into GINs.

There is an important element of continuity: GINs emerge as a natural extension of GPNs and hence share important characteristics with GPNs (Ernst 2006a). But, as we will see below, they also differ.

Global production networks

Let us first look at defining characteristics of GPNs and how they developed over time. Trade economists have explored the importance of changes in the organisation of international production as a determinant of trade patterns (e.g. Feenstra 1998; Jones and Kierzskowski 2000). Their work demonstrates that (a) production is increasingly 'fragmented', with parts of the production process being scattered across a number of countries, hence increasing the share of trade in parts and components; and (b) countries and regions which have been able to become a part of the global production network are the ones which have industrialised the fastest. And leading growth economists (e.g. Grossman and Helpman 2002) are basing their models on a systematic analysis of global production networking strategies.

Building on this work, I have developed a broader concept that emphases three essential characteristics (Ernst 2002a, 2002b, 2003, 2005c):

- *asymmetry*: lead firms ('flagships') dominate control over network resources and decision making;
- *knowledge diffusion*: the sharing of knowledge is the necessary glue that enables these networks to grow; and
- *scope*: GPNs encompass all stages of the value chain, not just production.

GPNs differ from multinational corporations (MNCs) (as described in Boyson and Han, Chapter 2 in this volume) in three important ways. First, these networks cover both intra-firm and inter-firm transactions and forms of coordination: a GPN links the flagship's own subsidiaries, affiliates and joint ventures with its subcontractors, suppliers and service providers, as well as partners in strategic alliances. A network flagship like IBM or Intel breaks down the value chain into a variety of discrete functions and locates them wherever they can be carried out most effectively, where they can improve the flagship's access to resources and capabilities, and where they are needed to facilitate the penetration of important growth markets.

Second, GPNs differ from MNCs in that a great variety of governance structures is possible (see Dee, Chapter 10 in this volume). These networks range from loose linkages that are formed to implement a particular project and that are dissolved after the project is finished (so-called virtual enterprises) to highly formalised networks ('extended enterprises'), with clearly defined rules, common business processes and shared information infrastructures. What matters is that formalised networks do not require common ownership: these arrangements may or may not involve control of equity stakes.

Third, 'vertical specialisation' ('outsourcing' in business parlance) is the main driver of these networks (Ernst 2002b). GPNs help flagships to gain quick access to skills and capabilities at lower-cost overseas locations that complement the flagships' core competencies. As the flagship integrates geographically dispersed production, customer and knowledge bases into global production networks, this may well produce transaction cost savings. Yet the real benefits result from the dissemination, exchange and out-sourcing of knowledge and complementary capabilities.

Over time, the focus of outsourcing is shifting from assembly-type manufacturing to knowledge-intensive support services, like supply chain management, engineering services, and new product introduction. Outsourcing may also include design and product development. This indicates that GPNs also differ from traditional forms of subcontracting – much denser interaction between design and production and other stages of the value chain require substantially more intense exchange of information and knowledge. Network flagships increasingly rely on the skills and knowledge of specialised suppliers to enhance their core competencies.

What distinguishes global innovation networks?

GINs share most of the above characteristics of GPNs, but they also differ. Take as an example changes in the methodology and organisation of chip design, a highly complex innovation activity (Ernst 2005a, 2005b).

Until the mid-1980s, global system companies and semiconductor firms did almost all their chip design in-house. Vertical integration focused on the design of an individual ontrol over network resources and

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component to be inserted on a printed circuit board. Since the mid-1990s, however, there has been an upheaval in chip design methodology owing to intensifying pressures to improve design productivity combined with increasingly demanding performance features of electronic systems.[10]

'System-on-chip' design combines 'modular design'[11] and design automation to move design from the individual component on a printed circuit board closer to 'system-level integration' on a chip. Such design has fostered vertical specialisation in project execution, enabling firms to disintegrate the design value chain as well as to disperse it geographically. This has given rise to complex, multi-layered global GINs.

Three GIN layers can be distinguished. The first is the network core, which encompasses five strategic groups of firms. A 'system company' (like IBM) defines the concept, but may well outsource everything else. Chip design may take place within the 'system company', an integrated global semiconductor firm (like Intel), a 'fabless'[12] design house (like Xilinx), or a combination of these. Chip fabrication and assembly also may be outsourced to specialised suppliers. A secondary GIN layer consists of suppliers of tools for electronic design automation, verification, and chip testing. This layer also includes licensors of design building blocks (for example, ARM Ltd processors) and design implementation services. And a third layer may involve system contract manufacturers, such as Flextronics or Taiwan's Foxconn.

Initially, vertical specialisation loosened the bonds between design and fabrication. This process started with application-specific integrated circuit design, where the goal was to avoid the high cost and time required to design a full-custom chip.[13] The Taiwan Semiconductor Manufacturing Company (TSMC), established in 1987, was an important catalyst. TSMC provides contract chip fabrication ('silicon foundry') services for fabless design houses that outsource chip fabrication and target specialised niche markets. Until the early 1990s, global design networks were centred on the well-known symbiotic fabless–foundry relationship, and hence retained a relatively simple structure.

Over time, however, vertical specialisation has increased the number and variety of network participants, business models, and design interfaces, bringing together design teams from companies that drastically differ in size, market power, location, and nationality. In one interview I conducted, a GIN included the following participants:

- a Chinese system company, which defined the system architecture;
- a Taiwanese contract manufacturer, which produced the resulting electronic equipment;
- an American integrated global semiconductor firm, which provided a design platform; and
- a European firm, which provided an embedded processor as an important design building-block.

Additional network participants included:

- fabless design houses from the United States and Taiwan;
- silicon foundries from Taiwan, Singapore, and China;
- chip-packaging companies from Taiwan and China;

- tool vendors for design automation and testing from the United States and India; and
- design support service providers from various Asian countries.

Intra-firm versus inter-firm innovation networks

Global firms like Intel and TI expand their intra-firm GINs by investing in offshore R&D labs (Table 3.1).

Take Intel as an example. Its labs in Santa Clara, Folsom and Austin remain primary locations for core technology development and applied research, while Haifa (established in 1974) is focused on processor research and Nishny Novgorod on software development. However, most of the action now is in Asia. In addition to its existing seven labs in Asia, Intel is planning to expand rapidly both the number of labs and their headcounts. Bangalore, Intel's largest lab outside the United States, conducts leading-edge dual processor development. With a workforce of around 2,700, management is seeking ways of recruiting additional engineers. In Shanghai, Intel has recently expanded its R&D team to focus on applied research to identify new applications for emerging markets. The Bangalore lab of TI signals the speed and depth of innovation offshoring to Asia. Established in 1985, it is TI's largest lab outside the United States, with more than 2,500 employees. By 1989 it was able to develop ASIC CAD libraries. Since 1998, it has conducted integrated development projects

Table 3.1 Intel's global innovation network

Location	*Site*	*Workforce*	*Function*
US (11 labs)	Santa Clara, Folsom, Austin		Core technology development
Asia (7 labs, more planned)	Bangalore	2,700 (largest lab outside US)	Leading-edge processor development
	Penang	500	Design implementation
	Shanghai	100++	Linux-based solutions for telecoms; new applications for emerging markets
	Beijing	50++	Platform and architecture lab
Israel	Haifa	1,400 since 1974	Processor research
Russia	Nizhny Novgorod	200++	Software

Source: Interviews conducted by the author.

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	Function
	Core technology development
est : US)	Leading-edge processor development
	Design implementation
	Linux-based solutions for telecoms; new applications for emerging markets
	Platform and architecture lab
1974	Processor research
	Software

for highly complex system-on-chip design. Since 2000, it has had the global mandate for co-developing 3G wireless chipsets and wireless local area network chipsets.

Global firms also outsource some stages of innovation, especially those related to product development, to specialised offshore suppliers as part of complex inter-firm GINs. For instance, global brand leaders for laptops and handsets use design services provided by so-called ODMs, mostly from Taiwan, for new product development. ODMs either implement a detailed set of design specifications provided by the global brand leader or provide their proprietary integrated 'turnkey' solution to basic performance parameters requested by the global brand leaders. In addition, global system companies (like IBM) and integrated device manufacturers (like Intel) are outsourcing to Asian fabless design houses the development of specific design building blocks and design implementation services (Ernst 2005a, 2005b).

The result is that, instead of a few pre-eminent centres of innovation, like Silicon Valley in the United States, there are now 'multiple locations for innovation ... around the world, and even lower-order or less developed centres can still be sources of innovation' (Cantwell 1995: 172). In chip design, for instance, a handful of new, but rapidly expanding, clusters is emerging in Asia in places like Hsinchu, Taipei, and Tainan (in Taiwan); in Shanghai, the Yangtze River Delta, Beijing, Shenzhen, the Pearl River Delta and Xián (China); in Seoul (South Korea); in Bangalore, Noida, Chennai, Hyderabad, Mumbai, Puneh and Ahmedabad (India); in Penang and Kuala Lumpur (Malaysia); and in Singapore (Ernst 2005a).

Centrifugal forces

Moreover, there is a growing recognition that the balance is shifting from 'centripetal' to 'centrifugal' forces. In other words, the globalisation of markets, technology, competition, and strategy and the resultant opening of corporate innovation systems have boosted the forces for geographical decentralisation of R&D. 'Pull' factors that attract R&D to particular locations include demand-oriented and supply-oriented forces and policies. 'Centrifugal' forces can be stronger than 'centripetal' forces when the host country market is large, grows rapidly, and becomes more sophisticated.

Supply-oriented forces are especially important in high-tech industries like electronics (Dalton and Serapio 1999: 40; Ernst 1997). Proximity to global manufacturing bases matters. However, the search for lower-cost overseas R&D personnel and for new ideas and innovative capabilities is increasingly important. As the pace and cost of technological development escalate and as the sources of breakthrough general-purpose technologies proliferate, companies must seek access to a wider range of scientific and technological skills and knowledge than is available in the home market.

We need to distinguish between 'home-base-exploiting' and 'home-base-augmenting' overseas R&D labs (Kuemmerle 1996). 'Home-base-exploiting' overseas R&D has been around for a long time. Its *raison d'être* is to transfer knowledge from the corporation's home base for commercialisation in overseas markets. The key requirement for overseas R&D is the adaptation of products, services, and production processes to local needs and resource endowments.

By contrast, 'home-base-augmenting' overseas R&D has become considerably more important during the last decades of the 20th century. Its rationale is 'external knowledge sourcing' – that is to say, tapping into new knowledge from an increasing number of overseas local innovation clusters, transferring that knowledge back to the home base (Kuemmerle 1997: 66), and combining these diverse technologies to create new products and processes (e.g. Granstrand *et al.* 1997). Hence, augmenting overseas R&D requires much more than adaptive engineering. It includes product development as well as applied and fundamental research.

Finally, what makes it possible to exchange complex knowledge among research teams that are located at distant locations? Research on the dynamics of global innovation networks shows that members of a specialised knowledge community – the people who share specialised skills like analog chip design – share rules and codes for exchanging knowledge. Even when dispersed far away in space, members of such communities 'will share more jargon and trust among each other than with any outsider within their present local communities. And even when meetings are required, their frequency will not necessarily be as high as to impose co-localisation as a necessary requirement for belonging to the epistemic community' (Breschi and Lissoni 2001: 991).

In short, for innovative activities that require complex knowledge it is now possible to create and connect teams of knowledge workers in distant locations, such as Silicon Valley, Seoul, Taiwan's Hsinchu Science Park, Beijing, Shanghai, Bangalore, Delhi and Hyderabad. The emergence of these kinds of multiple innovation clusters underlies the spread of innovation offshoring.

Driving forces

Innovation offshoring is driven by the same forces that gave rise to the offshoring of industrial manufacturing – liberalisation and technology (Dee, Chapter 10 in this volume; Ernst 1997, 2002b, 2005c). However, both forces have now reached a much higher level, pushing globalisation beyond markets for goods and finance into markets for technology and knowledge workers (Ernst 2006a).

Institutional change through liberalisation has played an important role in reducing constraints on the organisational and geographical mobility of innovation. Liberalisation includes four main elements: trade, capital flows, FDI, and privatisation. These different forms of liberalisation hang together. Trade liberalisation typically sparks an expansion of trade and FDI which, in turn, increases demand for cross-border capital flows. This increases pressure for liberalisation of capital markets, which forces more and more countries to open their capital accounts. This also encourages liberalisation of FDI and privatisation 'tournaments'.

The overall effect of liberalisation has been to reduce the cost and risks of international transactions and to considerably increase international liquidity. Global corporations have been the primary beneficiaries. Liberalisation provides them with a greater range of choices for market entry, be it via trade, licensing, subcontracting or franchising (*locational specialisation*); better access to external resources and capabilities that they may need to complement their core competencies (*outsourcing*); or fewer constraints on the geographic dispersion of the value chain (*spatial mobility*). Hence, liberalisation has acted as a powerful catalyst for the expansion of global production and innovation networks.

In addition, technology has played an important role in increasing the mobility of innovation. This is true in particular for the rapid development and diffusion of information and communication technology. The high cost and risk of developing IT have forced companies to search for lower-cost locations for R&D. Equally important is that IT and related organisational innovations provide effective mechanisms for constructing flexible network arrangements that can link together and coordinate economic transactions among geographically dispersed locations. IT-enabled network management reduces the cost of communication, helps to codify knowledge through software tools and databases, enables remote control, and facilitates exchange of tacit knowledge through audiovisual media.

This has substantially reduced the friction of time and space not only for sales and production, but also for R&D and other innovative activities. IT-enabled network management has facilitated the exchange of knowledge among diverse knowledge communities at distant locations that work together on an innovation project. In essence, IT has fostered the development of leaner and more agile production and innovation networks that cut across firm boundaries and national borders.

Liberalisation and IT have drastically changed the dynamics of competition and industrial organisation. Competition now cuts across national borders. The firm must be present in all major growth markets (dispersion). It must also integrate its activities on a worldwide scale in order to exploit and coordinate linkages between these different locations (integration). In addition, competition cuts across sector boundaries and market segments. Mutual raiding of established market segment fiefdoms has become the norm, making it more difficult for firms to identify market niches and to grow with them.

Vertical specialisation

To cope with the growing complexity of competition, global companies have had to adjust their strategies and organisation. Competitive success critically depends on vertical specialisation. Global firms selectively outsource certain capabilities from specialised suppliers and 'offshore' them to new, lower-cost locations. While vertical specialisation initially focused on final assembly and lower-end component manufacturing, increasingly it is being pushed into higher-end value-chain stages, including product development and research.

To make this happen, global firms have had to adopt collective forms of organisation, shifting from the multidivisional (M-form) functional hierarchy (Chandler 1977) to the networked global flagship model (Ernst 2002b).

The electronics industry has been an important breeding ground for this new industrial organisation model.[14] A massive process of vertical specialisation has segmented an erstwhile vertically integrated industry into closely interacting horizontal layers (Grove 1996). Until the early 1980s, IBM personified 'vertical integration.' Almost all ingredients necessary to design, produce, and commercialise computers remained internal to the firm. This was true for semiconductors, hardware, operating systems, application software, and sales and distribution.

Since then, however, vertical specialisation has become the industry's defining characteristic (Ernst 2003). Many activities that a computer company used to handle internally are now being farmed out to multiple layers of specialised suppliers. This has given rise to rapid market segmentation and to an ever-finer specialisation within each of the above value-chain stages. As firms accumulate experience in managing global distribution and production networks and learn from successes and failures in inter-firm collaboration, they have been able to expand vertical specialisation.

These adjustments were especially important in the choice of product and process specialisation, investment funding, and human resources management. As they feed into each other, small changes in any of these functions require adjustments in all the other aspects of the business model.

Vertical specialisation has been made possible by the spread of venture capital and related regulatory changes in the financial sector[15] that drastically changed corporate strategies of investment funding. US venture capital firms have provided access to a massive infusion of capital from US pension funds as well as hands-on industrial expertise. As a result, start-up companies in the electronics industry have been able to raise capital for high-risk innovation projects. At the same time, global industry leaders increasingly have used stock to attract and retain global talent and to acquire innovative start-up companies (Lazonick 2003).

This has led to a dramatically diminished commitment to long-term employment in the electronics industry. The result has been a substantial increase in the inter-firm and geographical mobility of labour, especially for highly skilled engineers, scientists, and managers. In the United States, the emergence of a 'high-velocity labor market' (Hyde 2003) for IT skills is driven by the proliferation of start-up companies, a drastic increase in the recruitment of highly educated foreigners, and the spread of lavish incentives (such as stock options) to induce job-hopping.

These practices have raised the cost of employing IT workers in the United States. For instance, between 1993 and 1999, computer scientists and mathematicians experienced the highest salary growth (37 per cent) of all US occupations (National Science Board 2004: chapter 3, p. 14). Average real annual earnings of full-time employees in California's software industry rose from $80,000 in 1994 to $180,000 in 2000, only to fall drastically to below $100,000 in 2002 after the bursting of the 'new economy' bubble.

But even in the midst of the IT industry recession, employees in the US IT industry continued to earn, on average, far more than workers in most other sectors of the economy, and between five and ten times more than their counterparts in Asia (outside Japan). In 2002, the average annual wage in the US IT industry was $67,440 ($99,440 in the software industry), compared with $36,250 in all private sector industries (US Department of Commerce 2003: appendix table 2.3). This has created a powerful catalyst for US IT firms to increase their overseas investment in R&D to tap into the growing pool of educated and experienced IT talent that is available in Asia at much lower wages.

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Changes in innovation management

The above transformations in strategy and organisation have provoked fundamental changes in innovation management, further enhancing the mobility of innovation. There is a transition under way towards more open corporate innovation systems based on increasing vertical specialisation of innovation.

Corporate innovation management must address five tasks simultaneously: (a) develop and protect IPRs; (b) upgrade innovative capabilities (including R&D);[16] (c) recruit and retain educated and experienced knowledge workers; (d) adjust innovation process management (methodologies, organisation and routines) in order to improve efficiency and time to market; and (e) match all four tasks with the corporation's business model.

No firm, not even a global market leader like IBM, can mobilise internally all the diverse resources, capabilities and bodies of knowledge that are necessary to fulfil these tasks. As a consequence, both the sources and the use of knowledge have become increasingly externalised. Firms now must supplement the in-house creation of new knowledge and capabilities with external knowledge sourcing strategies. There are strong pressures to reduce in-house basic and applied research and to focus primarily on product development and the absorption of external knowledge (e.g. Chesbrough 2003).[17]

No longer does this externalisation of innovation stop at the national border. Firms increasingly need to tap sources of knowledge that are located overseas (Ernst 2002a). The result is that GINs cut across sectors and national borders (Ernst 2005b). According to the most recent *Science and Engineering Indicators 2004* report by the US National Science Board:

> ... the speed, complexity, and multidisciplinary nature of scientific research, coupled with the increased relevance of science and the demands of a globally competitive environment, have ... encouraged an innovation system increasingly characterised by networking and feedback among R&D performers, technology users, and their suppliers and across industries and national boundaries. (National Science Board 2004: Volume I, page IV-36)

Global markets for technology

Global firms have been able to move to an open innovation system because an increasing division of labour in innovation has given rise to global markets for technology (Arora *et al.* 2001). Global firms can now outsource knowledge needed to complement their internally generated knowledge. Furthermore, they can elect to license their technology and, hence, enhance the rents from innovation.[18]

There is now much greater scope for external technology sourcing. Global markets for technology imply that a firm's competitive success critically depends on its ability to monitor and quickly seize external sources of knowledge (e.g. Iansiti 1997). As demonstrated by Iansiti and West (1997), a company can leverage basic or generic technologies developed elsewhere. This allows it to focus on developing unique applications that better suit the needs of specific overseas markets.

Innovation offshoring helps global firms to hedge against failures of internal R&D projects or against slippage in capacity expansion. Innovation offshoring also makes it possible to multiply opportunities for technology diversification. There is a choice between 'building or buying' new business lines. Furthermore, global firms can accelerate the speed of the innovation cycle and reduce the very high fixed cost of investing in internal R&D.

Late entrants from Asia can also benefit from external knowledge sourcing. While they continue to trail behind industry leaders in their in-house technological capabilities, Asian companies can now use external technology sourcing to enhance their in-house innovative capabilities (e.g. Ernst 1997, 2000).

An important constraint to the emergence of global markets for technology is a set of unresolved issues related to the protection of IPRs. Fear of IPR theft has shaped corporate decisions on the location and nature of R&D centres. As discussed below, it also poses important challenges for government policies. There is broad consensus that global firms are unlikely to establish an R&D lab in a country that cannot guarantee effective IPR protection. The underlying assumption, supported by a vast literature (e.g. Teece 2000), is that a strong IPR Regime is critical to encourage innovation.

Note however that, despite weak IPR protection, Asian countries, and especially China, have been able to attract a massive inflow of R&D investments by global corporations. One possible explanation for this puzzle may be that IPR protection may be less important for adaptive and production support R&D or when products that result from overseas R&D in China are exported to the world market and not to the domestic China market. In this case, IPR theft by local firms may be less likely.

An additional explanation may be that vertical specialisation ('fragmentation') within GINs may allow global firms to navigate better the pitfalls of weak IPR regimes, especially for export-oriented R&D. 'Vertical specialisation' means that an innovation project consists of multiple building blocks that complement each other and that can only be used jointly. Global firms can establish R&D affiliates in countries with weak IPR protection (for example, China) to undertake R&D on technologies that require multiple complementary elements as part of a complex technology system. In this case, IPR theft for a particular technology is unlikely to generate economic rents for the perpetrator.

There is no doubt, however, that, over time, effective IPR protection will increase in importance, especially if Asian countries seek to attract more advanced foreign R&D projects and as domestic firms develop their own IPRs. As indicated below, this raises important policy issues for Asian governments that need to be addressed in future research.

Evolving global markets for knowledge workers

The growing availability of knowledge workers outside the dominant corporations and their increasing geographical mobility have been equally important for the gradual opening of corporate innovation systems. As demonstrated in the first part of this chapter, the supply of knowledge workers suitable for work in global corporations is growing substantially in Asia's leading electronics exporting countries. The same is true in eastern Europe and Latin America.

The result is an evolving global market for knowledge workers, which has created vast new talent sources. At the urging of American business, the US government responded to the changes in the knowledge worker market by allowing greater immigration of foreign students and professionals, especially for S&E. Until the turn of the century, the United States was the main beneficiary of the globalisation of knowledge workers.

A 1998 National Science Foundation study showed that more than 50 per cent of the post-doctoral students at the Massachusetts Institute of Technology and Stanford were not US citizens and that more than 30 per cent of computer professionals in Silicon Valley were born outside the United States (quoted in National Science Board 2004). Data from the 2000 US Census show that in S&E occupations, approximately 17 per cent of bachelor's degree holders, 29 per cent of master's degree holders, and 38 per cent of doctorate holders were foreign born.

This has enabled US start-up companies to pursue 'learning-by-hiring away' strategies. They could rapidly ramp up complex innovation projects by recruiting highly experienced personnel that were trained by other corporations or countries. But the main beneficiaries were major global US firms that were able to reduce the cost of research, product development, and engineering by shifting from national to global recruitment strategies.

Over the past few years, global firms have faced new challenges in global markets for knowledge workers. The shift to knowledge-intensive industries has increased the importance and scarcity of well-trained knowledge workers. At the same time, ageing populations are reducing the available working populations in Europe, Japan and the United States. With the exception of India, ageing is also a serious challenge for Asia's leading exporting countries.[19] As a result, the growth of global markets for knowledge workers is likely to slow down. This implies that, over the next decade or so, global electronics firms will find it increasingly difficult to attract – and retain – enough qualified workers, especially scientists and engineers.

Intensifying competition for knowledge workers also reflects negative side effects of the aforementioned changes in corporate strategy. For instance, in their quest to improve return on investment, global electronics firms have increased the use of temporary workers and have outsourced so-called non-core activities. The resultant downsizing of permanent workforces has increased the vulnerability of these companies to sudden shifts in demand.

Some global corporations pushed downsizing to the limits, especially after 2000. In the words of one expert, 'they're running themselves so lean that if they get a little sand in their gears, the whole organisation breaks down'.[20] If demand shifts to new product generations that require new technologies, these firms must search for specialised talent to fill the gaps caused by previous rounds of downsizing. As a result, crisis management has become the dominant concern of human resources managers.

Global corporations are responding to the intensifying competition for scarce global talent by moving R&D and engineering overseas, especially to populous countries like China and India that have emerged as important new sources of lower-cost S&E students and workers. For many high-tech companies, competing for scarce global talent has become a major strategic concern. As a result, global sourcing of knowledge workers now is as important as global manufacturing and supply chain strategies. The goal is to diversify and optimise a company's human capital portfolio through aggressive recruitment in global labour markets.

The demand for 'bottleneck skills', such as experienced design engineers for analog integrated circuits, has led to global 'auction markets' for knowledge workers. These 'auctions' enable knowledge workers to sell their talents to the highest bidder. Overall, however, the emergence of a global market for knowledge workers seems to have kept a tight cap on increases in remuneration (Lazonick 2005). This is because the leading global electronics firms can tap this market for workers who are readily available for hire and need not require extensive internal training or the inducement of lifelong employment.

By the same token, this market can be highly volatile and pose substantial risks. At any time, demand for knowledge workers may outstrip supply in some locations and supply will exceed demand in other locations. Especially for more senior and experienced engineers and project managers, demand continues to overshoot supply in Asia's major offshore locations.

In China, for instance, there is a paucity of project managers well versed in implementing state-of-the-art innovation process management. Competition for scarce talent (especially in S&E) has intensified, as large Chinese companies, such as Lenovo and Huawei, are now seriously competing for the best talent.[21] In India, it is less of a problem finding experienced project managers owing to India's long-established links with the United States and the roles played by non-resident Indians. But turnover rates are extremely high, and global firms are facing serious problems in establishing effective control and efficient processes (NASSCOM and McKinsey 2005).

The volatility of global markets for knowledge workers reflects a fundamental characteristic of innovation offshoring – its geographic dispersion remains concentrated in a handful of new clusters. This tends to prematurely exhaust the limited supply of suitable engineers in these clusters, giving rise to severe bouts of localised wage inflation and excessive turnover rates for key personnel. Global corporations are forced to constantly readjust and rebalance their location decisions and network management strategies and to continuously search for and experiment with new locations.

As a result, companies that have accumulated some experience in innovation offshoring are now shifting from 'labour-cost arbitrage' to strategies to reduce the extremely high turnover and retain scarce talent. In fact, in well-established offshore locations in Bangalore or Shanghai global firms are now willing to conduct 'exciting' R&D projects that can attract the best and brightest of the local talent pool.

At the same time, global firms are constantly seeking to identify new offshore locations with lower-cost populations of knowledge workers, such as lower-tier cities in China and India, or new locations in Vietnam, Romania, Armenia and Slovakia. But to develop these new locations, global firms must invest in the training of local knowledge workers.[22]

Implications for innovation offshoring

The transition to open innovation networks has changed the way in which global corporations are using their overseas R&D centres in Asia. A recent study about

R&D investment in China by major international companies illustrates this point (Armbrecht 2003). The study emphasises that, while cost savings matter, global firms are expanding their R&D in China primarily for strategic reasons. They want to tap into the vast pool of talent and ideas in order to stay abreast of competitors in the increasingly sophisticated markets of China and Asia. The Industrial Research Institute, which conducted the study, predicts a substantial increase in innovation offshoring in China.[23] The institute argues that the focus of overseas R&D labs is shifting from support and adaptation to the sourcing of China's emerging technologies and talent pools.

The following taxonomy (Ernst, forthcoming) helps to capture the evolution of R&D labs established by global electronics firms in China.

- 'Satellite' R&D labs, the least developed type of lab, combine elements of 'home-base-exploiting' and 'home-base-augmenting' R&D. These labs are of relatively low strategic importance, as evidenced by their vulnerability to budget cuts decided by headquarters.
- 'Contract' R&D labs describe the pure-play version of 'innovation offshore outsourcing'. For these labs, China's role is confined to the provision of lower-cost skills, capabilities and infrastructure. While dense information flows link these labs with R&D teams at headquarters and other affiliates, knowledge exchange remains tightly controlled, and highly unequal.
- The term '(more) equal partnership' labs is reserved for labs at the highest stage: those R&D labs of global firms that are charged with a regional or global product mandate. For these labs, barriers to knowledge exchange are supposed to be much lower, and may eventually give way to full-fledged mutual knowledge exchange.

Recent research documents the continued domination of satellite and contract R&D labs (e.g. von Zedwitz 2004; Gassmann and Han 2004; Li and Zhong 2003). However, there are also examples of (more) equal partnership arrangements, especially related to the development of China's alternative standards in mobile telecommunications, open source software, and digital consumer electronics (Ernst and Naughton 2005; Garcia and Burns 2006).

POLICY IMPLICATIONS FOR ASIA

This chapter demonstrates that innovation offshoring results from fundamental changes in business organisation. 'Vertical specialisation' is no longer restricted to the production of goods and services. It now extends to all stages of the value chain, including research and new product development. As the number of specialised suppliers of innovation modules increases, this provides a powerful boost to the organisational and geographical mobility of innovation.

Over the years, this process has taken on an increasingly international dimension – global firms construct GINs to improve the productivity of R&D by recruiting knowledge workers from cheaper, non-traditional locations.

Since the turn of the century, these networks have been extended to emerging new innovation clusters, especially in Asia. This trend is expected to provide global firms with a powerful new source of competitive advantage because they can now quickly generate more and higher-value innovation at lower cost.

Benefits and challenges

For Asian countries, innovation offshoring could provide substantial benefits, *provided* adequate policies and business strategies are in place. Equally important are the removal of barriers to trade and investment and the establishment of a robust IPR regime that combines protection with incentives for the creation of new intellectual property.

Case studies show that integration into global innovation networks could facilitate knowledge diffusion and learning, and that it could catalyse efforts by local firms to develop innovative capabilities (Ernst 2005c). To the degree that this would be translated into the creation and successful commercialisation of new products and services, this might help Asian efforts to counter the decreasing returns to the export-led 'global factory' model. It might also help Asian countries to move from extensive growth with diminishing returns to augmented growth with constant or increasing returns to investment.[24]

However, massive challenges must be mastered before Asian countries can exploit the above opportunities. To benefit from innovation offshoring, Asian governments now need to develop policies in three inter-related areas: by attracting and expanding R&D investments by global firms; reducing opportunity costs of innovation offshoring; and enabling Asian firms to develop their own innovative capabilities.

Most debates have focused on the first policy challenge. A combination of trade and investment liberalisation and state-supported incentives are widely used policy tools to induce foreign R&D investments. However, if Asia fails to meet the other two challenges, it is unlikely to reap sustainable benefits from innovation offshoring.

Creating an enabling environment

Countries and regions around the globe are fiercely competing to attract and expand R&D by global firms. The goal is to become better connected to GINs. As countries progress in their economic development, they increasingly rely on knowledge exchange through these networks.

As more and more countries become connected to these networks, there will be increased pressure on other countries to attract foreign R&D as well, in order to avoid being sidelined as pariahs in an increasingly inter-connected global innovation system. Hence, whether one likes it or not, integration into GINs seems to emerge as an increasingly important determinant of future prospects for economic development.

But there are also concerns that network integration may be a poisoned chalice. It is feared that integration into GINs may at best produce only short-term benefits and may not provide the means for upgrading the host country's industry to higher value-added and more knowledge-intensive activities.

Unfortunately, research on these issues is still at a very early stage: there are few robust data, and getting data on the offshoring of R&D is becoming more difficult, as global corporations are loath to disclose this sensitive information because it could negatively affect their stock market quotation (Ernst 2006a).

However, the literature does provide theoretical as well as empirical reasons to argue that, from a developing country's policy perspective, integration into GINs may provide substantial benefits (e.g. Lall 2000; Ernst *et al.* 1998). In a case study of Malaysia's electronics industry, Ernst (2004) demonstrates that attracting foreign R&D may do more than compensate for initial weaknesses of the domestic knowledge base. Such international knowledge sourcing may also facilitate the adjustment of business organisation and strategy to abrupt changes in technology and markets. Attracting R&D by global firms may also catalyse the development and the diffusion of innovative capabilities *ahead* of what the market would provide.

All of this implies that Asian countries cannot build their innovative capabilities by solely relying on their national innovation systems and by developing localised innovation clusters. For quite some time, these countries will have to draw primarily on foreign sources of knowledge as the main vehicle of learning and capability formation. However, in order to reap the potential benefits from innovation offshoring, Asian countries must have in place vigorous policies to reduce the potentially high opportunity costs that may result from 'brain drain' (both domestic and international), when global firms are crowding out the local market for scarce skills. Other costs include the possible deterrence effect on local R&D by the involvement of global labs; the acquisition by global firms of innovative local companies; and the disproportionately high benefits that may accrue to a foreign parent company.

In other words, innovation offshoring can produce sustainable long-term economic benefits for Asian countries only if policies exist to develop strong local companies that can act as countervailing forces to the accumulated strengths of global firms. But for Asia to cope with the complex challenges and opportunities of innovation offshoring, new policies are required that are very different from earlier top-down 'command economy' industrial policies that were typical for the 'East Asian development model'.

Recent research on the offshoring of chip design to Asia demonstrates the importance of well-functioning product and factor markets (Ernst 2005a). Market failures *per se* may not necessarily prevent global firms from investing in R&D, especially if this generates windfall profits. The main concern appears to be a certain degree of transparency and predictability that allows for the longer-term planning that is necessary for R&D. Host country policies can actually use idiosyncratic market characteristics to differentiate a particular location and to increase its attractiveness for foreign R&D.

For instance, differences in financial markets can lead to diverse approaches to investment finance (for example, debt, equity or retained earnings) that will influence the volume and direction of investment in complementary R&D activities by local firms. In addition, the examples of South Korea and China demonstrate that host country policies to define alternative standards (for example, for 3G mobile communication systems or open source software), combined with the use of government procurement, can be powerful tools in attracting foreign R&D.

In the final analysis, however, policies to attract R&D by global firms can succeed only if they fulfil two critical conditions: they need to balance effective protection of IPRs with incentives for knowledge diffusion to local firms; and they need to provide a sufficiently large pool of knowledge workers who possess the skills needed to benefit from innovation offshoring.

Policies on intellectual property rights

If Asian countries seek to attract more advanced foreign R&D projects, an effective protection of IPRs becomes as important as the development of their own IPRs.

Well-defined enforceable patents reduce transaction costs, and thereby help increase the mobility of knowledge. In theory, smaller firms (for instance, local Asian firms) are expected to draw the greatest benefits. It is assumed that a stronger IPR regime increases the returns from investments in technology development more substantially for smaller innovative start-up companies than for the larger integrated companies.

In reality, however, the market for patents displays important imperfections (von Hippel 2005; Merrill *et al.* 2004; Cohen and Merrill 2003). For instance, reaping the benefits of IPRs may be costly, and small firms may face greater difficulties than large corporations in patenting. Even more important is the so-called 'anti-commons' problem (Arora *et al.* 2001: 263 ff). It is unrealistic to assume that each patent is associated with one innovation only.

In the IT industry this is a serious problem, as innovative activities require highly complex knowledge. In complex technology systems, innovation is systemic and cumulative, requiring many different pieces of knowledge, some of which may be patented and owned by companies with conflicting interests. Typically, however, IPR protection is fragmented. The resulting constraints to innovation can be substantial. For instance, for the inventor, the cost of 'inventing around' blocking patents can be extremely high. And the higher these costs are, the weaker is the innovator's bargaining power in the licensing negotiations.

This raises two important, but very tricky, policy questions. How should different contributors be rewarded? And who is likely to capture most benefits? While institutional arrangements for IPR protection matter, the outcome is primarily determined by bargaining power. This indicates how difficult it is for Asian governments to find the level of IPR protection that balances the interests of global and local companies.

It is important to emphasise that the protection of IPRs needs to be complemented with policies that foster the exchange of knowledge embodied in these IPRs. One critically important aspect is the development of effective linkages between universities and public research institutes, on the one hand, and R&D establishments of private business on the other (e.g. Ernst and Mowery 2004). There is a widespread perception that US leadership in industrial innovation owes much to the capacity of its higher education system to provide multiple and dense interlinkages between university research and innovation in enterprises.

This explains why major developing nations have launched or are considering significant public policy initiatives to strengthen university–industry linkages, in many cases consciously modelling these efforts on the perceived 'success factors' in the United States. Many of these initiatives seek to spur local economic development based on university research. This includes, for instance, the creation of 'science parks' located near research university campuses; support for 'business incubators' and public 'seed capital' funds; and the organisation of other forms of 'bridging institutions' that are believed to link universities to industrial innovation.

An important challenge for public policy is to establish a legal framework and a set of regulations that can facilitate the exchange of IPRs. A second equally important task would be to assign IPRs to the results of research that the government funds. One policy initiative that has attracted considerable attention from governments elsewhere is the 1980 Bayh–Dole Act in the United States, which provided a framework for the encouragement of patenting and licensing of publicly funded R&D results by universities.

But within the United States, the effects and desirability of the Bayh–Dole Act remain controversial (Mowery *et al.* 2004). There are concerns that this approach may slow down the diffusion of useful basic knowledge to the rest of society. While US universities have been important sources of knowledge and other key inputs for industrial innovation, much of this economic contribution has relied on channels other than patenting and licensing. Such broader university–industry linkages include knowledge exchange through, for instance, publications, conference presentations and faculty consulting, as well as the movement of personnel between universities and industry.

It is necessary to explore under what conditions the US approach to university–industry linkages can serve as a useful framework for policy elsewhere. Unfortunately, very little scholarly research is available to guide policy debates on this important issue. Research on the role of universities in industrial innovation has focused on the United States, Japan and major European economies (see e.g. Branscomb *et al.* 1999). While there are a few pioneering studies on national innovation systems in Asian countries like South Korea, Taiwan, China and Malaysia (e.g. Kim 1997; Naughton and Segal 2002; Rasiah 1995), the role of university–industry linkages has not been at the centre of analysis. Most importantly, there is no systematic cross-national comparative research on the diverse development trajectories of developing countries' higher education systems and the diverse array of university–industry linkages (Ernst and Mowery 2004).

Policies on education and skill development

Finally, an important yardstick for policies to attract foreign R&D is the supply of well-educated and experienced technicians, engineers, managers and scientists at a cost that is substantially lower than their cost at the home country locations of global firms. This requires incessant efforts on a massive scale to continuously upgrade existing skills and capabilities.

The lack of depth and horizontal mobility in the labour markets that is typical of most Asian countries increases the risk of individual investment in specialised skills. This explains why in many of these countries mismatches between the supply and the demand of specialised skills persist. To reduce these mismatches requires well-thought-out policies.

A recent study on Malaysia's electronics industry (Ernst 2004) shows that policy-makers and industry executives realise the need for new policies to:

- re-skill and re-train production workers, technicians, and engineers;
- expose S&E students to best-practice methodologies and tools and adjust curricula development to evolving labour market needs;
- produce graduates, especially for electrical and electronics engineering, IT, communication technology and circuit design, who are able to combine hardware, software and application knowledge;
- produce experienced managers, especially for strategic marketing, upgrading management, and management of international linkages;
- provide incentives for entrepreneurs that combine street-wise commercial and financial instincts with analytic capacity for strategic decision making;
- develop a cadre of experienced and industry-savvy administrators who are willing to stick out their necks and to do more than just follow the rules (this, of course, requires some incentive alignment);
- align incentives for university professors and academics that encourage close interaction with the private sector (company internships and sabbaticals);
- encourage dense interactions with expatriate nationals who are based in the United States, Australia and Europe, or in Asia; and
- bring in at short notice specialised experts from overseas who can help bridge existing knowledge gaps and who can catalyse necessary changes in organisation and procedures required to develop these capabilities locally.

The last two policy objectives are critical for policies to upgrade Asia's pool of knowledge workers. As global markets for knowledge workers evolve, such policies of leveraging international knowledge communities are also becoming more feasible. In the electronics industry, for instance, these informal social networks link developing countries with the world's centres of information and communications technology (encompassing Silicon Valley and other centres of excellence in less well-known places like Helsinki, Kista/Stockholm, Grenoble, Munich, Tsukuba and Tel Aviv).

This provides Asian countries with invaluable knowledge on global market and technology trends in a way that addresses the needs of domestic firms much better than formal linkages with global firms (Ernst 2006c). International knowledge communities also provide entrepreneurs and venture capitalists that can function in both worlds. This has created alternative and robust mechanisms of knowledge exchange across geographic borders and firm boundaries.

NOTES

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1 Throughout this paper, 'Asia' excludes Japan. Unless indicated otherwise, data are from the author's research (Ernst 2005a, 2005b, 2006a, and forthcoming).

2 'Knowledge workers' are defined to include science and engineering personnel, as well as managers and specialised professionals (in areas like marketing, legal services and industrial design) who provide essential support services to research, development and engineering.

3 Future PAFTAD conferences could help to develop the analysis of impacts of innovation offshoring. As emphasised by Ralph Huenemann at the conference, future research needs to explore whether there is diffusion of innovations from multinational corporation labs to extra-firm labs and identify the main mechanisms for technology diffusion (illustrative case studies can be found in Ernst 2006b, 2006c, 2006d). For one participant at the conference, Jenny Corbett, another important topic for the impact analysis is the connection between the development of GINs and productivity growth in Asia. Such an analysis can build on the findings of new growth theories to establish (a) whether GINs can lead Asia to move from extensive growth with diminishing returns to augmented growth with constant or increasing returns to investment; (b) whether this depends on the number of knowledge workers or the size of R&D expenditure; and (c) whether it depends on creating local capacity to initiate new technologies or on continuing to borrow. All of this indicates to what degree innovation offshoring and GINs are raising new questions for future theoretical and empirical research.

4 In 2000, 85 per cent of global R&D expenditures were concentrated in only seven industrialised countries. The United States occupied the leading position with 37 per cent (Dahlman and Aubert 2001: 34).

5 '*Chaebol*' is a Korean term for a business conglomerate.

6 The two dominant competing global 3G standards are wireless CDMA (W-CDMA) (compatible with existing 'Global System for Mobile Communications' (GSM) operations and supported by European firms), and CDMA 2000 (compatible with existing CDMA operations and supported by US firms).

7 See Farrell *et al.* (2005). 'Young professionals' are defined as university graduates with up to seven years of work experience, and include engineers, finance and accounting specialists, generalist professionals, life science researchers, and quantitative analysts.

8 This cost comparison includes salary, benefits, equipment, office space and other infrastructure.

9 The UNCTAD sample consists of the first 300 firms of the R&D scoreboard of the 700 top worldwide R&D spenders, published by the UK Department of Trade and Industry.

10 'Design methodology' is the sequence of steps by which a design process will reliably produce a design 'as close as possible' to the design target, while maintaining feasibility with respect to constraints.

11 'Modular design' is a particular design methodology in which parameters and tasks are interdependent within units (modules) and independent across them.

12 A 'fabless' company is one that outsources the manufacture (fabrication) of computer chips.

13 An application-specific integrated circuit typically is composed of standard building blocks called 'cells' that are designed to implement a specific customer application.

14 The biotech sector of pharmaceuticals, however, has made the most progress in pushing vertical specialisation into research and development. A senior R&D manager at Merck estimates that '99 per cent of the world's bio-medical research takes place outside our [big pharmaceutical company] research labs' (Ray Hill, quoted in 'Change of culture: how big pharma is picking the best of biotech as a sector starts to mature,' *Financial Times*, 12 January 2006: 13).

15 Important complementary changes in US financial institutions include the launch of the National Association of Securities Dealers Automated Quotations (NASDAQ) in 1971 (making it much easier for start-up firms to go public), the passage of legislation in 1978 that reduced capital gains tax from 49 per cent to 28 per cent, and the 1979 decree by the

Department of Labor that pension fund money could be invested not only in listed stocks and high-grade bonds but also in more speculative assets, including new ventures (Lazonick 2005: 23).

16 'Innovative capabilities' are defined as the skills, knowledge and management techniques needed to design, produce, improve and commercialise 'artifacts', that is, products, services, machinery and processes (Ernst 2002a).

17 Chesbrough's concept of 'open innovation' provides a useful stylised model of this gradual opening of corporate innovation systems (Chesbrough 2003). However, the model fails to address explicitly the international dimension – that is, the development of GINs.

18 The underlying assumption is that, once markets for technology exist, one can codify knowledge sufficiently and develop well-defined and protective IPRs (e.g. Kogut and Zander 1993). However, an excessive reliance on technology licensing may be risky because it cuts the company off from vital system integration knowledge that it needs for continuous innovation (e.g. Grindley and Teece 1997).

19 Ageing populations in China and other leading Asian exporting countries may constrain Asia's future supply of low-cost knowledge workers. In China, one of the by-products of the one-child policy is that in a decade or so many more people will be retiring than entering the workforce (Jackson and Howe 2004). In contrast, India is one of the few countries in which the working-age population is projected to grow for the next 40 years or so, keeping wages low.

20 J.A. Joerres, CEO of Manpower, quoted in Boehm (2005).

21 Until recently, managers working for global corporations could earn 50 per cent more than managers working for local Chinese companies. Now, however, leading Chinese companies offer competitive remuneration packages and aggressively headhunt Chinese managers employed at global firms.

22 This is somewhat ironic in light of the fact that the same firms are less willing to invest in training at home. But it is less puzzling in view of the fact that global firms often seek government support for training. The intensifying incentive tournaments among competing offshore locations suggest that they are quite successful in securing training assistance.

23 Members of the Industrial Research Institute include more than 240 leading global manufacturing firms that perform more than two-thirds of the industrial R&D in the United States.

24 But, as indicated in note 3, case study evidence needs to be complemented with systematic research that measures the incidence of learning and technology diffusion and that establishes the link between innovation offshoring and productivity growth in Asia.

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