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Economics Series

No. 90, July 2006

Innovation Offshoring: Root Causes of Asia's Rise and Policy Implications

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This paper has been prepared for the 31st Pacific Trade and Development Conference (PAFTAD 31) on Multinational Corporations and the Rise of a Network Economy in the Pacific Rim, Guadalajara, Mexico, 10-12 June 2006. A revised version will be published as chapter 3 in: Palacios, Juan J. (ed.), 2007, *Multinational Corporations and the Emerging Network Economy in the Pacific Rim.* London: Routledge.

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Acknowledgements

I owe Juan Palacios a great debt of gratitude for inviting me to present this paper at the 31st Pacific Trade and Development Conference and for his thought-provoking suggestions. I gratefully acknowledge ideas, comments and suggestions from Jenny Corbett, Ralph Huenemann, David Hong, Peng Eng Fong, Peter Petri, Shujiro Urata and Alfonso Mercado. At the East-West Center, I am grateful to Charles Morrison and Nancy Lewis for supporting this research. The Volkswagen Foundation provided generous funding for research on the offshoring of chip design. Kitty Chiu, Peter Pawlicki and Rena Tomlinson provided excellent research assistance.

Introduction

Much economic research on the role of Asia[1] in the global economy has focused on the impact of changes in macro-economic 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 labor that, to a large degree, result from changes in corporate strategies and organization. “Globalization” is a 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 globalization 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

[1] Throughout this paper, “Asia” excludes Japan. Unless indicated otherwise, data are from author’s research (Ernst, 2005 a, 2005b and forthcoming)

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" some stages of innovation to specialized 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 centers, 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, 2005c and 2002a). 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 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, very little research exists that addresses root causes and impacts of innovation offshoring. This paper presents preliminary findings of research on root causes[3]. The analysis focuses on the electronics industry, which dominates East Asia's trade and foreign direct investment[4].

- Part one 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.

- Part two analyzes the forces behind the growing organizational and geographical mobility of innovation within global innovation networks (GINs), and explores what this implies for innovation offshoring.

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[2] "Knowledge workers" are defined to include science and engineering personnel, as well as managers and specialized professionals (in areas like marketing, legal services and industrial design) that provide essential support services to research, development and engineering.
[3] For impacts of innovation offshoring on Asia's innovative capabilities, see Ernst, 2005 d and 2006b.
[4] Research is based on structured interviews with more than 150 electronics companies in the US, Asia and Europe.

- The paper concludes with generic policy suggestions for Asian governments to cope with the new opportunities and challenges of innovation offshoring.

I. Foundations of Asia's Rise

1. 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 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, Ernst, Haggard 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 foreign direct investment (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, 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.

In the semiconductor industry, for instance, roughly 70 percent of its output 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 is 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 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 Korea. China is the world's largest market for telecommunications equipment (wired and wireless), as well as a test bed for advanced third generation 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.

2. Upgrading through technology diversification

Asia's role as the "global factory" will continue to be an important source for 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, 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 locations.

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 (IPR), much of it centered on the United States.[5] 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

[5]In 2000, 85 percent of global R&D expenditures were concentrated in only seven industrialized countries. The United States occupied the leading position with 37 percent (Dahlman and Aubert 2001, p.34).

software companies are seeking to develop and improve the skills, knowledge, and management techniques needed to create and commercialize 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.

3. Achievements

The results of these efforts are impressive. Asian governments and leading electronics and software companies have mobilized 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 lead the world, together with small Nordic countries in Europe, in broadband access and speed. A few regions in China and India that are attracting innovation offshoring are also 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 U.S. Patent and Trademark Office (Wong, 2006; Hicks, 2005).

As a result, new innovation clusters have emerged for broadband technology and applications in Korea and Singapore; for mobile communications and digital consumer devices in 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, Korea's four leading players (Samsung, SK Telecom, KT, and LG) are all engaged in serious efforts to become major platform and contents 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 (ETRI), as well as in R&D labs of the chaebol, to develop complex technology systems like TDX (a switching system) and communication systems that are based on the CDMA (code-division multiple access) standard developed by Qualcomm.

Another important example is China's attempt to develop an alternative third generation (3G) digital wireless standard, called TD-SCDMA (time-division synchronous code-division multiple access), for which it received approval by the International Telecommunications Union (ITU) 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, the Korean LG group, and Taiwanese ODM (original design manufacturing) suppliers, 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.

4. 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 specialized 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 as product development focuses on manufacturability and the production of commercial samples. Asian firms also made substantial progress developing specialized skills required for complex R&D projects.

[6] The two dominant competing global 3G standards are W-CDMA (compatible with existing GSM operations and supported by European firms), and CDMA 2000 (compatible with existing CDMA operations and supported by U.S. firms).

Most importantly, 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 centers 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" (National Science Board 2004: chapter 1, overview, p.8).

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 (NSB 2004, Appendix 2-33). China is experiencing explosive growth in Ph.D.-level degrees in science and engineering, the critical indicator of a country's research capabilities. A recent report prepared for the National Bureau of Economic Research shows that between 1995 and 2003, first-year entrants in science and engineering Ph.D. programs in China increased six-fold, from 8,139 to 48,740. The report concludes that "… (a)t 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 elite universities. A recent McKinsey report argues that, if all negative factors are factored in, only 25 % of India's engineering graduates are suitable for work at global corporations, while the current share in China is only 10%[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% 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 than in high-wage countries.

Highly skilled knowledge workers are much cheaper in Asia (outside of Japan) than in the United States. For instance, the cost of employing a chip design engineer in Asia is typically between 10 to 20 percent 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 percent. Cost savings of such magnitude obviously are of quite significant importance for companies that are under

[7] Farrel, Laboissiere, and Rosenfeld, 2005. McKinsey defines "young professionals" as university graduates with up to seven years of work experience, and includes 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.

constant pressure to improve their return-on-investment, and provide an important incentive for innovation offshoring.

5. Asia's growing exposure to innovation offshoring

This is certainly true for large global corporations who are acting as pace setters for an increase in the offshoring of innovation to Asia. A recent survey of the world's largest R&D spenders shows that the world's leading R&D spenders intend to increase both their intra-firm and inter-firm GINs in Asia (UNCTAD 2005).[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 (6th) and Singapore (9th). 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 same survey projects that the pace of R&D internationalization will accelerate -- as many as 67 percent of the respondents to the UNCTAD survey stated that the share of foreign R&D will increase; only 2 percent indicated the opposite. In this new wave of R&D internationalization, large U.S. corporations are likely to play a critical role as they are planning to expand their reliance on R&D internationalization. Furthermore, Japanese and Korean firms are keen to move beyond their current low levels of R&D internationalization.

Finally, Asia is expected to receive much of the future R&D internationalization, 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.

II. 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 internationalized 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).

[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 (DTI).

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 localized innovation clusters (e.g., Feldman, 1999; Porter and Solvell 1998; Jaffe *et. al*. 2000).

1. Globalization

There is no question that the demanding requirements of managing complex innovation projects tend to concentrate innovation in the home country. However, research on globalization has clearly established that the center 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).

As markets for technology and knowledge workers have globalized, fundamental changes have occurred in corporate innovation management. A gradual opening and networking of corporate innovation systems is giving rise to global innovation networks (GINs) that cut across firm boundaries and national borders. Global firms like Intel and Texas Instruments expand their intra-firm GINs by investing in offshore R&D labs (**tables 1 and 2**).

Tables 1 and 2 about here

Take the Bangalore lab of Texas Instruments - its largest outside the US - which has been around for more than 20 years. Since 1998, this lab has conducted integrated development projects for highly complex system-on.-chip design. TI Bangalore now has the global mandate for co-developing 3G wireless chipsets and WLAN chipsets.

Global firms also outsource some stages of innovation, especially related to product development, to specialized 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 (=original design manufacturers), mostly from Taiwan, for new product development. ODMs either implement a detailed set of design specifications provided by the global brand leader. Or they 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, 2005 a and 2005b).

The result is that, instead of a few preeminent centers of innovation, like Silicon Valley in the US, there are now "multiple locations for innovation… (around the world), and even lower-order or less developed centers can still be sources of innovation" (Cantwell

1995: 172). In chip design, for instance, a handful of new, but rapidly expanding new clusters is emerging in Asia in places like Hsinchu, Taipei, and Tainan (in Taiwan), in Shanghai and the YRD, Beijing, Shenzhen and the PRD and Xián (China), Seoul (Korea), Bangalore, Noida, Chennai, Hyderabad, Mumbai, Puneh and Ahmedabad (India), as well as in Penang and Kuala Lumpur (Malaysia) and Singapore (Ernst, 2005 a).

Moreover, there is a growing recognition that the balance is shifting from “centripetal” to “centrifugal” forces -- i.e., the globalization of markets, technology, competition, and strategy and the resultant opening of corporate innovation systems have boosted the forces for geographical decentralization 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 et al. 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’etre is to transfer knowledge from the corporation’s home base for commercialization 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, to transfer that knowledge back to the home base (Kuemmerle 1997: 66), and to combine these diverse technologies to create new products and processes (e.g., Granstrand, Patel and Pavitt 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 specialized knowledge community – the people who share specialized skills like analog chip design -- share rules and codes of 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-localization 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.

2. Driving Forces

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

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

The overall effect of liberalization has been to reduce the cost and risks of international transactions and to increase considerably international liquidity. Global corporations have been the primary beneficiaries. Liberalization provides them with:

- A greater range of choices for market entry, be it via trade, licensing, subcontracting, and franchising (*locational specialization*);
- Better access to external resources and capabilities that they may need to complement their core competencies (*outsourcing*); and
- Fewer constraints on the geographic dispersion of the value chain (*spatial mobility*).

Hence, liberalization has acted as a powerful catalyst for the expansion of global production and innovation networks.

Technology, especially the rapid development and diffusion of information and communication technology, has also increased the mobility of innovation. The high cost and risk of developing IT has forced companies to search for lower-cost locations for R&D. Equally important is that IT and related organizational 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 data bases, enables remote control, and facilitates exchange of tacit knowledge through audio-visual 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.

Liberalization and IT have drastically changed the dynamics of competition and industrial organization. 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.

3. Vertical Specialization

To cope with the growing complexity of competition, global companies have had to adjust their strategies and organization. No firm, not even a dominant market leader, can generate all the different capabilities internally that are necessary to cope with the requirements of global competition.

Competitive success critically depends on "vertical specialization." Global firms selectively "outsource" certain capabilities from specialized suppliers and they "offshore" them to new, lower-cost locations. While vertical specialization 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 organization, 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 organization model.[10] A massive process of vertical specialization has segmented an erstwhile vertically integrated industry into closely interacting horizontal layers (Grove

[10]The biotech sector of pharmaceuticals, however, has made the most progress pushing vertical specialization into research and development. A senior R&D manager at Merck estimates that "99 percent 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*, January 12, 2006, p. 13).

1996). Until the early 1980s, IBM personified "vertical integration." Almost all ingredients necessary to design, produce, and commercialize computers remained internal to the firm. This was true for semiconductors, hardware, operating systems, application software, and sales and distribution.

Since then, however, vertical specialization 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 specialized suppliers. This has given rise to rapid market segmentation and to an ever-finer specialization 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 specialization.

These adjustments were especially important in the choice of product and process specialization, 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 specialization has been made possible by the spread of venture capital and related regulatory changes in the financial sector[11] that drastically changed corporate strategies of investment funding. U.S. venture capital firms have provided access to a massive infusion of capital from U.S. 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).

As a result, the electronics industry has seen a dramatically diminished commitment to long-term employment. The result has been a substantial increase in the inter-firm and geographical mobility of labor, 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 percent) of all U.S. occupations (National Science Board 2004, chapter 3, page 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

[11]Important complementary changes in U.S. financial institutions include the launch of 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 percent to 28 percent, 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).

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 U.S. 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 of Japan). In 2002, the average annual wage in the U.S. IT industry was $67,440 ($99,440 in the software industry), compared with $36,250 in all private-sector industries (U.S. Department of Commerce 2003, appendix table 2.3). This has created a powerful catalyst for U.S. 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.

4. Changes in Innovation Management

The above transformations in strategy and organization 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 specialization of innovation.

Corporate innovation management must address five tasks simultaneously: (1) develop and protect intellectual property rights; (2) upgrade innovative capabilities (including R&D);[12] (3) recruit and retain educated and experienced knowledge workers; (4) adjust innovation process management (methodologies, organization and routines) in order to improve efficiency and time-to-market; and (5) match all four tasks with the corporation's business model.

No firm, not even a global market leader like IBM, can mobilize internally all the diverse resources, capabilities, and bodies of knowledge that are necessary to fulfill these tasks. As a consequence, both the sources and the use of knowledge have become increasingly externalized. 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).[13]

No longer does this externalization 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 global innovation networks cut across sectors and national borders (Ernst, 2005b). According to the most recent *Science and Engineering Indicators 2004*

[12] "Innovative capabilities" are defined as the skills, knowledge and management techniques needed to design, produce, improve and commercialize "artifacts," i.e. products, services, machinery and processes (Ernst 2002a).

[13] Chesbrough's concept of "open innovation" provides a useful stylized model of this gradual opening of corporate innovation systems (Chesbrough 2003). However, the model fails to address explicitly the international dimension, i.e. the development of global innovation networks.

report by the U.S. 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 characterized 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).

5. Global Markets for Technology

Global firms have been able to move to an open innovation system because an increasing division of labor 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[14].

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 and 2000).

An important constraint to the emergence of global markets for technology are unresolved issues related to the protection of intellectual property rights(IPR). Fear of IPR theft has shaped corporate decisions on the location and the nature of R&D centers. 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

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

vast literature, is that a strong IPR regime is critical to encourage innovation (e.g., Teece, 2000).

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 specialization ("fragmentation") within GINs may allow global firms to navigate better the pitfalls of weak IPR regimes, especially for export-oriented R&D. "Vertical specialization" 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 (e.g., 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 intellectual property rights. As indicated in part III, this raises important policy issues for Asian governments that need to be addressed in future research.

6. 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 Part I, 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 U.S. government responded to the changes in the knowledge worker market by allowing greater immigration of foreign students and professionals, especially for science and engineering (S&E). Until the turn of the century, the United States was the main beneficiary of the globalization of knowledge workers.

A 1998 NSF study showed that more than 50 percent of the post-doctoral students at MIT and Stanford were not U.S. citizens and that more than 30 percent of computer professionals in Silicon Valley were born outside the United States (quoted in National Science Board 2004). Data from the 2000 U.S. Census show that in science and engineering occupations, approximately 17 percent of bachelor's degree holders, 29 percent of master's degree holders, and 38 percent of doctorate holders were foreign born.

This has enabled U.S. 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 U.S. firms that were able to reduce the cost of research, product development, and engineering by shifting from national to global recruitment strategies.

Over the last few years, global firms are facing 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, aging populations are reducing the available working populations in Europe, Japan and the US. With the exception of India, aging is also a serious challenge for Asia's leading exporting countries[15]. 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 (ROI), global electronics firms have increased the use of temporary workers and have outsourced so-called non-core activities. The resultant downsizing of permanent work forces 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 organization breaks down." [16] If demand shifts to new product generations that require new technologies, these firms must then search for specialized talent to fill the gaps caused by previous rounds of downsizing. As a result, crisis management has becomes 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 for knowledge workers now is as important as global manufacturing and supply chain strategies. The goal is to

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[15] Aging 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.

[16] J.A. Joerres, CEO of Manpower, quoted in: Boehm, 2005.

diversify and optimize a company's human capital portfolio through aggressive recruitment in global labor 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.[17] 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-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 localized 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 "labor-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

[17] Until recently, managers working for global corporations could earn 50 percent 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.

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.[18]

7. Implications for Innovation Offshoring

The transition to open innovation networks has changed the way in which global corporations are using their overseas R&D centers in Asia. A recent study about R&D investment in China by major international companies illustrates this point (Armbrecht 2003). The study emphasizes 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 (IRI), which conducted the study, predicts a substantial increase in innovation offshoring in China[19]. IRI 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 highest stage, "(more) equal partnership" labs, is reserved for 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 that satellite and contract R&D labs continue to dominate (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).

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[18]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.

[19]Members of the Industrial Research Institute (IRI) include more than 240 leading global manufacturing firms that perform more than two-thirds of the industrial R&D in the United States.

III. Policy Implications for Asia

This paper demonstrates that innovation offshoring results from fundamental changes in business organization. "Vertical specialization" 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 specialized suppliers of innovation modules increases, this provides a powerful boost to the organizational and geographical mobility of innovation.

Over the years, this process has taken on an increasingly international dimension - global firms construct global innovation networks 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.

1. Benefits and Challenges

For Asian countries, innovation offshoring could provide substantial benefits, *provided* adequate policies and business strategies are in place. For instance, integration into global innovation networks could facilitate knowledge diffusion, learning, and could catalyze efforts by local firms to develop innovative capabilities (Ernst, 2005 c). To the degree that this would be translated into the creation and successful commercialization of new products and services, this might help Asian efforts to counter the decreasing returns to the export-led "global factory" model.

Massive challenges however 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:

- attract and expand R&D investments by global firms
- reduce opportunity costs of innovation offshoring
- enable Asian firms to develop their own innovative capabilities.

Most debates have focused on the first policy challenge. But if Asia fails to meet the other two challenges, it is unlikely to reap sustainable benefits from innovation offshoring.

2. 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, this will increase the 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 only produce short-term benefits, but that it 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 TNCs are loathe to disclose this sensitive information that could negatively affect their stock market quotation (Ernst, 2006 a).

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, Mytelka and Ganiatsos, 1998). In a case study of Malaysia's electronics industry, Ernst (2004) demonstrates that attracting foreign R&D may not only compensate for initial weaknesses of the domestic knowledge base. Such international knowledge sourcing may also facilitate the adjustment of business organization and strategy to abrupt changes in technology and markets. Attracting R&D by global firms may also catalyze 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 localized 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 a possible deterrence effect of global labs on local R&D; 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 only produce sustainable long-term economic benefits for Asian countries, 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"-type 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 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 (e.g., 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 Korea and China demonstrate that host country policies to define alternative standards (i.e. 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 only succeed if they fulfill 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.

3. Policies on Intellectual Property Rights

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

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, Levin and Myers, 2004; Cohen and Merrill, 2004). 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 decisions are for Asian governments to find the level of IPR protection that balances the interests of global and local companies.

It is important to emphasize 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 (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 inter-linkages 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 modeling these efforts on the perceived "success factors" in the US. Many of these initiatives seek to spur local economic development based on university research. This includes, for instance, the creation of "science parks" located nearby research university campuses; support for "business incubators" and public "seed capital" funds; and the organization 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 Bayh-Dole Act of 1980 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 for instance through publications, conference presentations, 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 (e.g., Branscomb et al, 1999**)**. While there are a few pioneering studies on national innovation systems in Asian countries like 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 center 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).

4. 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 labor markets that is typical of most Asian countries, increases the risk of individual investment in specialized skills. This explains why in many of these countries mismatches between the supply and the demand of specialized 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 realize the need for new policies that address the following objectives (Ernst, 2004):

- re-skill and re-train production workers, technicians, and engineers;
- expose science and engineering students to best-practice methodologies and tools and adjust curricula development to evolving labor market needs.
- produce graduates, especially for electrical and electronics engineering, information technology, 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 private sector (company internships and sabbaticals);

- encourage dense interactions with expatriate nationals who are based in the US, Australia and Europe, or elsewhere in Asia; and
- bring in at short notice specialized experts from overseas who can help bridge existing knowledge gaps and who can catalyze necessary changes in organization and procedures required to develop these capabilities locally.

The latter 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 centers of information and communication technology (encompassing Silicon Valley and other centers of excellence in less well known places like Helsinki, Kista/Stockholm, Grenoble, Munich, Tsukuba, Tel Aviv, etc).

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, 2006 c). 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.

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Tables

Table 1

Intel's Global Innovation Network

Location	Description
US (11 labs)	core technology development in Santa Clara, Folsom and Austin
Asia (7 labs, more planned)	▪ **Bangalore (2700 = largest lab outside US), leading-edge processor development** ▪Penang (500), design implementation ▪Shanghai (100++) Linux based solutions for telecom; new applications for emerging markets ▪Beijing (50++), platform and architecture lab
Israel, Russia	▪ Haifa (1400, since 1974), processor research ▪Nizhny Novgorod (200++): software

Table 2

Texas Instruments India

- Bangalore R&D center established in 1985
- Largest lab outside the US (> 2,500)
- 1989: develop ASIC CAD libraries
- 1998: entire design of DSP chip
- 2000: co-development of 3G wireless chipsets and WLAN chipsets
- Global development mandate for broad product portfolio (including leading-edge)