Asia's "upgrading through innovation" strategies and global innovation networks: an extension of Sanjaya Lall's research agenda

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This paper demonstrates that the late Professor Sanjaya Lall's framework for analysing Asian pathways to development remains valid today. This is done by extending the framework to apply in circumstances where globalization of markets has moved beyonds goods and finance to technology and knowledge workers. The concept of "industrial upgrading" is used to identify conditions under which Asian countries could reap the benefits of innovation offshoring. The analysis shows that Lall was right to emphasize a divergence between the private interests of the TNCs and the social interests of the host economy in terms of long-term technology development. His plea for industrial policy is even more relevant today, since the stakes and risks have become much greater, as countries seek to move beyond the "global factory" model to "upgrading through innovation" strategies.

Keywords: innovation, industrial upgrading, global innovation networks, global production networks, learning, innovation policies, capabilities, TNCs, Asian development strategies

1. Introduction

I first met Sanjaya Lall in the late 1970s, when we were both consultants for Surendra J. Patel's Technology Division at UNCTAD. Since then, his writings have had a lasting impact on my research.

This essay is a very personal homage to Lall's work on technological change and industrialization, in particular his pioneering study on technological capabilities, prepared for the OECD Development Centre (Lall, 1990). I will not seek to add yet another review of Lall's work. Instead, I will sketch a roadmap for extending Lall's research agenda to explore the challenges resulting from the rise of global innovation networks (GIN) for Asian attempts to upgrade its industries through innovation. I will demonstrate that Lall's framework remains valid as globalization now extends beyond markets for goods and

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finance to include markets for technology and knowledge workers[1]. As a result of such transformations, Asia's integration into global production networks is now complemented by its integration into GINs, which adds a new dimension to the research agenda pursued by Lall. If not mentioned otherwise, the evidence used to support my arguments in this paper draws on a unique data base of GINs for a sample of now almost 150 companies in the information and communications technology industry (Ernst, 2008b).[2]

In the next section of this essay, I will introduce what I consider to be the essence of Lall's work, summarized in five propositions. In the rest of the paper, I will use these propositions to study the link between "upgrading through innovation" strategies and GINs. In section 3, I introduce a conceptual framework to examine how specialization, learning and innovation enhance the potential for industrial upgrading. Section 4 addresses the international dimension of industrial upgrading, and discusses the characteristics and drivers of GINs and explore implications for learning and knowledge diffusion. Section 5 presents policy suggestions.

2. Important lessons from Lall's research

For me, a defining characteristic of Lall's work is his assertion that industrialization in Asia has been shaped by the interplay of *global* forces (embodied in international trade and investment flows) and *local* strategies (pursued by host country firms and governments).

Specifically, Lall's research taught me the following important lessons. First, integration into the global economy and foreign direct investment (FDI) can act as important catalysts for change, but there is likely to be a "divergence between the private interests of the multinational company and the social interests of the host economy in terms of long-term technology development" (Lall and Urata, 2003, p. 4). Policies need to be based on a thorough understanding of these

[1] The term "knowledge workers" is 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.

[2] The sample includes large global brand leaders from Asia, Europe and North America, as well as specialized suppliers of technology, core components and product development services. We have also collected information on mini-GINs for small trans-Pacific start-up companies of foreign-born engineers from China, India and Taiwan Province of China that are headquartered in Silicon Valley.

divergent interests, and they need to adjust to changes in the strategies of transnational corporations (TNCs).

Second, liberalization of trade and investment should not be equalized with the retreat of the state: "[a] consideration of the technology development process at the micro-level provides a strong and valid economic case for industrial policy, and the East Asian case provides the empirical backing" (Lall, 2000, pp. 13, 14).

Third, as a country becomes more exposed to globalization, this increases the importance of local capabilities and innovation, because "technical efficiency in each location becomes the final determinant of success (Lall, 2003, p.46). The more a country depends on exports and financial markets, the more it is vulnerable to boom-and-bust cycles of global product and financial markets. To cope with this challenge, both firms and governments need to develop sophisticated management approaches and policies. Lall was one of the first to argue that the more a country moved up the industrial ladder, the more important advanced capabilities and innovation became. Specifically, Lall emphasized that while FDI could facilitate the development of basic operational capabilities required for the production and use of foreign technology, they might be "less efficient means of deepening capabilities, particularly into design and innovation" (Lall, 2003, p. 13).

Fourth, the key to success is generating a virtuous circle of building institutions and firm-level capabilities. Lall highlighted the following requirements for successful industrial upgrading: "skill development, industrial specialization, enterprise learning and institutional change are needed to create *cumulative* and *self-reinforcing processes* to promote further learning" (ibid, p. 47).

Fifth, Lall's writings consistently emphasize that host countries strategies to foster industrial upgrading need to be context-specific and are hence likely to differ from country to country. Lall's extensive research on Asian industrial policies showed that different policies were "successful in its own way in boosting export competitiveness, though each faces different… (risks and)… strategic challenges" (Lall, 2003, p. 4). There are no "one best way" solutions. Instead, policies and strategies need to be continuously adjusted to the vagaries of business cycles and, even more importantly, to the structural transformations of markets and technology.

Asia's rise as the global factory provides a fascinating example for Lall's proposition that industrialization in this region has been shaped by the interplay of *global* forces and *local* strategies. But this framework can also be used to analyze how integration into GINs affects Asia's "upgrading through innovation" strategies.

3. Conceptual framework

3.1 Industrial upgrading

The concept of "industrial upgrading" can serve as a focusing device for Asia's attempts to move beyond the "global factory" model and to unlock new sources of economic growth. The main objective is to exploit the productivity-enhancing potential of innovation in order to avoid a "race to the bottom" that is driven solely by cost competition. Hence, in general terms, industrial upgrading must focus on improvements in specialization, local value-added, productivity and linkages, all of which necessitate a broad base of knowledge and innovation (Ernst and Lundvall, 2004).

I distinguish two aspects of industrial upgrading that are of greatest policy relevance: "firm-level upgrading" from low to higher end products and value chain stages, and "industry-level linkages" with support industries, universities and research institutes.[3] Firm-level upgrading is the key dimension – Asian firms must develop the capabilities, tools and business models that will allow them to cope with the new challenges from integration into GINs.

But for firm-level upgrading to succeed, upgrading must take place simultaneously with the formation of "industry linkages". As

[3] Three other forms of "industrial upgrading" discussed in the literature are: (i) inter-industry upgrading from low value-added industries (e.g. light industries) to higher value-added industries (e.g. heavy and higher-tech industries); (ii) inter-factor upgrading from endowed assets (i.e. natural resources and unskilled labour) to created assets (physical capital, skilled labour, social capital); and (iii) upgrading of demand within a hierarchy of consumption, from necessities to conveniences to luxury goods. See Ozawa (2000) for discussion of upgrading taxonomies. Most research has focused on a combination of the first two forms of industrial upgrading, based on a distinction between low-wage, low-skill "sun-set" industries and high-wage, high-skill "sunrise" industries. Such simple dichotomies, however, have failed to produce convincing empirical results for two reasons (Ernst, 2001b). First, there are low-wage, low-skill value stages in even the most high-tech industry, and high-wage, high-skill activities exist even in so-called traditional industries like textiles. Second, both the capability requirements and the boundaries of a particular "industry" keep changing over time. An example is the transformation of the personal computer industry from an R&D-intensive high tech industry to a "commodity" where success depends on the optimization of supply chain management.

Powell and Grodal observed, "collaboration across multiple boundaries and institutional forms" is the norm today, and innovation networks "are now core components of corporate strategy" (Powell and Grodal, 2004, pp. 57, 58). This reflects the growing geographic mobility of knowledge (Ernst, 2003) and the emergence of information technology (IT)-enabled governance mechanisms to coordinate dispersed knowledge units (Ernst, 2005c).

To broaden the pool of firms that are capable of sustained firm-level upgrading, strong support industries and linkages with universities and research institutes are required. The challenge is to enable firm-level upgrading and industry-level linkage formation to interact in a mutually reinforcing way so as to create a "virtuous circle".

Asia's industrial upgrading efforts also face a second challenge. As its companies are integrated into multiple global networks of corporate production and innovation and informal knowledge communities, it is obvious that international linkages are critical for industrial upgrading. Hence, we need to distinguish the domestic (local) and international (global) elements.

Finding the right balance between firm-level upgrading and industry-level linkage formation, and between domestic and international aspects poses a continuous challenge for policy makers and corporate planners. The "right balance" is a moving target, it is context-specific and requires continual adjustments to changes in markets and technology. I argue that all four elements support each other; a strategy that neglects one element at the detriment of the others is unlikely to create sustainable gains. The stronger the links between those four elements and the better they interact, the greater are the chances that Asian firms shape markets, prices and technology road maps.

The international dimension of industrial upgrading will be addressed in section 4. Our focus in this section is on the domestic elements. I first explore how learning and innovation support one another. I will then turn to the role of specialization in products and types of production.

3.2 Learning and innovation

A fundamental insight of innovation theory is that learning and innovation are "the two faces of R&D" (Cohen and Levinthal, 1989, p. 569). Learning-by-doing establishes the routines – "the firm becomes more practiced, and, hence, more efficient, at doing what it is already doing"(ibid, p. 570). But a firm's growth depends on the firm's capacity to engage in a second type of learning, namely acquiring external knowledge "that will permit it to do something quite different" ("absorptive capacity").

For effective knowledge conversion to productive learning, two important elements are required: an existing knowledge base or competence and the intensity of effort or commitment (Ernst and Kim, 2002, p. 1425). In fact, a critical prerequisite for absorptive capacity is that a firm conducts in-house basic research. This is in contrast with the current fashion of "open innovation" (e.g. Chesbrough, 2003), which downplays the importance of a decline in corporate basic research. Cohen and Levinthal argued that that a firm needed to sustain a critical mass of internal basic research, "to be able to identify and exploit potentially useful scientific and technological knowledge generated by universities or government laboratories, and thereby gain a first-mover advantage in exploiting new technologies" (Cohen and Levinthal, 1989, p. 593). The same reasoning applies with regard to benefiting from spillovers from competitors' innovation.

What exactly then is innovation? Schumpeter's distinction between invention and innovation and his focus on "new combinations of existing resources" are a good starting-point. To capture the essence of innovation, I suggest a broad definition: innovation converts ideas, inventions and discoveries into "new combinations of existing resources" that lead to new products, services, processes and business models. It is important to emphasize that innovation is more than research and product development; users must perceive an advantage worth paying for the innovation. It is also worth emphasizing that "entrepreneurs" are not limited to just the founders of internet start-ups, but they vary in terms of size, business model and organization of their operations.

Innovations differ with regard to opportunities and barriers to learning. They also differ in the capabilities required from the firms. Four types of innovations may be distinguished: *incremental, modular, architectural* and *radical* innovations (Ernst, 2008a, drawing on Henderson and Clark, 1990).

(i) Incremental innovations

"Incremental" innovations adopt existing component designs and architectures, but improve on cost, time-to-market and performance. Their purpose is to exploit as much as possible the potential of a given "design", by introducing relatively minor changes to an existing product or process (Nelson and Winter, 1982). These innovations do not require substantial input from science, but they do require considerable skill, especially "soft" entrepreneurial and management capabilities, as defined in Ernst (2007a).[4]

(ii) Modular innovations

"Modular" innovations introduce a new component technology and plug it into fundamentally unchanged system architecture.[5] They have been made possible by the division of labour in product development: "[m]odularity is a particular design structure, in which parameters and tasks are interdependent within units (modules) and independent across them" (Baldwin and Clark, 2000, p. 88). One consequence of modularization has been the fragmentation of the innovation value chain as well as its dispersion across firm and geographic boundaries, giving rise to "innovation offshoring" through GINs (Ernst, 2006a).

It is important to emphasize that, although modularity has created opportunities for industrial latecomers, the barriers to successfully undertaking modular innovations are substantial. High technological complexity requires top scientists and experienced engineers in different fields. In addition, investment requirements can be very substantial (e.g. up to $4.5 billion for a state-of-the-art semiconductor fabrication plant), as are risks of failure.

(iii) Architectural innovations

"Architectural" innovations are "innovations that change the architecture of a product without changing its components" (Henderson

[4] Examples of incremental innovations are improvements in the organization of manufacturing, distribution and support services, like Dell's "direct sales" model and its integration of factory automation and supply chain management. Other examples are new approaches to subcontracting arrangements, pioneered especially by IT firms from the Taiwan Province of China, like original design manufacturing (ODM), foundry services (for integrated circuit fabrication) and design implementation services. Incremental innovations may also involve continuous improvements in industrial design that help attract the attention of customers and that enhance the user-friendliness of a product and its performance.

[5] This type of innovation has been a defining characteristic of the PC industry - within each generation of the Wintel architecture (combining Microsoft's Windows operating system and Intel's processor architecture), specialized suppliers have introduced new component technology, for instance for memory, storage and display devices.

and Clark, 1990, p. 9). They use existing component technologies but change the way they work together. Architectural innovations tend to have far-reaching implications for market shares and profitability of innovating firms. As highlighted by Henderson and Clark (1990, p. 9), architectural innovations can threaten incumbent market leaders – they "destroy the usefulness of the architectural knowledge of established firms, and since architectural knowledge tends to become embedded in the structure and information-processing procedures of established organizations, this destruction is difficult for firms to recognize and hard to correct".[6]

(iv) Radical innovations

Finally, "radical" innovations involve both new component technology and changes in architectural design. They require breakthroughs in both architectural and component technology.[7] Radical innovations require profuse interaction with leading-edge science – top scientists and engineers are needed who work at the frontier of basic and applied research in a broad range of disciplines. In addition, to implement radical innovations requires a broad set of complementary assets (as defined by Teece, 1986) and investment thresholds tend to be high.

In short, such innovations are costly and risky, and failure can destroy even large companies. They are beyond the reach of most companies in Asia (outside of Japan and the Republic of Korea), although they may be undertaken by public-private consortia coordinated by the government.

3.3 Innovative capabilities

To determine what kind of capabilities are required to foster innovation, we can draw on the growing literature that has followed Lall's pioneering study on technological capabilities (Lall, 1990). Particularly useful for our purposes are studies that have developed operational data sets for measuring firm-level innovatory and R&D capabilities, based on questionnaire surveys and structured firm interviews (e.g. Ernst and O'Connor, 1992; Hobday, 1995; Ernst, Mytelka and Ganiatsos, 1998; Jefferson and Kaifeng, 2004; Ernst, 2005d).

[6] Henderson and Clark (1990) use the decline of Xerox and RCA to illustrative the destructive power of architectural innovations.

[7] Examples include the discovery of new drugs, or the invention of the Internet.

Building on this literature, I propose to use a broad definition of "innovative capabilities" to emphasize that, in addition to R&D capabilities, complementary "soft" entrepreneurial, management and system integration capabilities are of critical importance. I define "innovative capabilities" to include the skills, knowledge and management techniques needed to create, change, improve and commercialize successfully "artefacts", such as products, services, equipment, processes and business models (Ernst, 2007a).

Innovations require R&D capabilities, especially in high-tech industries. Yet, research on successful IT innovations demonstrates that technology is the easy part to change. The difficulty is in social, organizational and cultural aspects. In order to create products and services that customers are willing to pay for, the following "soft" innovative capabilities are critical:

- to sense and respond to market trends before others ("entrepreneurship");
- to recruit and retain educated and experienced knowledge workers who are carriers of new ideas;
- to search globally for core components, reference designs, tools, inventions and discoveries;
- to raise finance required to bring an idea quickly to the market;
- to deliver unique and user-friendly industrial designs;
- to develop and adjust innovation process management (methodologies, organization and routines) in order to improve efficiency and time-to-market;
- to manage knowledge exchange within multidisciplinary and cross-cultural innovation projects;
- to participate in and shape global standard-setting;
- to combine protection and development of intellectual property rights; and
- to develop credible and sustainable branding strategies.

3.4 Specialization and upgrading potential

Specialization is an important indicator of the degree of industrial upgrading that a country or region can realistically expect to achieve. Specialization patterns reflect differences in product mix (e.g. homogeneous versus differentiated products) and in the type of production, i.e. "routine" and "complex" production.[8] These differences in specialization, in turn, give rise to divergence in the complexity of technology, demand patterns and market structures. Most importantly, differences in specialization shape a country's (a region's) upgrading potential, in terms of learning opportunities, capability requirements, value-added and linkages.

A critical policy issue is how to identify conditions under which specialization and upgrading potential are linked by a *virtuous circle*. In fact, a narrow specialization on homogenous products or on "modular" production may well make sense at an earlier stage of development. Yet, this very same specialization may later on hinder a transition to differentiated products or "integrated" production.

(i) Product specialization

Homogenous products ("commodities") have only a limited upgrading potential, in terms of learning opportunities, capability requirements, value-added and linkages. The opposite is true for differentiated products.

For our purposes, it is useful to establish a link between product specialization and the product life cycle (PLC) theory. Following Vernon (1966), differentiated products are typically associated with the early stage of the PLC, while homogenous products are most likely to be found in the later stages. Take the PC industry, a typical example of a "late-stage" industry, which is an important part of the IT industries in China and Taiwan Province of China. As a "commodity", the PC has very limited upgrading potential. The root cause is that Intel and Microsoft are in almost complete control of the standards and technologies, with a result that expected returns on innovation for PC manufacturers is low, while the cost of innovation is high.

In contrast, the scope for differentiation is broader for high-end handsets (especially smart phones) and for the mobile network industry. Both are examples of "early PLC stage" industries that are important for China, the Republic of Korea and Taiwan Province of China. While entry barriers in terms of investment and technology are high in both

[8] I use these distinctions to move the research agenda beyond the popular, but somewhat schematic dichotomy of "Fordist mass production" versus the "Post-Fordism Flexible Specialization". For a detailed theoretical discussion based on evidence from chip design, see Ernst (2005b).

industries, there are ample opportunities for new entrants to upgrade through innovation.

(ii) Routine versus complex production

The potential for industrial upgrading also differs for different types of production. For “routine” production, the upgrading potential is obviously lower than for “complex” production that needs to combine diverse technologies and may require customization, quick responses to changes in market and technology, and the provision of integrated solutions. The reward for upgrading to “complex” production can be high. If firm successfully implements complex processes, it may benefit from greater profit margins, which in turn could be used to finance further R&D. The downside, of course, is that a successful entry requires substantially higher costs and efforts.

Take, for instance, chip designing, where “routine” functions (“design implementation”) are distinguished from “complex” stages of design that centre on conceptualization, circuit architecture and system specification. The requirements for making the transition from design implementation to conceptualization are quite demanding. Entry barriers are extremely high, as design costs at the 90 nano-meter technology (the current best-practice) can be as high as $20–30 million (Ernst, 2005a).

These new challenges are likely to impose far-reaching changes on industry structure, business models and firm organization, illustrating again how closely inter-related firm-level upgrading and industry-level linkage formation are.

4. The International dimension

As Asia’s production and innovation systems are increasingly integrated into complex global network arrangements, it is obvious that industrial upgrading does not end at the national border. Nor should one assume that industrial upgrading occurs only if improved specialization leads to the formation of linkages *within* a particular region or within the national economy. Hence, international linkages are critical for the region’s industrial upgrading efforts.

4.1. Global production and innovation networks

A “closed economy” assumption became unrealistic, once liberalization and information technology (IT) drastically increased the international mobility of goods and services as well as finance and investment, giving rise to geographically dispersed ("fragmented") global production networks (Venables, 2006; Jones and Kierzskowski, 2000; Borrus, Ernst and Haggard, 2000; Ernst, 1997, 2002b). Asia's integration into these networks has created cross-border linkages that need to be exploited by its industrial upgrading strategies.[9]

Recent shifts in the global innovation system have further increased the importance of international linkages for industrial upgrading. As globalization has extended beyond markets for goods and finance into markets for technology and knowledge workers, this has increased the organizational and geographical mobility of innovation.[10] Global corporations are at the forefront of these developments. Profound changes are transforming their innovation management, and an increasing vertical specialization ("fragmentation") of innovation is giving rise to GINs.

According to the United States 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, pp. IV–36). As a result, global corporations are increasingly relying on "innovation offshoring" through GINs (Ernst, 2006).

4.2 How important is Asia?

Since the turn of the century, GINs have been extended well beyond the traditional high tech regions in the United States, EU and Japan. Global corporations construct such networks to improve the productivity of R&D by recruiting knowledge workers from cheaper, non-traditional locations.

Asia's role in these networks is increasing fast (albeit from a low base) and the resurgence of China and India obviously plays an important role. Take Intel as an example of an intra-firm innovation network that is expanding most rapidly in China and India. Its labs in

[9] Empirical research on Asia's leading export economies documents that progressive integration into global production networks has typically increased intra-industry trade, giving rise to growing "input imports', i.e. purchases of components and machinery from overseas sources, primarily in Japan and the United States (e.g., Ng and Yeats, 2003; Ernst and Guerrieri, 1998).

[10] The following draws on Ernst (2006a, 2005 a, 2005b, 2003 and 2002a).

Santa Clara, Folsom and Austin in the United States remain the primary locations for core technology development and applied research, while the lab in Haifa, Israel, (established as early as 1974) focuses on processor research and the lab in Nishny Novgorod, Russia, on software development. Intel has established seven R&D labs in Asia (outside Japan), and it is planning to expand rapidly both the number of labs and their headcounts. Bangalore has Intel's largest lab outside of the United States. With a workforce of around 3,000, the Bangalore lab conducts leading-edge dual processor development. Intel's management plans a substantial expansion in India, most likely in second-tier cities that have lower labour costs than Bangalore. In Shanghai, Intel has recently expanded its R&D team to focus on applied research to identify new applications for China and other emerging markets.

The Bangalore labs of Texas Instruments (TI) illustrate the speed and depth of innovation offshoring to Asia. Established in 1985, Bangalore is Texas Instruments' largest lab outside the United States, with a workforce of more than 2,800. Since 1998, this lab has conducted integrated development projects for highly complex system-on-chip design. It now has the global mandate for co-developing 3G wireless chipsets. Since 2003, TI Bangalore has been assigned the global product development mandate for leading-edge single-chip modems. As a result, TI Bangalore has successfully completed more than 500 patent filings at both the United States Patent and Trademark Office and the European Patent Office.

Global firms also outsource some stages of innovation, especially those related to product development, to specialized offshore suppliers as part of complex *inter-firm* GINs. For instance, global brand leaders for laptops (like HP, Dell, Acer and Lenovo) use design services provided by so-called original design manufacturers (ODMs), mostly from Taiwan Province of China, for new product development.[11] In addition, global system companies (like IBM) and integrated device manufacturers (like Intel) are outsourcing to Asian design houses the development of specific design building blocks and design implementation services (Ernst, 2005a, 2005b).

[11] These 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. ODM service providers from the Taiwan Province of China now account for 95% of the global notebook market – with three firms (Quanta, Compal and Wistron) accounting for 71%. It is important to emphasize that tier-3 suppliers, especially for power supply (Delta and Lite-On) and connectors (HonHai), are highly profitable and are investing heavily in the development of their innovative capabilities.

Over time, GINs have become increasingly diverse, bringing together R&D teams from companies that drastically differ in size, business model, market power, location and nationality. The flagship companies that control key resources and core technologies – and hence shape these networks – are still overwhelmingly from EU, Japan and the United States. However, there are also now network flagships from Asia (outside Japan). New Asian players develop their own networks and unique ("hybrid") networking strategies.

Huawei, China's leading telecommunications equipment producer, provides an example of a highly sophisticated GIN. The company has pursued a two-pronged strategy (Ernst and Naughton, 2007). It is building a range of linkages and alliances with leading global industry players and universities, while concurrently establishing its own GIN. In fact, Huawei has developed a web of project-specific collaboration arrangements with major suppliers of core components, such as Siemens (as part of China's TD-SCDMA project), 3Com (with a focus on sales and joint product development), as well as Intel and Qualcomm. As for Huawei's own GIN now includes, in addition to six R&D centres in China, five major overseas R&D centres in the United States (Plano/Texas and San Jose/California), Sweden (Kista/Stockholm), the Russian Federation (Moscow) and the United Kingdom (as part of British Telecom's list of eight preferred suppliers for the overhaul of its United Kingdom fixed-line phone network).

4.3 Driving forces and enabling factors

Corporate strategies shape the pace and contents of the global knowledge economy; they increase the mobility of innovation by constructing GINs. Global corporations construct these networks to cope with increasing pressures to internationalize innovation. Our research through interviewing global corporations suggests that GINs are expected:

- to increase the return on investment on R&D, despite rising cost, complexity and uncertainty of R&D;
- to facilitate entry into emerging markets to compensate for the slow demand growth in core OECD countries;
- to accelerate speed-to-market in line with shortening product life-cycles;
- to gain access to low-cost pools of knowledge workers;

- to tap into the resources and innovative capabilities of emerging economies and new innovation hubs; and
- to bypass social and environmental regulations.

It is important to emphasize the systemic nature of the driving forces. We find that global firms are attracted by supply-related factors, especially the lower cost of employing a chip design engineer in Asia, which is typically 10–30% of the cost in Silicon Valley. However, demand-related factors are equally important. Global firms emphasize the need to relocate R&D to be close to the rapidly growing and increasingly sophisticated Asian markets for communications, computing and digital consumer equipment and to be able to interact with Asia's lead users of novel or enhanced products or services. The main prize is the Chinese market which provides: the largest market for telecom equipment (wired & wireless) and may become a test bed for next generation (4G) mobile systems; the largest market for semiconductors and handsets; the second-largest market for cars and digital consumer electronics; a major export market for Japan, the Republic of Korea, Taiwan Province of China and the United States; and "bottom of the pyramid" markets for less over-engineered products and services with substantially lower costs of acquisition and operation.

Furthermore, some firms in Asia, especially in China and India, that are accumulating resources and innovative capabilities that are attractive to global corporations. For instance, it is projected that, by 2010, China will produce more science and engineering doctorates than the United States (National Science Board, 2008).[12] In addition, China's areas of scientific excellence now include materials science, especially nano-science, where China ranks third (after Japan and the United States) in the number of nanotech publications, and where the Chinese Academy of Science is ranked fourth for nano-science citations, after UC Berkeley, MIT and IBM. China's researchers also excel in areas like voice and image recognition, computer graphics, analytical chemistry, rice genomics and stem cell biology.

At the same time, a powerful mix of enabling factors has facilitated the construction of these networks by reducing uncertainty and the cost of transaction and coordination. The result has been a rebalancing of

[12] According to the National Science Board (2008), 64% of China's 23,446 Ph.D. degrees in 2004 are in science and engineering. Between 1995 and 2003, first year entrants in science and engineering Ph.D. programmes in China increased six-fold, from 8,139 to 48,740.

the “centripetal” forces that keep innovation tied to specific locations and the “centrifugal” forces that reward geographical dispersion. The latter have become more powerful, although the former have hardly disappeared.

There are two root causes of this rebalancing and the resultant increase in the mobility of knowledge: (1) the improvement of the information and communication infrastructure and its extension around the world, and (2) the liberalization of international economic policies that allows this technological change to be exploited more fully by firms and organizational networks.[13]

Institutional change through liberalization has played an important role in reducing constraints on the organizational and geographical mobility of knowledge. Hence, liberalization has acted as a powerful catalyst for the expansion of GINs.

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

- a greater range of the modes of entry, e.g. via trade, licensing, subcontracting, 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*).

Technological development, especially the rapid improvement and diffusion of information and communication technology, has also increased the mobility of knowledge. 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, and facilitates exchange of tacit knowledge through audio-visual media.

[13] Additional powerful enabling factors are the progressive globalization of IP protection (through TRIPS and TRIPS-Plus agreements) and standards (through formal but especially through informal standard-setting bodies). See Ernst (2008c).

In essence, IT has fostered the development of leaner and more agile production and innovation networks that cut across firm boundaries and national borders. IT-enabled network management has facilitated the exchange of knowledge among diverse knowledge communities at distant locations that work together on an innovatory project.

It is now possible to create and connect teams of knowledge workers in distant locations. This is true even for innovative activities that require complex knowledge. To the extent that the diversity of network players, locations, business models and network arrangements is increasing, this provides opportunities for knowledge diffusion, enabling Asian network participants to enhance learning, absorptive capacity and innovative capabilities.

4.4 Will network integration foster innovation?

The result, however, is by no means a flatter world. There is clear evidence that Europe, Japan and the United States retain their dominance in science and in high-impact intellectual property. In 2002, for instance, all 15 leading companies with the best record on patent citations were based in the United States, with nine of them in the IT sector (CHI/MIT, 2003). The 700 largest R&D spenders (mostly large United States firms) account for 50% of the world's total R&D expenditures and more than two-thirds of the world's business R&D (UNCTAD, 2005a). And, more than 80% of the 700 largest R&D spenders come from only five countries (United States dominates, followed by Japan, Germany, United Kingdom, and France).

Nevertheless, non-OECD countries account for a growing share of the world's R&D (OECD, 2008, p. 56). In 2005, the non-OECD countries accounted for 21.4% of global R&D expenditures (expressed in current United States dollars, PPP), up from 17% four years earlier. China made by far the largest contribution, accounting for 55% of the non-OECD share. China's R&D intensity (i.e. the ratio of R&D to GDP) has grown much faster than in Japan, the United States or any European country.[14] However, at 1.5%, China's R&D intensity is still way behind the global leaders (e.g. 2.6% for the United States).

Probably the most telling indicator of the persistent high concentration of innovative capabilities is the unequal control over resources and decision-making in standard-setting consortia in the IT

[14] Between 1999 and 2004, an average annual growth rate of more than 12% has been recorded for China's R&D intensity, compared to -0.2% for the United States.

industry (Ernst, 2008c). In many of these consortia, standards are highly "impure public goods" that are used by incumbent industry leaders to block competitors and to deter new entrants.

Clearly, the new geography of knowledge has dispersed innovative capabilities to new players, but overall, the spread of innovatory activities remains highly concentrated. For Asia, our data show that integration into GINs has created a handful of new, yet very diverse and competitive innovation offshoring hubs.[15]

There are concerns, however, that integration into GINs may be a poisoned chalice. It is feared that, apart from a few prestige projects that might provide limited short-term benefits, R&D by global corporations may not provide the means for upgrading the host country's industry to higher value-added and more knowledge-intensive activities.

The findings from our research confirm some of these concerns. We have found that Asian emerging economies face massive challenges before they can reap the benefits of network integration. Nothing is automatic about these processes, and they cannot be left to market forces. To cope with market failures identified a long time ago by Kenneth J. Arrow[16], appropriate policies need to be in place to develop absorptive capacity and innovative capabilities both at the firm and industry levels.

For instance, foreign R&D centres often intensify competition for the limited domestic talent, giving rise to bouts of localized wage inflation for knowledge workers (especially for experienced project managers). Inward R&D by global industry leaders may also give rise to a reverse "boomerang effect", providing global firms with valuable insights into business models and technologies developed by domestic firms.[17] Furthermore, foreign R&D centres typically show limited interest in sharing knowledge with domestic firms and R&D labs.

[15] Take chip design. In addition to the established global centres of excellence (like Silicon Valley), there are now a handful of rapidly expanding new clusters emerging in Asia, such as Hsinchu, Taipei, Tainan in Taiwan Province of China; Shanghai, Suzhou, Hangzhou, Beijing, Shenzhen, Xián in China; Seoul, Incheon, Daedok Science Town in the Republic of Korea; Bangalore, Noida, Chennai, Hyderabad, Mumbai, Puneh and Ahmedabad in India; Penang, Kuala Lumpur in Malaysia; and Singapore.

[16] Arrow (1962) argued that markets were weak in generating learning and knowledge, as both were subject to externalities, creating a gap between private and social rates of return on investment.

[17] Examples are attempts by IBM and Accenture to copy the successful business model of Indian IT service providers like Tata Consulting Services or Infosys.

Vigorous policies must be in place to reduce the potentially high opportunity costs of inward R&D investment that may result from "brain drain" (both domestic and international), when global firms are crowding out the local market for scarce skills. Other costs discussed in the literature include a possible deterrence effect of global labs on local R&D; acquisition by global firms of innovative local companies; and the large benefits that may accrue to a foreign parent company (UNCTAD, 2005a).

Support policies for local firms are required. As emphasized by Tassey (2007), substantial investment is needed in "human science and engineering capital" and "innovation infrastructure". An important objective is to improve the efficiency of a nation's innovation systems and to reduce the risks of innovation through "more comprehensive growth policies implemented with considerably more resources and based on substantive policy analysis capabilities" (Tassey, 2008, p. 2).

5. Generic policy suggestions

In short, Asia's progressive integration into GINs may well act as a catalyst for accelerating the development and the diffusion of innovative capabilities, provided, of course, that appropriate policies and firm strategies are in place to enhance local innovative capabilities.

There is no doubt that the innovative capabilities of Asian firms continue to lag substantially behind global industry leaders. Reducing the gap will take time. Hence, host country policies in Asia must continue to cajole and assist local firms by signalling opportunities, reducing risks, engaging in R&D and providing critical public goods. Liberalization and WTO regulations have reduced the scope for such policies. The challenge is to design new policies and institutions that help reduce the "divergence between the private interests of the multinational company and the social interests of the host economy in terms of long-term technology development" (Lall and Urata, 2003, p. 4).

Asia's emerging knowledge economies face a strategic dilemma. If they choose to compete as low-cost R&D contractors, this would result in a "commodity price trap", squeezing their profit margins and hence their ability to finance further innovatory activities. This implies that there is not much choice but to pursue "upgrading through innovation" strategies. Asian firms need to create unique products and solutions, addressing user and social needs that global firms have neglected.

However, deeply entrenched structural weaknesses and persistent inequality constrain the push for innovation.

The key to success is leveraging on integration into GINs to catalyze, not to replace, domestic innovation efforts. 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. This is in line with the findings of Lall's research. 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.

To reap the benefits of integration into GINs requires the active involvement of the state, i.e. local, regional and central government agencies, as well as a variety of intermediate institutions (Ernst, 2005b). Policies associated with the traditional East Asian development model are too rigid to cope with the complex challenges and opportunities of today's global network economy that have been explored in this study. Nor can the old policies cope with the conflicting needs of multiple and increasingly vocal domestic actors. In addition, command-economy type industrial policies are unable to deal with the high uncertainty and rapid changes in technology and markets that are typical for the new geography of knowledge.

In order to facilitate a continuous upgrading of local innovative capabilities through participation in GINs, new policy approaches are required that:

- strengthen the state's steering and coordination capacity;
- provide public goods in critical bottleneck areas (infrastructure, training and education);
- facilitate access to and diffusion of knowledge and balance this with the need to protect intellectual property rights;
- encourage overseas investment of leading local companies, to expose them to leading-edge innovation management approaches;
- encourage innovations in the financial sector;
- generate dialogues at various levels among multiple participants (local and foreign) in production and innovation networks;
- foster interactive learning and innovation;

- provide social protection and retraining options for those who lose out from economic transformation; and
- facilitate international knowledge sourcing through corporate networks, institutional collaboration and diverse social networks (global knowledge communities and expatriates).

There is, of course, no one best optimum formula for such policies. Their instruments and institutions need to differ from sector to sector, in scope, in kind, and in impact, as documented in Mowery and Nelson (1999, p. 377).[18]

Policies also need to differ across countries. A critical prerequisite to find out more about such policy variations is the construction of relevant country classifications. But most such classifications remain problematic.[19] Drawing on Lall (1990), Ernst, Mytelka and Ganiatsos (1998) and Ernst and O'Connor (1989), it is possible to suggest a broader country classification scheme that focuses on the following criteria:

- the size and structure of markets and the relative focus on internal versus external markets;
- production structures, including industry structure and firm size, extent of inter-industry linkages, and "core industries";
- degree and form of reliance on foreign technologies;
- role of the state in industrial and technological development;
- state of development of indigenous scientific, technological and innovative capabilities;

[18] Ernst (2005a) provides a case study of chip design that highlights characteristic features of global design networks, and the resultant specific implications for the development of local innovative capabilities. Future research needs to conduct similar case studies for sectors that are of particular importance for developing countries, such as textiles, footwear, food processing, chemicals, pharmaceuticals, transportation equipment, mechanical engineering, as well as software and information technology services. For each of these sectors, there are likely to be substantial differences in host country policy responses to innovation offshoring.

[19] For instance, the World Bank's research on strategic approaches to science and technology in development uses the RAND Corporation's matrix of science and technology capacity in the developing world that distinguishes three categories: 24 "scientifically proficient" countries, 24 "scientifically developing" countries and 80 "scientifically lagging" countries (Watson and Farley, 2003, Appendix 2).

- peculiar characteristics of economic institutions (i.e. labour and financial markets and education systems); and
- social, cultural and political factors that shape national, regional and sector-specific innovation systems.

Future research needs to examine realistic options for "upgrading through innovation" strategies in different groupings of Asian countries, and how each of these policies can maximize benefits from participating in GINs. For instance, Ernst (2005b) introduces a taxonomy of four strategies (i.e. "catching-up", "fast-follower", "technology diversification", and "technology leader") and explores capabilities local companies need to master in order to implement each of these four different strategies. Drawing on this taxonomy, the UN Millennium Project Report on Science, Technology and Innovation (UN Millennium Project, 2005, p. 127) recommends "technological diversification" as a particularly attractive policy to upgrade industries through innovation.

6. Conclusions

In this paper, I have demonstrated that Lall's framework for analyzing Asian pathways to development remains valid for today's global economy where globalization has extended beyond markets for goods and finance to reach markets for technology and knowledge workers. As offshoring has moved beyond industrial manufacturing into services, engineering and research, new opportunities and challenges arise for Asian economies.

To examine what this implies for Asia's "upgrading through innovation" strategies, I have introduced a concept of "industrial upgrading" that links specialization with firm-level and industry-level upgrading and integration into global networks. This concept allows us to identify conditions under which Asian countries could reap the benefits of innovation offshoring.

Our analysis shows that Lall was right to emphasize a divergence between the private interests of the TNCs and the social interests of the host economy in terms of long-term technology development. His plea for industrial policy is even more valid today, as the stakes and risks have become much greater, as countries seek to move beyond the "global factory" model to "upgrading through innovation" strategies.

Lall was also right to emphasize that, the more a country moves up the industrial ladder, the more important advanced capabilities and innovation become. I argue that there is room for cautious optimism that a host country's progressive integration into GINs could facilitate its efforts to push ahead with industrial upgrading.

Most importantly, we have seen that, in line with Lall's research, the key to success is to generate a virtuous circle of accumulating institutions and firm-level capabilities.

Finally, the paper also supports Lall's argument that there is no "one best way" solution. Instead, policies and strategies need to be continuously adjusted to the vagaries of technological change and business cycles, and to the structural transformations of global product and financial markets.

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