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GLOBAL PRODUCTION NETWORKS AND THE CHANGING GEOGRAPHY OF INNOVATION SYSTEMS. IMPLICATIONS FOR DEVELOPING COUNTRIES

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The paper addresses disruptive changes that globalization imposes on the geography of innovation systems, and identifies potential benefits that developing countries could reap from international linkages. The analysis is centered on three propositions. First, developing countries need to blend diverse international and domestic sources of knowledge to compensate for initially weak national production and innovation systems. Second, a greater variety of international knowledge linkages is possible, as globalization reduces the spatial stickiness of innovation. Third, globalization has culminated in an important organizational innovation: the spread of global production networks (GPN) combines concentrated dispersion with systemic integration, creating new opportunities for international knowledge diffusion. We argue that GPN provide firms and industrial districts in developing countries with new opportunities for reverse knowledge outsourcing. We explore resultant challenges that define the need for public policy response, define the new agenda for industrial upgrading, and discuss what types of policies and support institutions may help to reap the benefits from network participation.

Keywords: Globalization, Development and Diffusion of Technology, Growth of the Firm and Networks, Innovation and Knowledge, Industrial Dynamics

JEL Classification: F23, G34, L15, L22, L63, O14, O19, O3, R12

INTRODUCTION

Evolutionary and structuralist theories (as defined by Lipsey in this issue) have reached a certain level of maturity. Basic principles are now well established within the economics profession: a focus on learning and innovation as a major source of economic growth is no longer a minority position. Some key concepts are beginning to shape policy debates

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in the OECD, the World Bank, and the European Commission (*e.g.*, OECD, 1999). It is time to move beyond the defense of basic principles to a policy-oriented research agenda.

The paper suggests that some complementary work is needed to the systemic view of innovation dynamics and policy responses to technological change. The focus is on national innovation system (NIS) theory,[1] simply because it addresses most directly our concern of "integrating policy perspectives into research on technology and economic growth." (Bartzokas and Teubal, 2002: 477–496). Despite its impressive achievements, this theory has two important weaknesses that frustrate an effective implementation of technology policy in developing countries: it fails to address the disruptive changes imposed by globalization on the geography of innovation systems; it also fails to identify potential benefits that developing countries could reap from international linkages.

Three propositions are used to correct these weaknesses. In Section 1, we argue that developing countries need to blend diverse international and domestic sources of knowledge to compensate for initially weak national production and innovation systems. The challenge is to integrate this proposition explicitly into innovation system theory. The bulk of the paper develops our second proposition: a greater variety of international knowledge linkages is possible, due to the spatial impact of globalization (Sections 2 and 3). This runs counter to much of the established wisdom on the geography of innovation (2.1.): a central proposition of the latter literature is that knowledge is spatially sticky: innovation and inter-active learning require co-location. In Section 2.2., we reconsider the agglomeration economies argument, and ask how it needs to be revised in light of the impact of globalization. We highlight the puzzle of *concentrated dispersion*: agglomeration economies continue to matter, yet their spatial stickiness has been reduced (2.3.); introduce the *flagship model* of concentrated dispersion (2.4.), and explore why agglomeration propensities differ (2.5.).

In Section 3, we argue that globalization has culminated in an important organizational innovation: the spread of global production networks (GPN) combines concentrated dispersion with systemic integration, creating new opportunities for international knowledge diffusion. We first describe key features of *systemic integration*: an increasing *scope* of international *linkages* (3.1.), and a growing *intensity* of such linkages (3.2.). We then highlight the capacity of GPN to enhance international knowledge diffusion (3.3.) and discuss possible constraints (3.4.).

Finally, in Section 4, we pursue this issue from a developing country's perspective. We argue that GPN provide new opportunities for reverse knowledge outsourcing for firms and industrial districts in developing countries (4.1.), explore resultant challenges that define the need for public policy response (4.2.), define the new agenda for industrial upgrading (4.3.), and discuss what types of policies and support institutions may help to reap the benefits from network participation (4.4.). We emphasize that nothing is automatic about these processes: the key to success are institutions that facilitate the *concurrent leveraging of multiple and diverse sources of knowledge*—the global production networks of buyers and suppliers of both foreign and domestic origins, as well as the diverse carriers of national innovation systems. Equally important is that the nature and composition of such linkages needs to *change* over time as a country moves up the technological ladder.

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[1] Important sources include: Freeman, 1987, 1995 and 1997; Lundvall, 1992; Nelson, 1993; Boyer *et al.*, 1997; and Edquist, 1997. Mowery and Nelson, 1999 provides a complementary perspective on sectoral innovations sytems. For attempts to apply this concept to developing countries, see Shin, 1998, Gu, 1999; and Ernst and Lundvall, 2000.

1. BEYOND NATIONAL INNOVATION SYSTEMS (NIS): BLENDING INTERNATIONAL AND DOMESTIC SOURCES OF KNOWLEDGE

1.1. Achievements of NIS Theory

The concept of "national innovation systems" (NIS) is an attempt to analyze the institutional determinants of learning, knowledge creation and innovation. A basic proposition is that innovation is crucial for economic growth and welfare, and that it is an inter-active and socially embedded process. A second characteristic is a focus on the national economy: peculiar features of economic structures and institutions offer quite distinct possibilities for learning and innovation, and hence shape the technological (or economic) performance of a country. The economic structure determines specialization (*i.e.* the product mix) and learning requirements (the breadth and depth of the knowledge base). Institutions, on the other hand, shape learning efficiency: they define how things are done and how learning takes place. An important concern is the "congruence" (Freeman, 1997: 13) of different subsystems, which is necessary to create a *virtuous* rather than a *vicious* circle.

The strengths of this concept are well established: by bringing technical change and institutional change back into the analysis as key explanatory variables, it has given new life to the discourse on economic growth. A systemic view of innovation dynamics has moved the analysis beyond the "internalist" bias that characterizes much of the literature on industrial organization and the theory of the firm.[2] This internalist bias has its roots in Edith Penrose's observation that " . . . a firm's rate of growth is limited by the growth of knowledge within it", which has drastically changed our perception of how firms develop and compete.[3]

One way to overcome this internalist bias is to ask how firms organize inter-organizational linkages, especially with regard to knowledge creation. Lundvall (1992) highlights the interactive nature of innovation and documents how user-producer interaction and other forms of inter-firm cooperation give rise to a national system of innovation. And Coombs and Metcalfe (1998: 3) have convincingly argued that competitive success depends on a firm's ability to manage inter-organizational knowledge creation: "The creation of new capabilities is increasingly taking place through the combination of the capabilities of several firms and research organizations." Cross-organizational coordination of capability formation thus becomes of critical importance.[4]

1.2. Neglect of the International Dimension

Yet there are also important weaknesses that we need to address to broaden the acceptance of innovation system theory, and to improve its policy relevance. An important weakness is a neglect of the international dimension.[5] NIS theory uses two propositions to defend its focus on national linkages: First, globalization increases the need for strong national

[2] Two versions of the *internalist* bias can be distinguished. Teece (1998: 148) highlights a focus on internal *hierarchical control*: "Economists, as well as many organization theorists, have traditionally thought of firms as islands of hierarchical control embedded in a market structure and interacting with each other through the price mechanism". A second version of the internalist bias relates specifically to *innovation*: capability-based theories of the firm have focused primarily on the *internal* accumulation of knowledge and skills which underpins its productive activity (Coombs and Metcalfe (1998).

[3] Penrose, 1959/1995, Foreword, 3d edition, "The Theory of the Growth of the Firm", pages XVI and XVII. Ironically, this internalist bias is probably one of the few things that capability-based theories of the firm share with the more traditional proponents of the economics of organization. Take transaction cost economics. Williamson (1998) himself acknowledges that it is necessary to push the analysis " . . .beyond the generic level at which it now operates" (p. 15) to consider " . . . the strengths and weaknesses of a particular firm in relation to its rivals" (p. 29), peculiar characteristics of market niches and the overall "strategic situation" (Table I).

[4] This is in line with population level learning theory (Miner and Haunschild, 1995) which shows that organizational learning depends in important ways on the interaction of organizations, as opposed to feedback from trial and error events inside the organization.

innovation systems. Second, interactive learning requires close interaction between co-located users and producers; national linkages are thus likely to be more effective than international linkages.

We agree with the first proposition: a strong and specialized innovation system is of critical importance in a globalizing world; diversity and specialization are the keys to sustained growth (*e.g.*, Ernst and O'Connor, 1989). For policy purposes, it obviously makes sense to start with a focus on the *national* innovation system. This is in line with the current shift in the concept of development strategy away from a blind faith in markets, emphasizing privatization, deregulation, and trade liberalization to a debate on making both public and corporate governance more effective (*e.g.*, Rodrik, 2000).

From a developing country's policy perspective however, it is problematic to argue that national linkages are more effective than international linkages. This proposition is based on the (mostly implicit) assumption that a fairly homogeneous industry structure can be taken for granted: "... the nation contains a broad set of advanced producers and possible 'lead users'" (Andersen, 1992, note 6). In other words, it is assumed that no huge productivity differences exist, and that there is a strong local base of support industries. This in turn implies the existence of a broad local knowledge base that local firms can access.

This assumption however does not hold universally.[6] It excludes developing countries and most NIEs and second-tier OECD countries, as one of their primary features is a narrow and incomplete set of domestic linkages (*e.g.*, Lall, 1997; Ernst, Ganiatsos, and Mytelka, 1998). A basic characteristic is a *dualistic* industry structure, with widely diverging productivity levels, with technologically advanced firms (mostly foreign affiliates) producing for export alongside weaker domestic firms importing parts for screw driver assembly of products to be sold in the domestic market. We also find a narrow local knowledge base, and a very weak local base of support industries. Very limited sharing and pooling of resources occurs within the country, and often even within the export-oriented cluster

1.3. Innovation Systems in Developing Countries

More specifically, developing countries share four basic features which are not well accounted for in NIS theory: highly heterogeneous economic structures constrain agglomeration economies; weak and unstable economic institutions obstruct learning efficiency; a limited domestic knowledge base implies that developing countries must access and use external sources of knowledge; and a high vulnerability to volatile global currency and financial markets constrain patient capital that is necessary for the development of a broad domestic knowledge base. Initially at least, these countries thus have few opportunities to build their innovation systems on localized clusters. For quite some time, they have to rely primarily on foreign sources of knowledge as the main vehicle of learning and capability formation. In short, international linkages need to prepare the way for the development of national innovation systems.

Empirical research has shown that, as a developing country progresses in its industrial transformation, it reliance on international technology sourcing and knowledge linkages has substantially increased (*e.g.*, Ernst and O'Connor, 1989; Hobday, 1995; Lall, 1997; and Ernst, Ganiatsos, and Mytelka, 1998). A peculiar feature of its innovation system is a

[5] This constitutes a common weakness of economic theories of innovation and the firm: "...most of the work of scholars from these disciplines has not generally embraced an international dimension and, as a result, our understanding of the way resources are organized and distributed across national boundaries has been constricted." (Dunning, 1998, p.291).

[6] Much of the agglomeration economies argument has been developed for a handful for highly developed clusters, such as Silicon Valley, Route 128, Northern Italy, Baden Wuerttemberg, and some industrial districts in Nordic countries.

heavy integration into a variety of firm-specific regional and global production networks (*e.g.*, Ernst, 1994b, Ernst and Ravenhill, 1999; and Borrus, Ernst and Haggard, 2000).

The Korean way of building its innovation system in the electronics industry is emblematic for a heavy reliance on international linkages, combined with the development of complementary domestic linkages (Ernst, 1994a, and 2000b).[7] The government encouraged some of the leading chaebol to focus on learning and knowledge accumulation through a variety of links with foreign equipment and component suppliers, technology licensing partners, OEM clients and minority joint venture partners. By licensing well-proven foreign product designs and by importing most of the production equipment and the crucial components, Korean electronics producers were able to focus most of their attention on three areas: i) the mastery of production capabilities, initially for assembly, but increasingly for related support services and for mass production; ii) some related minor change capabilities, ranging from "reverse engineering" techniques to "analytical design" and some "system engineering" capabilities that are required for process re-engineering and product customization; and iii) a capacity to ramp up new production lines quickly and at low cost.

In order to succeed, Korean firms had to develop the knowledge and skills that are necessary to monitor, unpackage, absorb and upgrade foreign technology. Equally important was a capacity to mobilize the substantial funds for paying technology licensing fees and for importing "best practice" production equipment and leading-edge components.[8] Most Korean producers arguably would have hesitated to pursue such high-cost, high-risk strategies had they not been induced to do so by a variety of selective policy interventions by the Korean state. By providing critical externalities such as information, training, maintenance and other support services, and finance, the Korean government has fostered the growth of firms large enough to overcome high entry barriers.

It is this *co-evolution of international and domestic knowledge linkages* that explains Korea's extraordinary success. It has enabled Korean firms to *reverse* the sequence of technological capability formation (Dahlman, Ross-Larson and Westphal, 1987). Rather than proceeding from innovation to investment to production, they focused on the ability to operate production facilities according to competitive cost and quality standards. Through "reverse engineering" and other forms of copying and imitating foreign technology and by integrating into the increasingly complex global production networks of American, Japanese and some European global corporations (the network *flagships*), Korean firms were able to avoid the huge cost burdens and risks involved in R&D and in developing international distribution channels.

In short, international linkages provided an important initial catalyst for the development of domestic capabilities. The latter have substantially benefited from knowledge outsourcing through gradually more sophisticated international linkages. A theory of innovation systems needs to focus on this blending of domestic and international knowledge linkages. This raises an important question: Will globalization act as a carrier or barrier for such a dynamic coupling?

2. GLOBALIZATION AND THE MOBILITY OF KNOWLEDGE

2.1. Established Wisdom: Spatial Stickiness of Knowledge

The question how globalization affects the geographic dispersion of knowledge and innovation, and whether this fosters or constrains local capability formation has played an important

[7] Taiwan provides another, albeit very different approach to the development of NIS through international linkages (Ernst, 2000a).

[8] Already in the 1970s, most Korean electronics firms had to pay on average roughly 3% of their sales for technology licensing fees, a share which since then has increased to more than 12%.

role for theoretical debates on the role of FDI and multinational corporations (*e.g.*, Cantwell, 1994; Dunning, 1998). More recently, this question has also received attention in innovation theory, the theory of the firm, and economic geography (*e.g.* Chandler *et al*., 1998).

The dominant position has been 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, 1997). The main reason for such spatial stickiness is the inter-active nature of innovation (Kline and Rosenberg, 1986; Lundvall, 1988): it requires dense knowledge exchange between users and producers, much of it being tacit knowledge. Such information-rich transfers require localized clusters within a nation, or even better, an industrial district, or micro-region (*e.g.*, Porter, 1990; Lundvall, 1992; Saxenian, 1994; Storper, 1997; and Markusen, 1996). This reflects the importance of "dynamic agglomeration economies": co-location facilitates a continuous, intense and rapid exchange of new ideas about technical, organizational and production improvements.

Knowledge and innovation thus do not easily migrate across borders: they do not automatically follow, once production moves. If true, this would imply that even while globalization extends its reach beyond trade and finance, giving rise to an extensive relocation of production, this may not help to reduce the huge international gaps in knowledge and innovation. For industrial countries, the spatial stickiness of innovation may foster attempts to sustain their technological superiority. For developing countries however, spatial stickiness of innovation may fundamentally constrain their sources of growth, and hence perpetuate global inequality.

Our second proposition qualifies this argument. We argue that globalization has created an explosive mix of forces that facilitate international knowledge diffusion, increasing the variety of international knowledge linkages. This creates new opportunities and challenges for the development of innovation systems.

2.2. Reconsidering the Agglomeration Economies Argument

Proximity exerts a powerful constraining effect on the location of economic activities: industries tend to agglomerate and cluster in particular geographic locations, giving rise to persistent patterns of national and regional specialization. Alfred Marshall's pioneering concept of "externalities" (1890/1916) helps to identify both static and dynamic economies of agglomeration. While *static* agglomeration economies focus on efficiency gains resulting from scale economies, transaction and transport costs, and input-output linkages, *dynamic* agglomeration economies highlight the central role of learning and knowledge creation. Marshall emphasizes three advantages of an industrial district: i) it provides a pool of skilled workers with industry-specific capabilities; ii) intermediate inputs, especially non-tradable ones, are provided by local suppliers; and iii) there is a continuous, intense and rapid exchange of new ideas about technical, organizational and production improvements. In Marshall's view, the latter is clearly the decisive advantage.[9]

Marshall's important observations have been forgotten for a long time: neo-classical economists have neglected until recently the agglomeration or clustering of related activities. Since Krugman (1991, 1995), economic geography has been re-established as a respectable

[9] " . . .(P)eople following the same skilled trade get . . ..(substantial advantages)..from near neighbourhood to one another. The mysteries of the trade become no mysteries; but are as it were in the air, and children learn many of them unconsciously. Good work is rightly appreciated, inventions and improvements in machinery, in processes and the general organization of the business have their merits *promptly* (DE) discussed: if one man starts a new idea, it is taken up by others and combined with suggestions of their own; and thus it becomes the source of new ideas." (ibid, p. 271).

topic. This has brought back into economic theory "increasing returns" and other anomalies like the "path dependency" of spatial location. Unfortunately, these debates have remained trapped in the static efficiency paradigm and miss the importance of knowledge and learning.[10]

There is however now a growing literature that analyzes the *dynamics* of spatial agglomeration. It is argued that clustering effects are particularly important for *knowledge externalities* and *spill-overs* (Porter, 1990; Enright, 1998; Spender, 1998; Porter and Sølvell, 1998; OECD, 1999c). Concentrations of companies succeed when they cooperate as well as compete; the focus of cooperation is on the sharing of knowledge, skills and technologies among the companies and with public agencies.

Dynamic agglomeration economies are considered to be an important determinant of firm behavior. Resources and capabilities that are critical for a firm's competitive success "can often be found inside a region, rather than within any single firm"; "...regional clusters often involve activities that are shared across firms within the cluster" (Enright, 1998: pp. 315 and 316). A regional cluster provides access to specific resources and capabilities that are difficult to reproduce otherwise; it enables a firm to engage in peculiar types of coordination and organization; and it allows the firm to share activities with other cluster participants (ibid, pp. 328–336). In short, the "... notion that resources can be specific to a region rather than a firm lies at the heart of many of the major explanations for localization in industry". In regional clusters, tacit knowledge can be internal to an area, without being internal to any specific firm. Such knowledge can be tradeable locally *without being tradeable outside the regional cluster* (italics added, DE). "(ibid., 326)"

Attempts to construct a neo-Marshallian agglomeration theory are a positive development, as long as we remain conscious of some inherent limitations. It is not possible to use this concept today without substantial changes.[11] We need an explicit analysis of the impact of globalization on agglomeration economies and on international knowledge diffusion. Research on globalization has clearly established that the centre of gravity has shifted beyond the national economy. Cross-border linkages proliferate, with the result that no country can exist any longer in isolation. The same is true for regions and industrial districts: they are rapidly becoming internationalized, and increasingly depend on *international linkages* (Dunning, 1998) to import key inputs and to export outputs. Such external linkages cover both *tangibles* like materials and machinery, and *intangibles* like finance and knowledge. A significant increase in the share of the latter is an important distinguishing feature of current rounds of globalization.

Globalization thus poses some important *puzzles* that need to be addressed in a revised agglomeration theory: Why is it that, despite the advantages of co-location, there has been a massive geographic dispersion of certain stages of the value chain? More specifically, what factors explain that some value chain activities are more prone to geographic dispersion, while others are more sticky? How come that agglomeration economies are no longer restricted to the home country basis? What makes it possible to reproduce certain co-location

[10] For Krugman (1991), agglomeration in essence results from three factors: i) substantial *increasing* returns to scale-both at the level of the single firm (*internal* economies) and the industry (*external* economies). ii) sufficiently low transport costs; and iii) large local demand. Proximity matters, resulting in agglomeration, once these three factors interact. For an excellent critique of the "New 'Geographical' Turn in Economics", see Martin, 1999.

[11] After all, Marshall's analysis was shaped by value judgments which reflect a peculiar historical concern of late 19th century Britain (Lazonick, 1999, pages 10 passim: Will Britain be able to survive the new and aggressive competition from emerging nations such as the US and Germany, with their highly concentrated industries? Marshall believed that "a proliferation of small-scale proprietary enterprises was both a morally superior form of industrial organization and more favorable to economic development"). The implication was that economic development did not require concentrations of power within industry, like in the US and Germany.

effects at overseas locations? And what explains the creation of dense cross-border linkages between these locations that facilitate cross-border knowledge diffusion?

2.3. The Puzzle of Concentrated Dispersion

Despite the fundamental advantages of keeping production at home and at close proximity, geographic dispersion has occurred on a massive scale. This reflects a shift in the carriers of globalization: while intra-industry trade dominated till the mid-1980s, since then, international production has grown considerably faster than international trade (*e.g.*, UNCTAD, 1998). By the 1990s, sales of foreign affiliates of multinational enterprises (MNEs) far outpaced exports as the principal vehicle to deliver goods and services to foreign markets.

In contrast to the assumptions of convergence theory, globalization does not lead to the wonderland of a "borderless world" (Ohmae, 1991) where capital, knowledge and other resources move freely around the globe, acting as a powerful force of equalization.[12] Globalization does not rescind the gravitational forces of geography. It has given rise to "ever more finely grained patterns of locational differentiation and specialization" (Scott, 1998: 399). Inequality and diversity prevail. A breath-taking speed of geographic dispersion has been combined with spatial concentration: much of the recent cross-border extension of manufacturing and services has been concentrated on a handful of specialized local clusters, both within the Triad and some so-called emerging economies, especially in East Asia.

Let us look at some indicators in the electronics industry, a pace setter of globalization (Ernst, 1998). A good proxy of *geographic dispersion* are the growing methodological problems that one encounters when one tries to determine the importance of individual countries and regions in the world electronics market. The difficulties reflect the fact that final products, almost without exception, involve substantial inputs across the value chain that are produced in diverse locations across the globe.

Two measures exist: one is based on company *ownership*, the other on the *country of origin of exports*. Both market share measures were largely similar, as long as trade was the most important vehicle for international market share expansion. Both indicators however began to diverge, once production dispersed across borders. Take semiconductors (Reed Electronics Research, 1998): there is a huge gap between the US share of world exports (18%) and its market share based on company ownership (32%). This suggests that a very high share of US production is taking place overseas. The gap between ownership-based and export market shares is even higher for Asia (38% by country of origin, versus 19% by ownership), which suggests that Asia has attracted the bulk of investments not only from the US but also from Japan and Europe.

Geographic dispersion however is heavily *concentrated* in a few specialized local clusters. For instance, the supply chain of a computer company typically spans different time zones and continents, and integrates a multitude of transactions and local clusters. The degree of dispersion differs across the value chain: it increases, the closer one gets to the final product, while dispersion remains concentrated especially for critical precision components.

On one end of the spectrum is final PC assembly that is widely dispersed to major growth markets in the US, Europe and Asia. A good example is provided by Taiwan's Acer group, one of Asia's role models of how a small company can rapidly grow and transform itself into a global competitor.[13] Out of Acer's 21 manufacturing sites, six are large volume

[12] For a critique, see Boyer, 1996; and Ernst and Ravenhill, 1999.

[13] From humble origins, Acer has grown within less than two decades into a global network flagship that employs more than 32,000 people in 120 enterprises in 37 countries, supporting dealers and distributors in over 100 countries. Acer Group revenues in 1998 were US$ 6.7 billion (acer.com).

manufacturing sites located overseas: two in China, and one each in the Philippines, Malaysia, Mexico and Wales. Equally important are Acer's 19 overseas final assembly and configuration centers that are much more geographically dispersed to major markets. Adding further complexity, Acer needs to integrate its networks into the GPN of major OEM customers, like IBM (its largest customer).

Dispersion is still quite extended for standard, commodity-type components (*homogeneous products* in the parlance of industrial economists), but less so than for final assembly. For instance, keyboards, computer mouse devices and power switch supplies are sourced from many different sources, both in Asia, Mexico and the European periphery, with Taiwanese firms playing a major role as supply coordinators. The same is true for lower-end printed circuit boards. Concentration of dispersion increases, the more we move toward more complex, capital-intensive precision components: memory devices and displays are sourced primarily from Japan, Korea, Taiwan and Singapore; and hard disk drives from a Singapore-centered triangle of locations in Southeast Asia. Finally, dispersion becomes most concentrated for high-precision, design-intensive components that pose the most demanding requirements on the mix of capabilities that a firm and its cluster needs to master: microprocessors for instance are sourced from a few globally dispersed affiliates of Intel, two secondary American suppliers, and one recent entrant from Taiwan, Via Technologies.

The *hard disk drive (HDD)* industry provides another example both for the breath-taking speed of geographic dispersion, as well as for its spatial concentration (Ernst, 1997b) Until the early 1980s, almost all HDD production was concentrated in the US, with limited additional production facilities in Japan and Europe. Today, only 1 percent of the final assembly of HDDs has remained in the US, while Southeast Asia dominates with almost 70% of world production, based on units shipped. Slightly less than half of the world's disk drives come from Singapore, with most of the rest of the region's production being concentrated in Malaysia, Thailand, and the Philippines.

2.4. The Flagship Model of Concentrated Dispersion

One major impact of globalization has been the spread of global production networks (GPN) that provide international corporations (the network *flagships*) with quick access to lower-cost capabilities overseas that are complementary to their own core competencies. This reflects the rising cost of innovation (OECD, 2000: chapter 2). Flagships are also under increasing pressure to exploit *complementarities* that result from the *systemic* nature of knowledge (Antonelli, 1998). We thus need to shift the focus of our analysis away from the industry and the individual firm to the level of a *network flagship* and its evolving GPN. This distinguishes our approach from earlier research on international technology transfer through stand-alone foreign direct investment projects of multinational corporations (*e.g.*, Enos, 1989).

Take again the hard disk drive industry. Seagate, the current industry leader provides a good example of the flagship model of concentrated dispersion (Ernst, 2002a). Today, Seagate operates 22 plants worldwide: 14 of these plants, *i.e.* 64% of the total, are located in Asia. Asia's share in Seagate's worldwide production capacity, as expressed in sq-ft, has increased from roughly 35% in 1990 to slightly more than 61% in 1995-an incredible speed of expansion. Concentrated dispersion is also reflected in the regional breakdown of Seagate's employment. Asia's share increased from around 70% in 1990 to more than 85% in 1995.

The fact that Asia's share in employment is substantially higher than its share in capacity, while the opposite is true for the US, indicates a clear-cut division of labor: volume manufacturing and the production of low- and mid-range components has been shifted to Asia, while the US retains the high-end, knowledge-intensive stages of the value chain, especially hard-core R&D. It is this network-specific division of labor that determines distinct development trajectories for specialized industrial clusters in the US and in Developing Asia.

We need to add a further aspect: an extreme spatial concentration *within* East Asia. Slightly more than 92% of Seagate's capacity in Asia is concentrated in three locations: in Bangkok (almost 32%), Penang (more than 30%) and Singapore (a bit less than 30%). And almost 50% (26,000 out of 55,000) of Seagate's Asian employment is concentrated in its plant in the outskirts of Bangkok. This indicates that network specialization also defines the development opportunities of industrial districts within a particular macro-region. Bangkok is the centre for low labor cost volume manufacturing. Next comes Singapore with more than 27% (15,000), substantially more than Malaysia's 16% (9,000 people). For both Singapore and Malaysia, the low ratio of employment relative to its share in Seagate's production capacity indicates that production facilities have been rapidly automated and include now higher-end manufacturing activities such as component manufacturing.

Over time, Seagate has developed a quite articulate regional division of labor in East Asia. Bottom-end work is done in Indonesia and China. Malaysian and Thai plants make components and specialize in partial assembly. Singapore is the centre of gravity of this regional production network: its focus is on higher-end products and some important coordination and support functions. It completes the regional production network, by adding testing, which requires precision. This indicates that for individual specialized industrial clusters, development trajectories are path-dependent.

In short, rapid cross-border *dispersion* coexists with *agglomeration*. Globalization often occurs as an *extension* of national clusters across national borders. This implies two things: First, some stages of the value chain are internationally dispersed, while others remain concentrated. And second, the internationally dispersed activities typically congregate in a limited number of overseas clusters. This clearly indicates that agglomeration economies continue to matter, hence the path-dependent nature of development trajectories. What needs to be explained however is *how they have changed under the impact of globalization*. There is a growing literature that explains the *bifurcation* of geographic location patterns along functional activities (Audretsch and Feldman, 1996, McKendrick *et al*., 2000) or value-chain stages (Dicken, 1992; Ernst, 1997b).

The essential point is that such distinctions should be made not on the basis of different industries, but rather for different value chain stages.Earlier research has been 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 results, for two reasons: 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 (Ernst, Ganiatsos and Mytelka, 1998). Second, both the capability requirements and the boundaries of a particular "industry" keep changing over time, which makes an analytical focus on the industry level even more problematic.

2.5. Diverse Agglomeration Propensities

Concentrated dispersion thus raises an important question: What factors explain that some value-chain activities are more prone to geographic dispersion, while others are more prone to proximity constraints? The usual suspects of course are differences in labor costs and knowledge-intensity. There is a strong presumption that high-wage and more knowledge-intensive activities are more prone to agglomeration effects, and hence resistant to geographic dispersion. By the same token, geographic dispersion can be expected to be most prominent for low-wage, and low-skill value chain activities.

There is nothing surprising about these propositions—this is precisely what one would expect from an agglomeration economies perspective. This would seem to imply that a clear-cut separation is possible between low-end activities that are highly dispersed, and knowledge-intensive ones that require localized clusters. Yet, reality is considerably more messy. An important complication results from the *diversity* of agglomeration propensities: co-location requirements differ across industries and product markets; they also differ across firms. Those industry and firm-specific differences provide one possible explanation for the diversity of development trajectories.

Take first industry-specific features: co-location becomes more important, the greater an industry's volatility, *i.e.* the shorter its product-life cycle, the quicker the required speed-to-market, and the greater the number of design changes. Yet, such co-location can occur at different places. This is borne out by the example of the hard disk drive industry. Due to its high volatility, HDD assemblers cannot afford to have a geographically extended supply chain. Hence the importance for suppliers to locate close to the main drive assemblers (Ernst, 1997b; McKendrick *et al.*, 2000). During the early stages of this industry, this implied co-location at home (primarily around IBM's San José facility in California). We have seen that globalization has given rise to the concentrated international dispersion of such clusters.

Agglomeration propensities also differ by type of supplier.[14] For suppliers of standard equipment and components, there is no need for close interaction with their customers. Intense interaction is essential however for the client's relation with high-end suppliers of differentiated products that require proprietary technology. Paraphrasing price theory terminology, we call these suppliers "technology makers".[15] Now suppose the client has established an overseas affiliate in country C. Here again, globalization has broadened the co-location options. Interaction does not need to be localized, *i.e.* it does not need to occur on the spot, at the client's overseas facility in country C. It frequently takes place at the client's or the supplier's home facilities that often may reside in different countries A and B.

Intense localized interaction (*i.e.* interaction on the spot) is necessary only for newly established and still relatively weak lower-tier suppliers (technology takers) who need to be nurtured till they can stand on their own feet. In the electronics industry, for instance, technology takers are frequently used as second sources. Their main purpose is to provide the client with a price leverage against suppliers who are technology setters and who are inclined to charge premium prices. Technology takers are also used as capacity buffers, especially when the technology setters resist client requests for price cuts. Divergent agglomeration propensities by type of supplier thus provides us with another differentiating factor that shapes distinct development trajectories.

Probably the most important caveat to the agglomeration economies argument is that dispersion is no longer restricted to lower-end activities. This becomes clear when we look at the role played by GPN as carriers of international knowledge diffusion.

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[14] Williamson's concept of site specificity, a particular form of physical asset specificity, provides a formal treatment of this issue. A fundamental weakness however is the theory's inherent incapacity to address the issue of innovation. As Williamson himself explains: "The introduction of innovation plainly complicates the earlier-described assignment of transactions to markets and hierarchies based entirely on an examination of their asset specificity qualities. Indeed, the study of economic organization in a regime of rapid innovation poses much more difficult issues than those addressed here." (1985: 143). In the final analysis, Williamson's theory explains the firm as a response to market failure: "The cause of this market failure is "asset specificity"—a technological condition that is given to the firm." (Lazonick, 1999: 22).

[15] Price theory distinguishes perfect competition, where the firm is a "price taker", *i.e.* has no choice but to accept the price that has been determined in the market, and monopolistic competition, where the monopolist can, if so inclined, raise his price ("price maker"). In analogy, we distinguish "technology makers" that possess proprietary technology and hence can shape the design trajectory of a particular product or service, and "technology takers" that have no choice but to accept the design principles established by the former.

3. SYSTEMIC INTEGRATION: GLOBAL PRODUCTION NETWORKS AS CARRIERS OF KNOWLEDGE DIFFUSION

Geographic dispersion poses increasingly demanding coordination requirements. Global production networks (GPN) are an organizational innovation that enables network flagships to combine concentrated dispersion with *systemic* forms of *integration*. These networks *integrate* the dispersed supply and customer bases of a *network flagship*, *i.e.* its subsidiaries, affiliates and joint ventures, its suppliers and subcontractors, its distribution channels and value-added resellers, as well as its R&D alliances and a variety of cooperative agreements, such as standards consortia.[16] The flagship breaks down the value chain into a variety of discrete functions and locates them wherever they can be carried out most effectively, where they improve the firm's access to resources and capabilities, and where they are needed to facilitate the penetration of important growth markets. Under certain conditions, these networks may enhance the diffusion of knowledge across firm boundaries and national borders.

3.1. Scope of Linkages

One reason to talk about systemic integration[17] is a substantially broadened *scope* for international linkages: a GPN encompasses both *intra*-firm and *inter*-firm linkages; creates a diversity of network participants; links together *multiple* locations; and covers a variety of value chain stages, including higher-end, and more *knowledge-intensive* ones.

This raises a number of important issues that are highly contested in the literature. For instance, GPN do not necessarily give rise to less hierarchical forms of firm organization (as predicted for instance in Bartlett and Ghoshal, 1989). Network participants differ in their access to and in their position within such networks, and hence face very different challenges. We use a *taxonomy* of network participants that distinguishes various hierarchical layers that range from *flagship companies* that dominate such networks, down to a variety of usually smaller, local network participants. The flagship is at the heart of a network: it provides strategic and organizational leadership beyond the resources that, from an accounting perspective, lie directly under its management control (Rugman, 1997: 182).

The strategy of the flagship company thus directly affects the growth, the strategic direction and network position of lower-end participants, like specialized suppliers and subcontractors. The *flagship* derives its strength from its *control* over critical resources and capabilities, and from its capacity to *coordinate* transactions between the different network nodes. Both are the sources of its superior capacity for generating economic rents.[18] This taxonomy helps to distinguish the different capacities of these firms to reap potential network

[16] The concept of a *global production network* (GPN) captures the spread of the value chain across firm boundaries and national borders. It may, or may not, involve ownership of equity stakes. For details, see *e.g.*, Ernst, 1994b, 1997a, 1997b, 1998, 2000a, 2002a, 2002c and 2002d. For empirical case studies on diverse GPN, see Ernst and Ravenhill, 1999, and various chapters in Borrus, Ernst and Haggard (Eds.), 2000.

[17] *Partial* integration is characterized by a loose patchwork of arm's-length trade and stand-alone, unrelated investment projects. Most of these focus either on access to domestic markets or on exploiting particular resources (cheap labor). They are *footloose*, in the sense that they are prone to rapid closure and redeployment. Partial integration implies a limited scope for international specialization. This is due to an absence of interactions across functions and locations, and to a lack of coordination.

[18] I refer of course to Penrose-type rents. Spender (1998, p. 433) demonstrates that " . . . each type of knowledge can, in principle, be associated with a different kind of rent and competitive advantage". Tacit social knowledge (which Spender calls *collective*) is of critical importance: "The collective knowledge which develops as key players interact under conditions of uncertainty leads to Penrose rents, so labelled because such activity-based learning lies at the core of her theory of the growth of the firm".

benefits, and the institutions and policies required to support weaker network participants from developing countries.

One critical capability for instance is the intellectual property and knowledge associated with setting, maintaining and continuously upgrading a de facto market standard. This requires perpetual improvements in product features, functionality, performance, cost and quality. It is such "complementary assets" (Teece, 1986) that the flagship increasingly *outsources*. This has given rise to a number of organizational innovations that culminate in the spread of GPN. Take recent developments in the electronics industry which has become the most important breeding ground for a *New Industrial Organization* model (*e.g.*, Chandler, *et al*., 1998). For instance, for a typical flagship in the PC business, the cost of components, software and services purchased from outside, has increased from less than 60 percent to more than 80 percent of total (ex factory) production costs (Ernst and O'Connor, 1992, chapter I). As external sourcing relations become geographically dispersed and increasingly complex, they are fraught with very high coordination costs: some firms report that the cost of coordinating such outside relations can exceed in-house manufacturing costs.[19] As a result, the focus of *cost reduction* strategies is shifting from scale economies in manufacturing to a reduction of the cost of global sourcing.

In the electronics industry, this has given rise to a proliferation of specialized suppliers, segmenting the industry into separate, yet closely interacting horizontal layers (Grove, 1996). The initial catalyst was the availability of standard components, which allows for a change in computer design away from centralized (IBM mainframe) to decentralized architectures (PC, and PC-related networks). As a result, new options emerged for outsourcing, transforming an erstwhile vertically integrated industry into horizontally disintegrated, yet closely interacting market segments (*e.g.*, integrated circuits, board assembly, disk drives, operating systems, applications software, and networking equipment).

Each of these individual market segments became rapidly globalized. This has given rise to the *co-existence* of *complex*, globally organized *sector*-specific value chains, for instance for microprocessors, memories, PCs, HDD, and other components, a process accelerated by the introduction of Internet-enabled *virtual* integration (*e.g.*, Ernst, 2002a). Each of these value chains consists of a variety of GPN that compete with each other, but that may also cooperate. The number of such networks, and the intensity of competition varies across sectors, reflecting their different stage of development and their idiosyncratic industry structures. These fundamental changes in the organization of international production have been largely neglected in the literature, both in research on knowledge spill-overs through FDI, and in research on the internationalization of corporate R&D.

Take the outsourcing of volume manufacturing and related support services that enables global brand-name companies in the electronics industry (especially PC and telecommunications) to combine cost reduction, product differentiation and time-to-market (Sturgeon, forthcoming, and Luethje, 1999). A peculiar feature of this new model of industrial organization is that manufacturing is de-coupled from product development, and is dispersed across firm and national boundaries. With an average annual growth of more than 25%, the so-called *electronics manufacturing services* (EMS) market is one of the fastest growing electronics sectors, expanding twice as quickly as the total electronics industry.[20]

[19] Such costs are typically defined as " . . . all incremental cost associated with dealing with suppliers remote from the initial design site and/or the final assembly site", with communication costs and administrative overheads absorbing the largest share (Ernst and O'Connor, 1992, ibid.).

[20] The role model for such changes is Solectron that, only a few years ago was a typical SME, but has transformed itself into the world's largest EMS provider. With a CAGR of 43% over the past five years, Solectron has now more than 46,000 employees in 41 locations worldwide, with more than 9 million square feet of capacity. Revenues for FY 1999 were $8.4 billion.

The network flagship outsources not only manufacturing, but also a variety of high-end, knowledge-intensive support services. Most research on the location of knowledge-intensive activities has focused on the role of R&D, but this may be a too narrow focus (for details, see Ernst, 2002d). It is necessary to cast the net wider and to analyze the geographic dispersion of *cross-functional*, *knowledge-intensive support services* that are intrinsically linked with production. Even if these activities do not involve formal R&D, they may still give rise to considerable learning and innovation. The latter include for instance trial production (prototyping and ramping-up), tooling and equipment, benchmarking of productivity, testing, process adaptation, product customization and supply chain coordination.

The result is that an increasing share of the value-added becomes dispersed across the boundaries of the firm as well as across national borders. Take the spread of "turnkey production arrangements" in the PC industry. A typical example is the contract between Taiwan's Mitac International and Compaq: the latter has out-sourced all stages of the value chain for a particular PC family, except marketing; and Mitac is responsible for the design and development of new products, as well as for manufacturing, transport and after-sales services at its manufacturing facilities in Taiwan, China, Britain, Australia and the US. For Compaq, Mitac's greatest attraction is its network of plants and sales subsidiaries located in most of the world's key computer markets (Ernst, 2000a). What matters for our purposes is that Mitac and other smaller Taiwanese companies can use such arrangements as a catalyst for upgrading their firm-specific capabilities and their collective knowledge base in the Taipei-Hsinchu industrial district.

This example illustrates a tendency to extend international subcontracting to comprise an integrated package of higher-end support services, to be provided by a foreign partner. With the exception of hard-core R&D and strategic marketing that remain under the control of the network flagship, the supplier must be able to shoulder all steps in the value chain. In some cases, it must even take on the coordination functions necessary for global supply chain management. This necessitates dense linkages between geographically dispersed, yet concentrated and locally specialized clusters, and their integration into GPN.

3.2. Intensity of Linkages

Systemic integration also implies that linkages between any two countries A and B are no longer secondary, quasi optional to their domestic linkages. Instead, existing clusters in both countries supplement each other and may experience mutual inter-penetration. Under such conditions, international linkages are essential for the continuous growth of specialized cluster.

This is self-evident for network *suppliers*, especially lower-tier ones, whose growth and strategic direction is heavily determined by the *network flagship*. Dependence however also works the other way round. To the degree that the flagship has moved to *global sourcing*, it may no longer have any credible domestic suppliers. This implies an *erosion* of the *collective knowledge* which used to be a characteristic feature of the flagship's home location. In some cases, that collective knowledge may have migrated for good to the supplier's overseas cluster(s).

The semiconductor industry provides a typical example (Ernst, 1983 and 1997b, chapter IV). Since the 1970s, leading American producers had moved much of their final assembly and testing to Asia, with the result that knowledge had to follow suit. Take the case of Texas Instruments: "As far as assembly and testing are concerned we have more expertise here (*i.e.* in Malaysia) than we have in the US. We sometimes have to send our Malaysian engineers to the States to solve their problems."[21] In the case of Intel's Penang subsidiary, such expertise

[21] Author's interview at Texas Instruments Malaysia, May 1984.

became particularly strong for the design and production of specialized automated assembly equipment. When Intel, in 1983, set up highly automated assembly plants in Chandle-r/Arizona and in Ireland, the company had to rely on senior Malaysian engineers from its Penang affiliate for plant lay-out, equipment design, as well as for sorting out technical teething problems.[22] Intel Penang even claims that the first manager of its Mechanisation and Automation group has been seconded to automate Intel's wafer fabrication lines in the United States and that its automation team makes substantial contributions to upgrade the level of automation in Intel's worldwide operations.

Over time, much of this knowledge has moved out of individual subsidiaries and has become widely diffused across different network nodes, especially in East Asia. The irony is that, today, chip assembly is no longer the uninspiring "back-end" of the semiconductor industry. Assembly and packaging technologies in this industry have become highly complex and play an important role for yields and performance features of leading-edge devices. Knowledge diffusion through GPN has enabled chip contract assemblers in Korea (*e.g.*, Anam Industrial, the world's largest chip contract assembler being a prime example), Taiwan, and Singapore to accumulate design capabilities for innovative new circuit packaging technologies. This has provided ample opportunities for the development of local SME-based clusters of small-and-medium-site enterprises that support chip assembly.

3.3. New Opportunities for International Knowledge Diffusion

We have seen that the main purpose of GPN is to gain quick access to lower-cost foreign capabilities that are complementary to the flagship's own competencies. To mobilize and harness these external capabilities, flagships are forced to accept a certain *dispersion* of the value chain. They also must broaden their capability transfer to individual nodes of their GPN. The (often unintended) result is a creeping diffusion of knowledge to external actors abroad. This opens *new opportunities* for international knowledge linkages that developing countries should strive to exploit. It however also raises complex challenges for policies as well as firm organization.[23]

A GPN can create a *virtuous circle* of international knowledge diffusion for two reasons. *First*, it increases the length of a firm's value chain, as well as its logistical complexity. This creates new gaps and interstices that can be addressed by small, specialized suppliers. While in some cases (like for instance "screw-driver" contract assembly), such entry may be short-lived, this is not necessarily so. Outsourcing requirements have become more demanding and have forced specialized suppliers to develop their capabilities. Over time, they may be able to upgrade their position from simple contract manufacturers to providers of integrated service packages, and hence increase the benefits that they can reap from network participation.

A typical example is Solectron, the world's largest electronics manufacturing services company that we mentioned before. Founded in 1977 as a tiny contract manufacturer of electronic controllers for solar energy equipment, it only began to grow once it moved into circuit board assembly for the PC industry, acting as a low-cost buffer for the periodic capacity deficits of large electronics equipment producers. Given the low entry barriers of this business, this market was soon inundated with lower-cost competitors. Competitive survival required a focus on quality and speed, necessitating substantial investments in assembly automation (surface-mount-technology), leading-edge process technology, and training. This high-risk strategy paid off, as it allowed Solectron to move up the ladder in the contractor hierarchy

[22] Author's interview at Intel Penang (April 1992).

[23] Part 4 addresses policy implications for developing countries, while management implications are explored in Ernst (2000d).

and to a become a preferred supplier of leading electronics companies. This in turn required investments in overseas facilities (geographic dispersion) to provide manufacturing and design services where required. Since the late 1990s, the company has further upgraded its capabilities. It defines itself now as a global supply chain facilitator: "...customers can turn to Solectron at any stage of the supply chain, anywhere in the world, and get the highest-quality, most flexible solutions to optimize their existing supply chains" (Solectron, 2000: 1).

Second, once a network supplier successfully upgrades its capabilities, this creates further pressure for a continuous migration of knowledge-intensive, higher value-added support activities to individual network nodes. This may also include engineering, product and process development. This reflects the increasingly demanding competitive requirements. In the electronics industry for instance, product-life-cycles have been cut to six months, and sometimes less (Ernst, 1998). Overseas production thus frequently occurs soon after the launching of new products. This is only possible if key design information is shared more freely between the network flagship and its overseas affiliates and suppliers. Speed-to-market requires that engineers across the different nodes of an GPN are plugged into the lead company's design debates (both on-line and face-to-face) on a regular basis.

3.4. Constraints

Important constraints exist to the diffusion of knowledge within GPN. Of particular importance are changes in organizational routines that result from geographic dispersion. Once a network flagship extends its value chain across national boundaries, it is faced with complex coordination problems and the risk of abrupt disruptions. Four sources of disruption can be discerned: (1) those caused by suppliers, either through late delivery or through the delivery of defective materials; (2) unforeseen fluctuations in demand and abrupt changes in demand patterns; (3) a variety of production problems that result from the transfer of immature products and production processes: and (4) abrupt changes in management decisions, for instance last-minute corrections of product launch dates and performance features.

Flagships have tried to reduce the likelihood of such disruptions—yet so far with only limited success (Levy, 1995). While production-related disruptions decline with increasing product maturity, this has not been the case for demand-related disruptions and for abrupt changes in management decisions that have been imposed by financial markets. On both counts, the geographic dispersion of GPN has considerably increased the pace of change and uncertainty. This poses increasingly complex trade-offs between *specialization* advantages from geographic dispersion and the dynamic benefits from *learning* and *innovation*. Coping with these trade-offs requires far-reaching changes in existing organizational structures. This has given rise to a debate about how firms can improve *corporate coherence*, as more and more value chain activities migrate to external actors (Teece, Rumelt, Dosi and Winter, 1994).

Another constraint to the diffusion of knowledge within GPN are differences in the approach to knowledge creation. It has been argued that peculiar features of national institutions have led to distinctive national approaches of firms to learning and knowledge formation and that this constrains knowledge sharing and inter-organizational learning across national borders (Lam, 1998). The dominant form of knowledge held in organizations, its degree of tacitness, and the way in which it is structured, utilized and transmitted can vary considerably between firms in different societies. This reflects differences in social institutions, especially with regard to knowledge formation, labour markets and occupational systems.

Knowledge outsourcing through GPN thus requires lengthy trial-and-error learning processes and substantial investment to strengthen the absorptive capacity of different network nodes and participants. This implies that network flagships may now have a vested interest in the formation of regional clusters of specialized capabilities that are located within or in close proximity to their main growth markets. This has important implications for developing countries, to which we now turn.

4. IMPLICATIONS FOR DEVELOPING COUNTRIES

For developing countries, integration into GPN poses a fundamental dilemma. An increased mobility of firm-specific resources and capabilities may enhance the diffusion of knowledge across firm boundaries and national borders, and hence provide new opportunities for development strategies. Nothing however guarantees this outcome. Network integration may equally well may erode a country's sources of competitive advantage. It may also erode the strengths of existing clusters. This may increase the divide between firms and districts that have and those that do not have access to the information and knowledge that is necessary to reap the benefits of network participation. Many people are understandably concerned that this may lead to a decline in economic growth and welfare.

4.1. Opportunities: The Dual Nature of Knowledge Outsourcing

There is however cause for cautious optimism: network participation may provide new opportunities for *reverse knowledge outsourcing* for firms and industrial districts in developing countries. Our analysis has shown that are powerful vehicles for knowledge outsourcing across firm boundaries and national borders. It is important to emphasize their *dual* nature. Most debates focus on the strategic rationale underlying knowledge outsourcing by large global network flagship companies, and their organizational implications (*e.g.*, Patel and Pavitt, 1991; and Granstrand *et al.*, 1993.). For developing countries however what matters is the other side of the coin: participation in GPN can facilitate *reverse* knowledge outsourcing by smaller, lower-tier network participants that may help them to overcome some of their knowledge-related disadvantages.

Three effects of such reverse knowledge outsourcing can be distinguished: First, it can act as a *conduit* for *knowledge diffusion* of state-of-the-art management approaches as well as product and process technologies. At the same time, these international linkages can also act as *catalysts* for *knowledge creation* and *capability development within* firms and industrial districts in developing countries. Thirdly, over time these linkages may also give rise to *joint knowledge creation*, with roughly symmetrical contributions from the global network flagship and from the developing country network participants.

Take the participation of Taiwanese computer firms in GPN (Ernst, 2000a). Let us look at the most important of such linkages, *i.e.* manufacturing on an OEM basis.[24] Taiwan's involvement in the OEM business has gone through different incarnations, from very simple arrangements to highly complex ones. Each of these stages has given rise to a peculiar

[24] Definitions of what constitutes an OEM (original equipment manufacturing) contract keep changing. Probably the most widely accepted definition refers to arrangements between a brand name company (the network flagship) and the contractor (the supplier) where the customer provides detailed technical blueprints and most of the components to allow the contractor to produce according to specifications. Using this definition of OEM arrangements, we can then distinguish ODM (original design manufacturing) as arrangements where the contractor is responsible for design and most of the component procurement, with the brand name company retaining exclusive control over marketing.

pattern of knowledge outsourcing. It started with very simple OEM arrangements covering low-end desktop PCs and labor-intensive peripherals that generated limited opportunities for knowledge outsourcing. In response to such draw-backs, some Taiwanese computer companies have tried to move up into own brand-name manufacturing (OBM) sales. Most of them failed and are now content to consolidate and upgrade their position as OEM suppliers. Paradoxically, this increasing reliance on OEM arrangements has had positive effects for knowledge creation in Taiwan's computer industry. In contrast to a widespread perception (*e.g.*, Hobday, 1995), successful knowledge outsourcing does not necessarily require a *sequential* move from OEM, up to ODM, and then further up to OBM. Instead, Taiwanese suppliers were able to learn and to create knowledge through *concurrent* implementation of these different knowledge outsourcing approaches.

It is important to emphasize the *diversity* of such linkages and their *non-linear evolutionary* character. International linkages include a variety of ties with sales, manufacturing, and engineering support affiliates of foreign firms; they also include different forms and trajectories of integration into global production networks. Taiwanese firms for instance have typically pursued different approaches in parallel, rather than concentrating exclusively on one particular linkage. It is through such concurrent and multiple linkages that a *virtuous circle* between knowledge outsourcing and knowledge creation becomes feasible.

4.2. Challenges that Define the Need for Public Policy Response

To reap the benefits of network participation, developing countries must broaden their domestic knowledge base and generate specialized capabilities. This cannot be left to market forces alone. Markets are notoriously weak in generating knowledge and capabilities, as both are subject to *externalities*: investments are typically characterized by a gap between private and social rates of return (Arrow, 1962). Reducing this gap requires corrective policy interventions that provide incentives, as well as the necessary infrastructure, support services and human resources.

While the neo-classical concept of "market failure" provides a rationale for policy intervention, it is of limited value for designing its contents (Lipsey, in this issue). A fundamental weakness of this concept is its general equilibrium assumption: defined as a deviation from the market clearing equilibrium under conditions of perfect competition, the remedy is to return to a theoretically achievable static optimum. It is now well accepted that perfect competition hardly ever reigns in markets that characterize modern industry. It is thus misleading to think of market failure as something that can, or should, be "remedied" so that the economy can be brought back to a desired static optimum

In any case, this concept is patently inappropriate for defining the agenda for public policy response in the context of rapid technological change (such as information technology) and globalization.

Both accelerate the pace of change in markets and technology and increase uncertainty and the volatility of market structures, industrial organization and firm behavior (*e.g.*, Ernst, 2002a). Equally important, almost all aspects of knowledge creation and learning are characterized by market failure: this is true for information and codified knowledge, and even more so for tacit knowledge. Information/codified knowledge is difficult to trade in a market: whenever information is imperfect, "externalities" diffuse and markets incomplete, which is invariably the case with technical change, free markets cannot in principle meet the strict requirements of optimal resource allocation (Stiglitz, 1998). And "...tacit knowledge is plain market failure in the sense that it cannot, as such, be transacted in the market." (Lundvall and Borras, 1997: 49).

The result is that there is now a much greater need for public policy that goes well beyond the "market failure" rationale. This does not imply a return to the status quo ante of the strong developmental state (as suggested for instance by Wade & Veneroso, 1998). The challenge is to redefine the role of government intervention (Rodrik, 2000). The real question, then, is no longer whether national policies and institutions can make a difference. Instead, it is what kind of policies and institutions will prove most conducive for unlocking new sources of economic growth.

4.3. The New Agenda: Industrial Upgrading through International Linkages

Coping with these new opportunities and challenges is simply not possible as long as development strategies continue to stick to the old recipes. Fundamental changes are overdue. Talking about such changes is no longer taboo. After decades of exposure to liberalization, earlier naïve expectations are now being challenged by a more realistic definition of the policy agenda. A consensus is emerging in Latin America, the ex-Soviet bloc, and (since 1997) also in Asia: it is no longer possible to assume that a passive reliance on foreign capital and technology inflows guarantees sustainable industrial upgrading. In brackets, one may add that such debates are also high on the agenda in major OECD countries. Earlier assumptions and prescriptions need to be reconsidered.

Of course, nothing goes without a consolidation of the financial sector that reduces the vulnerability of volatile international capital. Equally obvious is the need for reforms of public as well as corporate governance that improve transparency, reducing the likelihood of moral hazards. There is also no doubt that this needs to be combined with cost-cutting and a reduction of surplus capacity in key sectors. But, and this is a big BUT, very different approaches are possible to financial and governance reforms and to corporate restructuring. Much depends on how one defines the long-term development model.

The concept of "industrial upgrading" (IU) can serve as a focusing device. This concept has recently gained acceptance among economists who are interested in identifying new sources of growth, both in industrialized and in developing countries. It attempts to model the link between innovation, specialization and Hirschmann-type linkages ("industrial deepening"), and possible consequences for economic growth through induced improvements in productivity. All four elements are essential prerequisites for improving a country's capacity to raise patient capital that is necessary for facility investment, R&D, human resource development and welfare expenditures.

This requires a development model that focuses on knowledge and innovation as major sources of economic growth. This is in line with the leading-edge in economic theorizing, such as endogenous growth theories (Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992, and Helpman, 1998); Lipsey's structuralist growth theory (Lipsey, 1997; Lipsey, Bekar and Carlaw, 1998 a and b); evolutionary economics (*e.g.*, Penrose, 1959/1995; Richardson, 1960/1990; Nelson and Winter, 1982); and attempts to reunite economic growth and innovation theory and business history (*e.g.*, Lazonick, 1999).

Industrial upgrading essentially implies that a country shifts to higher value-added products and production stages through increasing specialization: the more a country focuses on higher-end, knowledge-intensive products and support services, the more it is expected to experience sustainable export growth and increasing export revenues. Drawing on Chenery (1960), Chenery and Syrquin (1975) and Ozawa (2000: 2–3), one can construct a *taxonomy* that distinguishes four forms of IU (Ernst, 2002c):

- *inter-industry* upgrading with capital and technology deepening within a hierarchy of industries that proceeds from low value-added industries (*e.g.*, light industries) to higher-value added industries (heavy and higher-tech industries);

- *inter-factorial* upgrading within a hierarchy of factors of production that proceeds from "endowed assets" or "natural capital" (natural resources and unskilled labor) to "created assets", *i.e.* "physical capital", "human capital" (specialized skills), and "social capital" (a region's support services);
- upgrading of *demand* within a hierarchy of consumption, that proceeds from "necessities" to "conveniencies", to "luxury goods"; and
- upgrading along *functional* activities within a hierarchy of *value-chain* stages, that proceeds from sales & distribution to final assembly and testing, to component manufacturing, system integration, and knowledge-intensive support services.

Most research has focused on a combination of the first two forms of IU, based on a distinction between low-wage, low-skill sun-set industries and high-wage, high-skill sunrise industries. We define IU as a *broadening* and *deepening* of a country's product *specialization*. Both necessitate a strong domestic knowledge base. A broadening specialization stands for a move to higher-end and increasingly complex product groups. This can happen within a given industry, but it can also involve an extension beyond industry boundaries. A deepening specialization stands for the creation of forward and backward linkages, and the strengthening of knowledge-intensive and higher value-added stages. Our analysis focuses on the determinants of firm behavior, simply because these are the main actors in the game. There is a growing consensus that industry structure is insufficient to explain the dynamics of innovation, and that firm behavior (organization and strategy) has an important bearing on the strength as well as the kinds of innovation activity (Teece, 1998: 134). It is also necessary to move beyond the internalist bias that characterizes much of the literature on industrial organization and the theory of the firm. Policies thus need to consider the sources of innovation and growth in a broader frame of reference that extends between the boundaries of the firm.

Most importantly, we do not share the assumption that IU ends at the national border, and that it occurs only if improved specialization generates pressures to create dense forward and backward linkages within the economy. This assumption is problematic, to the degree that globalization and information technology increase the scope for cross-border forward and backward linkages. As argued in this paper, this is precisely what is happening as a result of the spread of GPN. This obviously raises important issues for the industrial upgrading agenda, especially in small nations that heavily depend on international trade and investment. But this is true even for a large, quasi-continental economies like the US, Brazil, China or India. In all of these countries, the importance of knowledge outsourcing through international linkages has drastically increased, hence internationalizing forward and backward linkages.

In short, while the first priority needs to be a continuous upgrading of the domestic innovation systems, this needs to be complemented with a variety of international linkages. This is a necessary caveat to Rodrik's otherwise refreshing statement that it is domestic investment that makes an economy grow, not integration into the global economy (Rodrik, 1999, p. 16). After all, investment is only half of the story; it needs to be complemented with knowledge (Nelson and Pack, 1995) which requires international linkages.

4.4. Policy Implications

What role can public policy play in increasing the benefits from network participation?

Taxonomy

Drawing on Evans (1995), once can construct a *taxonomy* of four roles of public policy in industrial development: (i) the "custodian" role in which the state regulates the market, generally privileging the policing function over promotional policies; (ii) the "demiurge" in which the state plays an entrepreneurial role, not just to provide public goods but out of a presumption that private capital is not adequate to attain the whole gamut of production; (iii) "midwifery" where instead of substituting for the private sector the state tries to shape it out of a belief that the capacity of the private sector is malleable and (iv) "husbandry" in which the state takes a long term view by recognizing that even if it successfully induces private groups to tackle promising sectors in its role of midwife, this is only just the beginning of a long process of industrial upgrading. As globalization poses new opportunities and challenges that local firms are ill-equipped to address on their own, public policy must continue to cajole and assist these firms by signaling opportunities, reducing risks, engaging in R&D etc.

It follows from our earlier discussion of the transformations imposed by GPN on the geography of innovation systems that very limited scope exists for the custodian and the demiurge role of public policy. The challenge is to design policies and institutions that allow to combine midwifery and husbandry. This implies that the key to success is to catalyze, not replace, the private sector and to monitor and to hold firms accountable for their use of incentives and subsidies. Once the initial catching-up phase is over, equal treatment should be provided to domestic and foreign firms, subject however to one important exception: the promotion of risk-taking and innovative smaller companies (*e.g.*, Ernst, 2000a).

Globalization, paradoxically enough, has increased the necessity of such policies. But there is also now more space for national policy and politics to vary and to make a difference. A growing body of research on economic policy-making in advanced industrial countries has demonstrated that choice is possible, in terms of institutions and policy instruments, and that this applies to macro-economic policy-making as well as to industrial and technology policies (*e.g.* Berger and Dore (Eds.), 1996). The same is true for developing countries.

There is now a growing consensus that liberalization of trade and investment flows should not be equalized with a retreat of the state (*e.g.*, Rodrik, 1999; UNCTAD, 1999). Liberalization needs to be complemented with proactive and sophisticated industrial, innovation and investment policies. Without such policies, it may well produce *negative* results: instead of improving allocative efficiency and growth, liberalization may increase a country's vulnerability to highly volatile international finance and currency markets; and it may divert attempts to strengthen local capabilities and innovation. As the example of small Nordic countries and The Netherlands demonstrate, the scope for pro-active technology and industrial policies in a liberal ownership regime is far greater than commonly assumed. Taiwan, Singapore and recent developments in Korea also illustrate that a variety of approaches is possible to such policies, involving a variety of interesting hybrid combinations. The choice is much larger than normally assumed.

Generic Principles

The following generic principles can help to delineate key components of such policies. There is a broad consensus that monetary and macroeconomic stability is of the essence to provide appropriate incentives for investment and innovation. These fundamentals are a necessary, but not sufficient condition for economic growth. Equally important are sector-specific policies that take into account the peculiar requirements of particular industries, as well as the strengths and weaknesses of sectoral production, support and innovation systems. This is inevitable in any economy where markets are based on a sophisticated social division of labor.

Such policies however differ significantly from sector to sector, in scope, in kind, and in impact, as documented in Mowery and Nelson (1999: 377). They also differ across countries. For instance, there is now less resistance to the idea that direct support via protectionism and subsidies can help to promote effective catching-up in developing countries (*e.g.*, Stopford, 1997). There is also agreement that the value of these policies becomes doubtful, once a country has reached the limits of catching-up. In short, there is no one best optimal solution; rather, such policies are context-specific; they also need to be adjusted over time.

A third important generic policy principle is that competition policy is of critical importance (*e.g.*, OECD, 1999b and 2000; Mowery and Nelson, 1999): firms will only invest in productivity-enhancing technology, learning and innovation if competition and regulatory reform force them to do so. It has been argued for instance that the relatively stringent postwar competition policy of the US weakened the ability of incumbents in such industries as computers and semiconductors to control new technologies and markets, and hence facilitated new market entry (*e.g.*, Langlois and Steinmueller, 1999). This is contrasted with much less aggressive competition policies in Europe and Japan which has left incumbents in control of the development of new technologies, yet often at a much slower pace. Competition may also help to lower costs, say access charges for telecommunications and internet services-a key factor in the diffusion of knowledge (OECD, 2000).

Competition however is only part of the story-it needs to be balanced with the requirements of IU. Intellectual property rights provide story-it needs an example. Initially, liberal cross-licensing and weak IPR may be required to facilitate knowledge diffusion. Yet, once catching-up has been achieved, the pendulum may swing in the opposite direction, with strict IPR enforcement gaining in importance. Equally important are policies that provide support for innovation and for the rapid diffusion of knowledge.

Fourth, implementing such policies however poses daunting political and administrative challenges. Combining liberalization with the development of a robust national innovation system (NIS) requires fundamental changes in the objectives and policy instruments, and a deep understanding of the global competitive dynamics. Not less, but actually more knowledge and expertise are required in the public sector. More specifically, developing a viable NIS requires a deep understanding of sectoral specificities, rather than a sector-neutral and minimally active policy stance. It requires an understanding of the widely varying technological properties of specific industries, the logistical and strategic concerns of multinational businesses, the fundamental transformations in the organization of their global production networks, and the rapidly evolving international investment environment.

Finally, organizational and policy innovations are critical for reaping the benefits of globalization. So far, such innovations have taken place primarily in the private sector: under pressure to cope with globalization, a handful of MNEs and financial firms are pioneers in organizational innovations; such innovations however are patently absent in the public sector. For developing countries, the challenge is to learn from these organizational innovations introduced in the private sector, and to use them to improve the efficiency in public institutions and government policies. This does not imply that one subscribes to the ideological prescriptions of neo-liberalism: the underlying rationale in fact is to strengthen the corrective forces to the market.

5. CONCLUSIONS

A central proposition of this paper is that the spread of GPN has substantially enhanced the scope for international knowledge diffusion. This implies that it would be anachronistic to stick to "go-it-alone" development strategies. Of critical importance is an openness to foreign ideas and knowledge, and a capacity to absorb these and blend them with existing capabilities. International knowledge linkages can help to broaden the range of options. This is especially true for developing countries where the best policies on paper are useless if weak institutions prevent their effective implementation. The dynamics of change adds additional requirements. Policies and support institutions need to be adjusted to frequently unpredictable changes in technology and markets. There is no "one-size-fits-all" approach to policies and institution-building: both need to be context-specific and open to continuous adjustment. Hence, the critical importance of diversity, flexibility and adaptability in both policy instruments and institutions, Here again, an international perspective can help.

One important reason for international cooperation is that a national system might be locked into paths that are sub-optimal. The sharing of knowledge between actors of different national systems of innovation (NIS) may increase the chances to pursue more potential options, and hence to reduce the lock-in risk. But there is a more fundamental reason: the de facto internationalization of local capability clusters and industrial districts through GPN. Rather than denying this, it is better to try to shape this process. NIS can no longer exist in splendid isolation: they need to open up and internationalize.

This requires a progressive internationalization of public R&D institutions and knowledge service providers. Take the example of the Fraunhofer Society (FhG), a key component of Germany's NIS: over the last years, FhG has established overseas affiliates in world centers of excellence centers (example: graphic data processing in the US) as well as in potential markets for German technology (*i.e.*, Malaysia). This needs to be complemented with policies that help to improve the absorptive capacity of an NIS, *i.e.* its ability to tap into sources of knowledge world-wide and to pass relevant knowledge quickly on to domestic industries. The focus should be on the rapid application of new knowledge.

Equally important are policies that induce global network flagships to locate relatively knowledge-intensive activities to create dynamic clusters (*e.g.*, Best, 1999), and to continuously upgrade these activities. At present, there is a mismatch between the location decision criteria used by network flagships and policy debates on what constitutes an optimal location. Policies must be adapted to the important changes in firm behavior that we have described in this paper. Locational debates must shift from an exclusive concern with costs (static efficiency) to the development of specialized capability clusters (dynamic efficiency based on dense forward and backward linkages). In principle, an optimal location would combine attractive lead markets, a highly developed production structure (supply base) and excellent research conditions. But very few locations can fulfil all three criteria simultaneously.

A lack of world-leading R&D excellence centres does not necessarily disqualify a country/region/location from participating in a GPN. The experience of East Asia demonstrates that the development of a competitive production base can be a good starting-point. Over time, this needs to be complemented however with the development of lead markets and a gradual improvement of R&D capabilities. These are essential requirements for industrial upgrading.

Globalization however also raises a fundamental dilemma. On the one hand some degree of stability must exist in policies and institutions: without such stability it is very difficult to mobilize resources and to provide incentives for learning and innovation. On the other hand, globalization, combined with information technology, imposes disruptive changes on the very same institutions and policies. While the latter may have been successful during certain periods, for instance for rapid catching-up, they may well become barriers at a later stage. Any attempt to preserve the status quo ante of institutions and policies in the context of rapid change and increasing uncertainty is likely to constrict learning and innovation that are necessary for industrial upgrading.

In short, continuity needs to be combined with continuous adaptation in institutions and policies. It is obviously very difficult to achieve the right balance. Change however should be constrained by the need to build on accumulated capabilities. "Big Bang" change, which discards the latter, often involves prohibitively high opportunity costs; it may also destroy social consensus, the most fundamental prerequisite for economic development.

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