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Global Production Networks, Knowledge Diffusion, and Local Capability Formation. A Conceptual Framework

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INTRODUCTION

Global production networks (GPN) transform the production and use of knowledge, with far-reaching implications for an evolutionary theory of economic change. There is a fundamental trend towards increasing mobility of knowledge, yet little do we know about drivers and implications. Twenty years after the pioneering book of Nelson and Winter (1982), it is time to develop a research agenda that addresses these transformations, based on a combination of appreciative theory, case studies, econometric work and formal modeling.

A major constraint is a lack of communication between research on GPN, research on international knowledge diffusion, and research on local capability formation. While all three are highly relevant strands of research, their lack of interaction obstructs our understanding of how global networks affect knowledge diffusion and the formation of local capabilities. There is a need to bridge this gap through “appreciative theories”, as defined in Richard Nelson’s thought-provoking review of economic growth theory (1995)¹.

This paper develops a conceptual framework that links together the above three areas of research, as a first step towards an appreciative theory. We argue that globalization has culminated in an important organizational innovation: the spread of GPN. These networks combine concentrated dispersion of the value chain across firm and national boundaries, with a parallel process of integration of hierarchical layers of network participants. This has created new opportunities for international knowledge diffusion that lower-tier network suppliers should strive to exploit. To substantiate this argument, we proceed as follows. Section 1 sketches our research agenda, while section 2 analyzes the three dynamic forces that drive the rapid development of GPN. Section 3 highlights the economic structure and peculiar characteristics of the flagship model of GPN. Section 4 explores the categories of knowledge, and the mechanisms of knowledge transfer from flagship companies to local network suppliers. And in section 5, we discuss under what conditions GPN can act as mediators of local capability formation. We conclude with policy and management implications for global flagships and local suppliers, and spell out priorities for future research.

1. RESEARCH AGENDA

Multinational corporations (MNCs) have been around for a long time (e.g., Wilkins, 1970). Until recently, their international production has focused on the penetration of protected markets through tariff-hopping investments, and on the use of assets developed at home to exploit international factor cost differentials, primarily for

¹ In contrast to formal growth theories, appreciative theories do not attempt to compress stylized facts into rigorous formulations. Rather, an attempt is made to include more of the observed empirical richness of IT and transformations in business organization than formal theories. This of course comes at the cost of being unable to model these relationships mathematically. Hence the need for formal theories. But for the latter to be fruitful, they need to be based on appreciative theories, and on the findings of case studies and econometric analysis.

labor (e.g., Dunning, 1981). This has given rise to a peculiar pattern of international production: offshore production sites in low-cost locations are linked through triangular trade with the major markets in North America and Europe (e.g., Dicken, 1992).

A progressive liberalization and deregulation of international trade and investment, and the rapid development and diffusion of information and communication technology (IT) have fundamentally changed the global competitive dynamics, in which MNCs operate. While both market access and cost reductions remain important, it became clear that they have to be reconciled with a number of equally important requirements that encompass: the exploitation of uncertainty through improved operational flexibility (e.g., Kogut 1985; and Kogut and Kulatilaka, 1994); a compression of speed-to-market through reduced product development and product life cycles (e.g., Flaherty, 1986); learning and the acquisition of specialized external capabilities (e.g., Antonelli, 1992; Kogut and Zander, 1993; Zander and Kogut, 1995; Zanfei, 2000; Dunning, 2000); and a shift of market penetration strategies from established to new and unknown markets (e.g., Christensen, 1997).

In response to the increasingly demanding requirements of global competition, three interrelated transformations have occurred in the organization of international economic transactions. First, global production networks (GPN) have proliferated as a major organizational innovation in global operations (e.g., Borrus, Ernst and Haggard, 2000). Second, these networks have acted as a catalyst for international knowledge diffusion, providing new opportunities for local capability formation in lower-cost locations outside the industrial heartlands of North America, Western Europe and Japan. Third, a long-term process of “digital convergence” (e.g., Chandler and Cortada, 2000), enabling the same infrastructure to accommodate manipulation and transmission of voice, video, and data, has created new opportunities for organizational learning and knowledge exchange across organizational and national boundaries, hence magnifying the first two transformations.

The combination of these three transformations has changed dramatically the international geography of production and innovation. We focus on the first two of these transformations². The first transformation signals a new *divide* in industrial organization: a transition is under way from “multinational corporations”, with their focus on stand-alone overseas investment projects, to “global network flagships” that integrate their dispersed supply, knowledge and customer bases into global (& regional) production networks (Ernst, 1997b and 2001a). There is a growing acceptance in the literature that, to capture the impact of globalization on industrial organization and knowledge diffusion, the focus of research needs to move from the industry and the individual firm to the international dimension of business networks (e.g., Ghoshal and Bartlett, 1990; Gereffi and Korzeniewicz, 1994; UNCTAD, 1993; Rugman and D’Cruz, 2000; Birkinshaw and Hagstrøm, 2000).

² The impact of “digital convergence” is addressed in Ernst 2001 c and 2001d

But our understanding of these networks is limited. Research on GPN is at the formative stage and shares three common weaknesses. First, most studies have focused too narrowly on the perspective of the network flagship (“flagship bias”) (e.g., Rugman and D’Cruz (2000). We need research that explores as well implications for network suppliers, especially lower-tier suppliers from developing countries. Second, research has focused primarily on the geographic dispersion of tangible production, but tells us little about other aspects of global networks (“production bias”). While global networks in financial services are relatively well covered, we need research on the evolving global networks of business and information services (such as research presented in Aharoni and Nachum, 2000). Third, there is also an “R&D bias”: research has focused narrowly on the relocation of R&D and strategic alliances primarily among regions in the US, Western Europe and Japan (e.g., Birkinshaw and Hagstrøm, 2000; Rugman and D’Cruz, 2000). The impact of GPN on the diffusion of other forms of knowledge, especially knowledge-intensive support services, has been largely neglected, and this is true in particular for their diffusion to lower-cost locations.

We adopt a broader approach, analyzing as well the geographic dispersion of cross-functional, knowledge-intensive support services that are intrinsically linked with production, such as human resource management, global supply chain management, and knowledge management. Even if these activities do not involve formal R&D, they still give rise to considerable international knowledge diffusion and knowledge sharing (Ernst, 2001 b).

Equally important is the second transformation: GPN in their operations reportedly disseminate important knowledge to local suppliers in low-cost locations, which could catalyze local capability formation. Knowledge transfer, however, is not automatic. It requires a significant level of absorptive capacity on the part of local suppliers and a complex process to internalize disseminated knowledge. But our understanding of knowledge transfer and local capability formation is limited. International knowledge transfer has been extensively studied, but research has primarily focused on such formal mechanisms as foreign direct investment (FDI) and foreign licensing (FL) (Reddy and Zhao, 1990). These formal mechanisms, however, are only the tip of the iceberg. A larger amount of knowledge is transferred through various informal mechanisms (Westphal, Kim, and Dahlman, 1985; Kim, 1991; 1997; Ernst, Ganiatsos and Mytelka, 1998; Ernst, 2000a). Research on informal knowledge transfer is scarce. The importance of local capabilities in assimilating, adapting, and improving imported technology has long been recognized, but few studies exist on the complex process of local capability formation in developing countries.

2. FORCES DRIVING GLOBAL PRODUCTION NETWORKS

What has driven the shift in industrial organization from “multinational corporations” to “global network flagships” that integrate their dispersed supply, knowledge and customer bases into global (& regional) production networks? To answer this question, we introduce a stylized model of globalization drivers, focusing on three

inter-related explanatory variables: institutional change through liberalization, information technology, and competition.

2.1. Institutional Change: Liberalization

North (1996; 12) defines institutions as “the rules of the game of a society that structure human interaction.” They are composed of formal rules (statute law, common law, regulations), informal constraints (conventions, norms of behavior, and self-imposed codes of conduct), and the enforcement characteristics of both. Institutions shape the allocation of resources, the rules of competition and firm behavior.

We take liberalization as convenient shorthand for institutional changes that affect globalization. Liberalization dates back to the early 1970s: it thrived in response to the breakdown of fixed exchange rate regimes and the failure of Keynesianism to cope with pervasive stagflation. To a large degree, it has been initiated by government policies. But there are also other actors that have played an important role: financial institutions; rating agencies; supra-national institutions like bi-lateral or multi-lateral investment treaties and regional integration schemes, like the EU or NAFTA. In some countries with decentralized devolution of political power, regional governments can also play an important role.

Liberalization includes four main elements: trade liberalization; liberalization of capital flows; liberalization of FDI policies; and privatization. While each of these has generated separate debates in the literature, they hang together. Earlier success in trade liberalization has sparked an expansion of trade and FDI, increasing the demand for cross-border capital flows. This has increased the pressure for a liberalization of capital markets, forcing more and more countries to open their capital accounts. In turn this has led to a liberalization of FDI policies, and to privatization tournaments.

The overall effect of liberalization has been a considerable reduction in the cost and risks of international transactions and a massive increase in international liquidity. Global corporations (the network flagships) have been the primary beneficiaries: liberalization provides them with a greater range of choices for market entry between trade, licensing, subcontracting, franchising, etc. (*locational specialization*) than otherwise; it provides better access to external resources and capabilities that a flagship needs to complement its core competencies (*outsourcing*); and it has reduced the constraints for a geographic dispersion of the value chain (*spatial mobility*).

We also need to emphasize a perplexing result: as liberalization has been adopted as an almost universal policy doctrine, it has lost much of its earlier power to influence locational decisions. As their FDI policies become indistinguishable, host countries are forced to differentiate themselves by other means, and to implement much more aggressive policies. The result has been a rapid proliferation of *complementary* policies geared to *business facilitation* and the development of *created assets*. This explains why a replication of clustering effects at multiple locations is now a realistic option.

2.2. The Dual Impact of Information and Communication Technology

A second important driver of GPN has been the rapid development and diffusion of information and communication technology (IT). These technologies have had a dual impact: they increase the need and create new opportunities for globalization. This argument is based on two propositions. First, the *cost* and *risk* of developing IT has been a primary cause for *market* globalization: international markets are required to amortize fully the enormous R&D expenses associated with rapidly evolving process and product information technologies (Kobrin, 1997, p.149). Of equal importance are the huge expenses for IT-based organizational innovations. (Brynjolfsson and Hitt, 2000; Ernst and O'Connor, 1992: chapter 1). As the extent of a company's R&D effort is determined by the nature of its technology and competition rather than its size, this rapid growth of R&D spending requires a corresponding expansion of sales, if profitability is to be maintained. No national market, not even the US market, is large enough to amortize such huge expenses.

A second proposition explains why international production rather than exports have become the main vehicle for international market share expansion. Of critical importance has been the enabling role played by IT: it has substantially increased the mobility, i.e. *dispersion* of firm-specific resources and capabilities across national boundaries; it also provides greater scope for cross-border linkages, i.e. the *integration* of dispersed specialized clusters. This has substantially reduced the friction of time and space, both with regard to markets and production: a firm can now serve distant markets equally well as local producers; it can also now disperse its value chain across national borders in order to select the most cost-effective location.

In addition, IT and related organizational innovations provide effective mechanisms for constructing flexible infrastructures that can link together and coordinate economic transactions at distant locations (Hagström, 2000; Antonelli, 1992). This has important implications for organizational choices and locational strategies of firms. In essence, IT fosters the development of leaner, meaner and more agile production systems that cut across firm boundaries and national borders. The underlying vision is that of a network of firms that enable a global network flagship to respond quickly to changing circumstances, even if much of its value chain has been dispersed.

2.3. Competition and Industrial Organization

Together with liberalization, IT has drastically changed the dynamics of competition. Again, we reduce the complexity of these changes and concentrate on two impacts: a broader geographic scope of competition; and a growing complexity of competitive requirements. Competition now cuts across national borders - a firm's position in one country is no longer independent from its position in other countries (e.g., Porter, 1990). This has two implications. The firm must be present in all major growth markets (*dispersion*). It must also integrate its activities on a worldwide scale, in order to exploit and coordinate linkages between these different locations (*integration*). Competition also cuts across sector boundaries and market segments: mutual raiding of

established market segment fiefdoms has become the norm, making it more difficult for firms to identify market niches and to grow with them.

This has forced firms to engage in complex strategic games to pre-empt a competitors' move. This is especially the case for knowledge-intensive industries like electronics (Ernst, 2001a). Intense price competition needs to be combined with product differentiation, in a situation where continuous price wars erode profit margins. Of critical importance, however, is speed-to-market: getting the right product to the largest volume segment of the market right on time can provide huge profits. Being late can be a disaster, and may even drive a firm out of business. The result has been an increasing uncertainty and volatility, and a destabilization of established market leadership positions (Richardson, 1996; Ernst, 1998).

This growing complexity of competition has changed the determinants of firm organization and growth, as well as the determinants of location. No firm, not even a dominant market leader, can generate all the different capabilities internally that are necessary to cope with the requirements of global competition. Competitive success thus critically depends on a capacity to selectively source specialized capabilities *outside* the firm that can range from simple contract assembly to quite sophisticated design capabilities. This requires a shift from individual to increasingly collective forms of organization, from the multidivisional (M-form) functional hierarchy (e.g., Williamson, 1975 and 1985; Chandler, 1977) of "multinational corporations" to the networked global flagship model (Ernst, 2001 c).

Take the electronics industry, which has become the most important breeding ground for this new industrial organization model. Over the last decades, a massive process of vertical specialization has segmented an erstwhile vertically integrated industry into closely interacting horizontal layers (Grove, 1996). An important catalyst was the availability of standard components, which allowed for a change in computer design away from centralized (IBM mainframe) to decentralized architectures (PC, and PC-related networks). This has given rise to the co-existence of complex, globally organized product- specific value chains (e.g., for microprocessors, memories, board assembly, PCs, operating systems, applications software, and networking equipment).

Each of these value chains consists of a variety of GPN that compete with each other, but that may also cooperate (Ernst, 2001b). The number of such networks, and the intensity of competition varies across sectors, reflecting their different stage of development and their idiosyncratic industry structures. Until recently, these fundamental changes in the organization of international production have been largely neglected in the literature, both in research on knowledge spill-over through FDI, and in research on the internationalization of corporate R&D.

3. GLOBAL PRODUCTION NETWORKS: STRUCTURE AND CHARACTERISTICS

3.1. The Network Flagship Model

The concept of a GPN covers both intra-firm and inter-firm transactions and forms of coordination (see **Figure 1**): it links together the flagship's own subsidiaries, affiliates and joint ventures with its subcontractors, suppliers, service providers, as well as partners in strategic alliances (e.g., Ernst, 1997a, 1997b, 2001b). These arrangements may, or may not involve ownership of equity stakes. A network flagship like IBM or Intel breaks down the value chain into a variety of discrete functions and locates them wherever they can be carried out most effectively, where they improve the firm's access to resources and capabilities and where they are needed to facilitate the penetration of important growth markets.

The main purpose of these networks is to provide the flagship with quick and low-cost access to resources, capabilities and knowledge that are complementary to its core competencies. In other words, transaction cost savings matter. Yet, the real benefits result from the dissemination, exchange and outsourcing of knowledge and complementary capabilities.

A focus on international knowledge diffusion through an extension of firm organization across national boundaries distinguishes our concept of GPN from network theories developed by sociologists, economic geographers and innovation theorists that focus on localized, mostly inter-personal networks (e.g., Powell and Smith-Doerr, 1994: 368-402). The central problem of these theories is that industries now operate in a global rather than a localized setting (Ernst, Guerrieri, et al, 2001). Important complementarities exist, however, with work on global commodity chains (GCC) (e.g., Gereffi and Korzeniewicz, 1994). A primary concern of the GCC literature has been to explore how different value chain stages in an industry (i.e. textiles) are dispersed across borders and how the position of a particular location in such GCC affects its development potential.

As for the dynamics of network evolution, our approach differs fundamentally from the transaction cost approach to networks and vertical disintegration that centers on the presumed efficiency gains from these organizational choices (e.g., Williamson, 1985 and 1997; Milgrom and Roberts, 1990). This approach skips some of the more provocative chapters in the economic history of the modern corporation. Chandler's vibrant histories (e.g., 1962) show that the quest for profits and market power via increased throughput and speed of coordination were more important in explaining hierarchy than the traditional emphasis on transaction costs. This implies that the analysis of the determinants of institutional form must shift away from the narrow focus on transactions costs to the broader competitive environment in which firms operate. It is time to bring back into the analysis market structure and competitive dynamics, as well as the role played by knowledge and innovation.

Our concept of GPN similarly points to these often-overlooked dimensions of organizational choice. Like hierarchies, GPN not only promise to improve efficiency, but

can permit flagships to sustain quasi-monopoly positions, generate market power through specialization, and raise entry barriers (Ernst, 2001a); they also enhance the network flagships' capacity for innovation (e.g., Lazonick, 2000). These considerations are of particular concern for developing countries' integration into GPN, and their capacity to strengthen their local capabilities. Two distinctive characteristics of GPN shape the scope for international knowledge diffusion: a rapid yet concentrated dispersion of value chain activities, and, simultaneously, their integration into hierarchical networks.

3.2. Concentrated Dispersion

GPN typically combines a breath-taking speed of geographic dispersion with spatial concentration: much of the recent cross-border extension of manufacturing and services has been concentrated on a growing, but still limited number of specialized lower-cost clusters. Apart from the usual suspects in Asia (Korea, Taiwan, China, Malaysia, Thailand, and now also India), this includes once peripheral locations in Europe (e.g., Ireland, Central and Eastern Europe and Russia), Brazil, Mexico, and Argentina in Latin America, some Caribbean locations (like Costa Rica), and a few spots elsewhere in the so-called RoW (= rest of the world).

The inclusion of these clusters into GPN creates new opportunities for knowledge diffusion to local suppliers, which could catalyze local capability formation. Different clusters face different opportunities and constraints, depending on the product composition of the GPN. 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.

Let us look at some indicators in the electronics industry, a pace setter of GPN (Ernst, 2001b). On one end of the spectrum is final PC assembly that is widely dispersed to major growth markets in the US, Europe and Asia. Dispersion is still quite extended for standard, commodity-type components, but less so than for final assembly. For instance, flagships can source keyboards, computer mouse devices and power switch supplies from many different sources, both in Asia, Mexico and the European periphery, with Taiwanese firms playing a major role as intermediate supply chain 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 quick dispersion, as well as for spatial concentration (Ernst, 1997b). Until the early 1980s, almost all HDD production was concentrated in the U.S., 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.

Seagate, the current industry leader, provides a good example of the flagship model of concentrated dispersion. 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.

In short, rapid cross-border dispersion coexists with agglomeration. GPN extend 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 for individual specialized industrial clusters.

3.3. Integration: Hierarchical Layers of Network Participants

A GPN encompasses both intra-firm and inter-firm linkages and integrates a diversity of network participants who differ in their access to and in their position within such networks, and hence face very different opportunities and challenges for GPN. This implies that GPN do not necessarily give rise to less hierarchical forms of firm organization (as predicted for instance in Bartlett and Ghoshal, 1989, and in Nohria and Eccles, 1992). GPN typically consist of various hierarchical layers that range from network flagships that dominate such networks, down to a variety of usually smaller, local specialized network suppliers. This taxonomy helps to assess the different capacities of these firms to benefit from knowledge diffusion and to upgrade local capability formation.

Network flagships

We distinguish two types of global flagships: i) "brand leaders" (BL), like Cisco, GE, IBM, Compaq or Dell; and ii) "contract manufacturers" (CM), like for instance Solectron or Flextronics, that establish their own GPN to provide integrated global supply chain services to the "global brand leaders". Cisco is an interesting example of a "brand leader": its GPN connects the flagship to 32 manufacturing plants worldwide. These suppliers are formally independent, but they go through a lengthy process of certification to ensure that they meet Cisco's demanding requirements. Outsourcing volume manufacturing and related support services enable "brand leaders" to combine cost reduction, product differentiation and time-to-market. Equally important are

financial considerations: getting rid of low-margin manufacturing helps the BL to increase shareholder returns³.

“Contract manufacturers” have rapidly increased in importance since the mid-1990s. This represents an acceleration of a long-standing trend towards vertical specialization in the electronics industry (Mowery and Macher, 2001). The role model of CM-type network flagships is Solectron that only a few years ago was a typical SME, but has transformed itself into the electronics industry’s largest CM. With an average growth rate of 43% over the past five years, Solectron has increased its worldwide locations from about 10 in 1996 to almost 50 today (Luethje, 2001). The company defines itself now as a global supply chain facilitator: global brand leaders “... 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).

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 latter, in turn, “ have no reciprocal influence over the flagship strategy” (Rugman and D’Cruz, 2000, p.84)⁴. The flagship derives its strength from its control over critical resources and capabilities that facilitate innovation (e.g., Lazonick, 2000), and from its capacity to coordinate transactions and knowledge exchange between the different network nodes. Both are the sources of its superior capacity for generating profits.

Increasing vertical specialization is the fundamental driver of this flagship model of industrial organization (Ernst, 2001a). Flagships retain in-house activities in which they have a particular strategic advantage; they outsource those in which they do not. It is important to emphasize the diversity of such outsourcing patterns (Mowery and Macher, 2001; Ernst, 1997b). Some flagships focus on design, product development and marketing, outsourcing volume manufacturing and related support services. Other flagships outsource as well a variety of high-end, knowledge-intensive support services. This includes for instance trial production (prototyping and ramping-up), tooling and equipment, benchmarking of productivity, testing, process adaptation, product customization and supply chain coordination. It may also include design and product development.

³ Other important drivers of outsourcing include hedging against damage due to volatile markets and periodic excess capacity; and scale economies: surface-mount-technology (SMT) requires large production runs, reflecting its growing capital and knowledge intensity.

⁴ With Rugman’s flagship model, we share the emphasis on the hierarchical nature of these networks. However, there are important differences. Rugman and D’Cruz (2000) focus on localized networks within a region; they also include “non-business infrastructure” as “network partners”. We do not share their assumption that a combination of transaction cost and resource-based theory is sufficient to explain such forms of business organization.

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. Even if these activities do not involve formal R&D, they may still require a substantial diffusion of knowledge. Take the spread of "turnkey production arrangements" in the PC industry (Ernst, 2000): a flagship (e.g., Compaq) out-sources all stages of the value-chain for a particular PC family, except marketing; and a local lead supplier (e.g., in Taiwan) is responsible for the design and development of new products, as well as for manufacturing, transport and after-sales services, delivered through its own mini-GPN.

Local suppliers

This example brings us to the role of local network suppliers and the factors that determine their network position. "Turnkey production arrangements" illustrate a tendency of flagships to extend outsourcing to comprise an integrated package of higher-end support services, to be provided by a local lead supplier. Greatly simplifying, we distinguish two types of local suppliers⁵: higher-tier "lead suppliers" and lower-tier suppliers.

"Higher-tier" suppliers, like for instance Taiwan's Acer group (Ernst, 2000b) play an intermediary role between global flagships and local suppliers. They deal directly with global flagships (both "brand leaders" and "contract manufacturers"); they possess valuable proprietary assets (including technology); and they have developed their own mini-GPN (Chen & Chen, 2001). With the exception of hard-core R&D and strategic marketing that remain under the control of the network flagship, the lead supplier must be able to shoulder all steps in the value chain. As our example shows, it must even take on the coordination functions necessary for global supply chain management. This requires that the lead supplier develops dense linkages between geographically dispersed, yet concentrated and locally specialized clusters, integrating these into its own networks.

"Lower-tier" suppliers are in a much more precarious position. Their main competitive advantages are low cost and speed, and flexibility of delivery. They are typically used as "price breakers" and "capacity buffers", and can be dropped at short notice. This second group of local suppliers rarely deals directly with the global flagships; they interact primarily with local higher-tier suppliers. Lower-tier suppliers normally lack proprietary assets; their financial position is weak; and they are highly vulnerable to abrupt changes in markets and technology, and to financial crises.

This distinction helps us to explain why some suppliers are more prone than others to knowledge diffusion and capability development. In most cases, "higher-tier" suppliers can reap substantial benefits through knowledge diffusion, while "lower-tier" suppliers are unlikely to benefit, unless effective support institutions and policies are in place.

⁵ We do not consider arms'-length suppliers of standard (off-the-shelf) equipment and components. In reality there are of course many more layers of local suppliers that hang together in complex and continuously evolving arrangements.

4. GLOBAL PRODUCTION NETWORKS AND KNOWLEDGE DIFFUSION

Let us recapitulate the fundamental rationale of GPN: they help flagships to sustain their competitiveness, by providing them with access to specialized suppliers at lower-cost locations that excel in quick and flexible response to the flagships' requirements. The flagships can exert considerable pressure on local suppliers, especially in small developing countries: they can discipline suppliers by threatening to drop them from the networks whenever they fail to provide the required services at low price and world class quality.

At the same time, GPN also act as powerful carriers of knowledge. First, flagships need to transfer technical and managerial knowledge to the local suppliers. This is necessary to upgrade the suppliers' technical and managerial skills, so that they can meet the technical specifications of the flagships. Second, once a network supplier successfully upgrades its capabilities, this creates an incentive for flagships to transfer more sophisticated knowledge, including engineering, product and process development. This reflects the increasingly demanding competitive requirements that we referred to earlier. In the electronics industry for instance, product-life-cycles have been cut to six months, and sometimes less (Ernst, 2001a). Overseas production thus frequently occurs soon after the launching of new products. This is only possible if flagships share key design information more freely with overseas affiliates and suppliers. Speed-to-market requires that engineers across the different nodes of a GPN are plugged into the flagship's design debates (both on-line and face-to-face) on a regular basis.

Of course, knowledge transfer is not a sufficient condition for effective knowledge diffusion. Diffusion is completed only when transferred knowledge is internalized and translated into the capability of the local suppliers (e.g., Kim, 1997, and Ernst, Mytelka and Ganiatsos, 1998). Much depends on the types of knowledge involved and the mechanisms that flagships use to disseminate different types of knowledge. Section 4 is devoted to these issues. Equally important for effective knowledge diffusion however are the motivations, resources and capabilities of local suppliers, an issue that we address in section 5.

4.1 The Categories of Knowledge

Knowledge may be classified into various categories depending on the purpose of its use. Polanyi's (1962) classified knowledge into explicit and tacit knowledge. Explicit knowledge refers to knowledge that is codified in formal, systematic language (*encoded* knowledge). It is knowledge that can be combined, stored, retrieved, and transmitted with relative ease and through various mechanisms. With the falling cost of information processing and communication, due to microprocessors, optical fibers and the Internet, it is expected that this will increase further the mobility of explicit knowledge, making it accessible worldwide in real time at minimal cost (e.g., David and Foray, 1995), reshaping established organizational arrangements, work practices and life styles.

But explicit knowledge is useful only when tacit knowledge enables individuals and organizations to make sense of and utilize it. Tacit knowledge refers to knowledge that is so deeply rooted in the human body and mind that it is hard to codify and communicate. It is knowledge that can only be expressed through action, commitment, and involvement in a specific context and locality. Tacit knowledge is based on experience: people acquire it through observation, imitation, and practice. Its diffusion requires apprentice-type training and face-to-face interaction. It can also be transferred, however, through the movement of human carriers of such knowledge, a fact that much of the literature on industrial districts used to neglect.

It is hard to exaggerate the importance of tacit knowledge. Nonaka (2001) for instance argues that it accounts for three quarters of all knowledge used by firms. Tacit knowledge is the key to the long-term growth of a firm: it provides the fertile intellectual ground for all knowledge management (Gelwick, 1976) and for the effective performance of an economy (Nelson and Winter, 1982). In the face of increasing uncertainties in globalization, tacit knowledge becomes even more important (Ernst and Lundvall, 2000).

Many have attempted to unpackage the blackbox of tacit knowledge (e.g., Sparrow, 1998; Antonelli, 1998; Spender, 1996). For our purpose, the following classification, first coined by Collins (1993) and later expanded by Blackler (1995), appear to be most useful. Tacit knowledge may become part of the human body as skills (*embodied* knowledge); part of human being as cognitive capacity (*embrained* knowledge); routinized in organizational practice (*embedded* knowledge); and inculcated in the organization as basic assumptions, beliefs and norms (*encultured* knowledge). Different types of tacit knowledge are associated with different aspects of organizational activities and with different degree of difficulties in transferring it.

4.2 Knowledge Transfer Mechanisms

Flagships transfer knowledge across borders through various mechanisms. First, the transfer may be mediated through the market, involving a formal contract for terms and conditions between the knowledge supplier and the knowledge buyer with payment involved. Knowledge may also be transferred informally without any payment involved. Second, the flagship may play an active role, exercising significant control over the way in which knowledge is disseminated to and used by the local supplier. Alternatively, the flagship may play a passive role, having almost nothing to do with the way the local supplier takes advantage of available knowledge that is either embodied in or disembodied from the physical items. These two dimensions -market-mediation and the role of flagships - offer a useful two-by-two matrix, as shown in **Figure 2**, to identify different mechanisms of knowledge transfer through global production networks (Kim, 1991).

First, network flagships use largely formal mechanisms such as foreign direct investment (FDI), foreign licensing (FL), technical consultancies, etc. in quadrant 1 to transfer knowledge to local suppliers, if the latter are subsidiaries or joint venture

partners. For instance, when such flagships as Intel, Motorola, Texas Instruments, and Fairchild decided to outsource assembly operations of their semiconductor devices, they took the mechanisms of FDI, FL, and technical consultancies to establish their subsidiaries in the Philippines (Antonio, 2001) and other countries in Southeast Asia. They owned a majority ownership in the subsidiaries, licensed and transferred a complete production system.

Second, independent local suppliers rely heavily on standard machinery in quadrant 2 to improve their productivity in production operations. Machinery is a major source of process innovation for their users (Abernathy and Townsend, 1975). Flagships are not necessarily the suppliers of the machinery, but they can play an important indirect role, by forcing independent local suppliers to purchase more sophisticated equipment to improve their production capabilities. For instance, Mando, one of the major auto components suppliers from Korea, purchased a series of robots to automate their production processes. Each of the robots embodied state-of-the-art production knowledge. The suppliers of the robots, however, had little influence over the way Mando used it.

Third, a more direct way for flagships to transfer knowledge to independent local suppliers are informal mechanisms in quadrant 3, largely through the original equipment manufacturing (OEM) arrangements. As in the quadrant 1, flagships actively transfer knowledge in the form of blue prints, technical specifications, and technical assistance, mostly free of charge, to independent local suppliers to ensure that products and services produced by the latter meet the former's technical specifications. For instance, Boeing outsources some parts of fuselage from independent local suppliers in Japan, Taiwan, and Korea. In doing so, Boeing actively provides the local suppliers technical literature, product specifications, and technical assistance to help them meet its specifications.

Fourth, independent local suppliers can also rely on knowledge transfer mechanisms in quadrant 4. Like in quadrant 2, flagships exert little direct influence over the way independent local suppliers use such mechanisms as reverse engineering, observations, and human mobility to expedite upgrading their capabilities. For instance, lower-tier suppliers in Asia undertake reverse engineering of foreign products not so much to produce imitative products as to acquire knowledge embodied therein. A group of lower-tier suppliers often take an observation tour of foreign firms as a way to acquire new knowledge. The Small Industry Promotion Corporation and industry-related SME associations in Korea often organizes such observation tours. Human mobility in quadrant 4 includes not only the repatriation of top-rated engineers trained abroad but also the active use of experienced foreign engineers who are hired for short periods as so-called "moonlighters".

To what degree do the flagships use the knowledge transfer mechanisms? The shift from MNCs to global network flagships has expanded both the mechanisms and the volume of knowledge transfer. MNCs relied heavily on the mechanisms in quadrant 1 of Figure 2 in setting up their plants either for the penetration of protected markets or for exploiting differential factor costs. In contrast, flagships transfer knowledge not only

through mechanisms in quadrant 1 but also through mechanisms in quadrant 3. Flagships also tend to transfer more knowledge to local suppliers than vertically integrated MNCs. These transfers are necessary to enable local suppliers to provide the flagship with competitive products and services, in line with the changing requirements of markets and technology. Section 4.2 explores how flagships transfer explicit and tacit knowledge to local suppliers.

Let us now turn to the local prerequisites for effective knowledge diffusion: Under what can local suppliers internalize transferred knowledge and use it to enhance their own capabilities?

5. LOCAL CAPABILITY FORMATION

Local suppliers can only effectively absorb knowledge disseminated by global network flagships, if they have developed their own capabilities. Knowledge internalization and capability building require individual and organizational learning. Individuals are the primary actors in learning and knowledge creation (Hedberg, 1981). They constitute local capabilities that may be combined at the organizational level. Organizational learning, however, is not the simple sum of individual learning. Only effective organizations can translate individual learning and capabilities into organizational learning and capabilities.

5.1 Concepts

Firms create knowledge primarily through the dynamic process of conversion between explicit and tacit knowledge (Nonaka, 1991). Tacit-to-tacit conversion (called *socialization*) takes place when tacit knowledge of one individual is shared with others through training, whereas explicit-to-explicit conversion (*combination*) takes place when an individual or a group combines discrete pieces of explicit knowledge into a new whole. Tacit-to-explicit conversion (*externalization*) occurs when an individual or a group is able to articulate the foundations of individual tacit knowledge. Finally, explicit-to-tacit conversion (*internalization*) takes place when new explicit knowledge is shared throughout the firm and other members begin to use it to broaden, extend, and reframe their own tacit knowledge. Such conversion tends to become faster in speed and larger in scale in a spiral process, as more actors in and around the firms become involved in knowledge conversion. Using Japanese examples, Nonaka and Takeuchi (1995) develop a model that pictures organization knowledge creation as an upward spiral that starts from the individual and moves up to the organizational level.

For effective knowledge conversion to lead to productive learning, it requires two important elements are required (**See Figure 3**): an existing knowledge base (most of it tacit knowledge), and the intensity of effort. Of the two, the intensity of effort or commitment is more important than the knowledge base, as the former creates the latter, but not vice versa (Ulrich, 1998). Cohen and Levinthal (1990) call this “absorptive capacity”. How fast and successfully the local suppliers internalize and translate

transferred knowledge into their own capability through learning will be largely determined by their absorptive capacity and their ability to upgrade it continuously

A large part of the existing knowledge base is tacit knowledge. We have seen that this type of knowledge shapes individual and organizational learning. Tacit knowledge enables the individual as well as the organization to use both explicit and tacit knowledge available elsewhere and to create new knowledge through various knowledge conversion activities in production and R&D. Tacit knowledge also influences the nature and direction of learning and is responsible for its path-dependency. For instance, it is the richness of tacit knowledge accumulated as part of the existing knowledge base that enables leading suppliers in Korea, Singapore, and Taiwan to implement more sophisticated technological and organizational innovations than firms in other Southeast Asian countries.

The intensity of effort, on the other hand, determines the speed of knowledge conversion. It represents the amount of emotional, intellectual, and physical energy that members of an organization invest in acquiring and converting knowledge.

Exposure of individuals and firms to relevant external knowledge is insufficient, unless they make a conscious effort to internalize and use it. Learning how to solve complex problems is usually accomplished through trial-and-error involving a series of knowledge conversions. Hence, considerable time and effort must be directed to learning (Kim, 1998). For instance, Samsung was a late entrant in electronics but has evolved from OEM to ODM (own design manufacturing) and to OBM (own brand manufacturing) in both consumer and industrial electronics. It is on a par with Japanese and American competitors in areas such as semiconductor memory chips, flat panel display, and certain telecommunications technologies. These achievements are due to heavy investments in the development of the domestic knowledge base. For instance, Samsung's R&D expenditures have soared from \$8.5 million in 1980 to \$905 million in 1994 and to \$1.3 billion by 1999. As a result, its U.S. patents increased from 2 to 752 and to 1,549 during the same period. Samsung ranked 4th in 1999 only after IBM, NEC, and Cannon.

5.2. GPN as Mediators of Local Capability Formation

Let us now examine how GPN affect the development of capabilities by local suppliers. Let us first look at explicit knowledge. Flagships typically provide the local suppliers with *encoded* knowledge, such as machinery that embodies new knowledge, blueprints, production and quality control manuals, product and service specifications, and training handouts. This is done to assist the suppliers in building capabilities that are necessary to produce products and services with the expected quality and price. Personnel at the local suppliers read and try to assimilate the transferred explicit knowledge into their tacit knowledge (*internalization* in **Figure 4**). In most cases, the acquisition of explicit knowledge alone is not sufficient for the local suppliers to assimilate and use it in production, as the translation of explicit knowledge into actual operations requires a significant amount of tacit knowledge. Thus, to augment the explicit

knowledge, flagship companies also invite engineers and managers of the local suppliers to the former's site to observe how actual production systems work and to receive a systematic training.

This can help to translate knowledge gained from the literature into actual operations (*internalization*). It also enables local engineers to internalize how the flagships' organization and production systems are managed (*internalization* of *embedded* knowledge), and to absorb tacit knowledge directly transferred from foreign engineers through training (*socialization*). Once they return home, however, these engineers confront various unforeseen problems in their attempts to translate what they have learned at the flagships into the operational systems that exist at home. For this reason, the flagships also send their own engineers (*embodied* and *embrained* knowledge) to help local engineers debug problems in engineering and manufacturing systems (*socialization*).

Take the case of subsidiaries or joint ventures. For instance, when Sony established Hwashin Electronics Company in Korea as a joint venture to outsource its consumer electronics products, it supplied not only machinery and equipment for the mass-production system of its joint venture partner. Sony also provided blue prints of products, product specifications, and production and quality control manuals (*encoded* knowledge). In addition, the flagship invited a number of Korean engineers, technicians, and managers to undergo training at Sony's plant in Japan on production, organization, and human resource management, transferring *embedded* and *encultured* knowledge. Sony also dispatched a number of engineers and technicians to Korea to help Korean engineers debug problems encountered in operating and maintaining the production system and controlling the quality of products to ensure that Hwashin meet the technical specifications of Sony's products (*embodied* and *embrained* knowledge). Sony had done these knowledge transfer activities formally as part of its FDI and FL to Hwashin.

In the case of independent local suppliers, when General Electric decided to outsource its microwave ovens from Samsung under the OEM arrangements, it sent its engineers to Samsung to explain its technical specifications (*encoded* knowledge) and taught Samsung engineers master the engineering details of the product (*embrained* knowledge), (Magaziner and Patinkin, 1989). GE had done all these knowledge transfer activities free of charge to ensure that Samsung's products meet GE's technical specifications.

Second, local suppliers may attempt to translate such explicit knowledge as production and quality control manuals, human resource management handbooks, and other literature transferred from flagships into their own production and quality control manuals and human resource management handbooks. They may be more compatible with local institutions and business behavior. Then a *combination* takes place from a set of explicit knowledge to a new set of explicit knowledge at the local suppliers. In this process, *externalization* of knowledge also takes place from tacit knowledge of local engineers and managers to explicit knowledge in the form a new set of manuals and handbooks. For instance, when Volvo took over the ownership of Samsung's heavy

machinery division after the Asian crisis to turn it into its Asian supplier, Volvo introduced its own management systems, which reflects both Volvo's requirements and those shaped by local institutions. In developing a new set of manuals and handbooks, the ground was laid for *internalization*, *combination* and *externalization*.

Third, the link with GPN also induces knowledge conversions within local suppliers. The key is the diffusion of localized and internalized knowledge accumulated by a limited number of engineers and managers of the local suppliers through training provided by the network flagship. This knowledge needs to be diffused within local suppliers through spiral processes of *socialization*, as more actors in and around the firms get involved in knowledge conversion activities. *Externalization* and *internalization* take place internally, as actors convert from/to explicit to/from tacit knowledge within the local supplying firms, gradually developing *embedded* knowledge. For instance, Samsung Electronics recently sent a group of human resource management (HRM) specialists to GE to learn the latter's HRM system. Upon return, these specialists have conducted a series of seminars for HRM specialists in the firm to share the knowledge, leading to the development of new HRM policy and procedures and to the gradual formation of new embedded knowledge.

Fourth, knowledge conversion cannot take place without the active intervention of tacit knowledge. This is true even for the conversion from explicit knowledge to explicit knowledge. Once again, this highlights how important it is for local suppliers to develop a rich tacit knowledge base. In other words, the effectiveness and speed of knowledge conversion will be determined not so much by quantity and quality of the knowledge transferred by the flagships as by the absorptive capacity of the local suppliers. This holds regardless of the knowledge transfer mechanisms. The strength of the domestic knowledge base determines the level of sophistication of the converted knowledge, while the intensity of effort accelerates the speed of the conversion processes. In turn, spiral processes of knowledge conversion determine the level of the company's internal knowledge base. Leading local suppliers thus invest heavily in recruiting the cream of the crop from universities; they also develop intensive training programs to upgrade the existing knowledge base.

CONCLUSIONS

Liberalization, digital convergence, and intensifying global competition have produced a major organizational innovation: a transition from "multinational corporations" that exploit labor cost differentials in different countries to "global network flagships" that integrate their dispersed supply, knowledge, and customer bases into global (or regional) production networks. The paper demonstrates that these networks have boosted international knowledge diffusion, providing new opportunities for capability formation by local suppliers in developing countries. Under pressure from flagships, local suppliers have a strong incentive to internalize transferred knowledge through various forms of knowledge conversion. The baseline however is the absorptive capacity of the local suppliers: it determines the effectiveness of capability formation.

Policy and Management Implications

Our analysis has important implications for global flagships and local suppliers. First, flagships should actively transfer to local suppliers not only encoded knowledge but also embrained, embedded, and encultured knowledge. Such a broad-based transfer of knowledge enhances the capabilities of local suppliers; it also strengthens the competitiveness of the flagships' global production networks.

Second, flagships might worry about a possible switching of local suppliers to other flagships, once the suppliers have reached a certain level of capabilities. The flagships can avoid this by raising the local suppliers' switching costs. This can be done by helping the local suppliers develop the network-specific embedded systems and organizational culture through the active transfer of such knowledge. Once the local suppliers develop a strong embedded procedures and culture, which is tuned to those of the flagship, it is costly to switch to other GPN.

Third, local suppliers need to take an active approach to maximize their benefits from network participation. Flagships place business orders and transfer valuable knowledge to local suppliers with only one objective in mind: to strengthen the competitiveness of their GPN. To maximize the benefit of such transfers, local suppliers must constantly upgrade their absorptive capacity. Their existing knowledge base is largely determined by the embrained knowledge of the firm. Local suppliers, therefore, should tap, develop, and retain highly skilled human resources for developing existing their knowledge base. More important is the intensity of effort. There may be various means to intensify effort. One possibility, illustrated by some Korean firms, is to construct a deliberate crisis by establishing ambitious goals (Kim, 1997, 1998).

Fourth, as flagships transfer valuable knowledge to the first-tier local suppliers to strengthen the competitiveness of their GPN, higher-tier local suppliers should also help lower-tier suppliers build capability by transferring valuable knowledge to them in order to strengthen their own competitiveness. The competitiveness of GPN is determined by the competitiveness of each of the nodes in the networks.

Priorities for Future Research

We have seen that GPN transform the production and use of knowledge, considerably enhancing the mobility of knowledge. This may have far-reaching implications for an evolutionary theory of economic change. We suggest four main priorities for future research.

A first priority is to move beyond the "flagship bias". We need research on GPN, undertaken from the perspective of local suppliers that are located in small open economies and in developing countries. Some of the research questions include: Why do local suppliers join GPN? What are the advantages and disadvantages for local suppliers to take part in GPN? What are differences in learning and capability building between intra-firm suppliers and inter-firm suppliers?

A second research priority is to move beyond the current “production bias.” Digital convergence has created new opportunities for the exchange of knowledge-intensive services across organizational and national boundaries. We need research on the evolving global networks of business and information services, and especially on the transformation of these networks through the Internet⁶. Possible research questions include: What are idiosyncratic features of service-oriented GPN? How do production GPN and service GPN differ in terms of their mobility, location dynamics, and their capacity to enhance knowledge transfer? And how does knowledge transfer take place in service GPN?

Third, research needs to move beyond the current “R&D bias” and an exclusive preoccupation with the location of R&D and patents among major industrialized countries. We need to establish what forces explain that flagships are now beginning to outsource certain R&D activities to a handful of newly industrializing economies (NIEs) and even to some developing countries, and how this affects international knowledge transfer. Possible research questions include. What rationale explains such R&D outsourcing strategies to some NIEs? What distinguishes these arrangements from R&D alliances among leading American Japanese and European flagships? And how successful are the former arrangements?

Finally, we still know little about how GPN differ by country of origin. GPN are no longer the exclusive playground for American flagships. Asia’s electronics industry for instance is shaped to a large degree by the patterns of cooperation and competition between networks that center on American flagships as well as on flagships from Japan, Europe, Taiwan, Singapore and Korea (Borras, Ernst, and Haggard, 2000). This raises questions like⁷: How do these networks differ in terms of their basic characteristics, such as accessibility, permanence, flexibility to respond to market and technology shifts, and governance? How do they differ in terms of their impact on international knowledge transfer? Does nationality of ownership matter? And is diversity primarily a result of peculiar features of national institutions, or are there other forces at work?

⁶ These issues are addressed in an international collaborative research project, coordinated by the East-West Center, on “How the Internet Transforms Global Flagship Networks? And What This Implies for Knowledge Diffusion?”

⁷ Ernst and Ravenhill (1999) explore the diversity of these networks in Asia, and the limits to convergence.

Figure 1: The nodes of a global production network

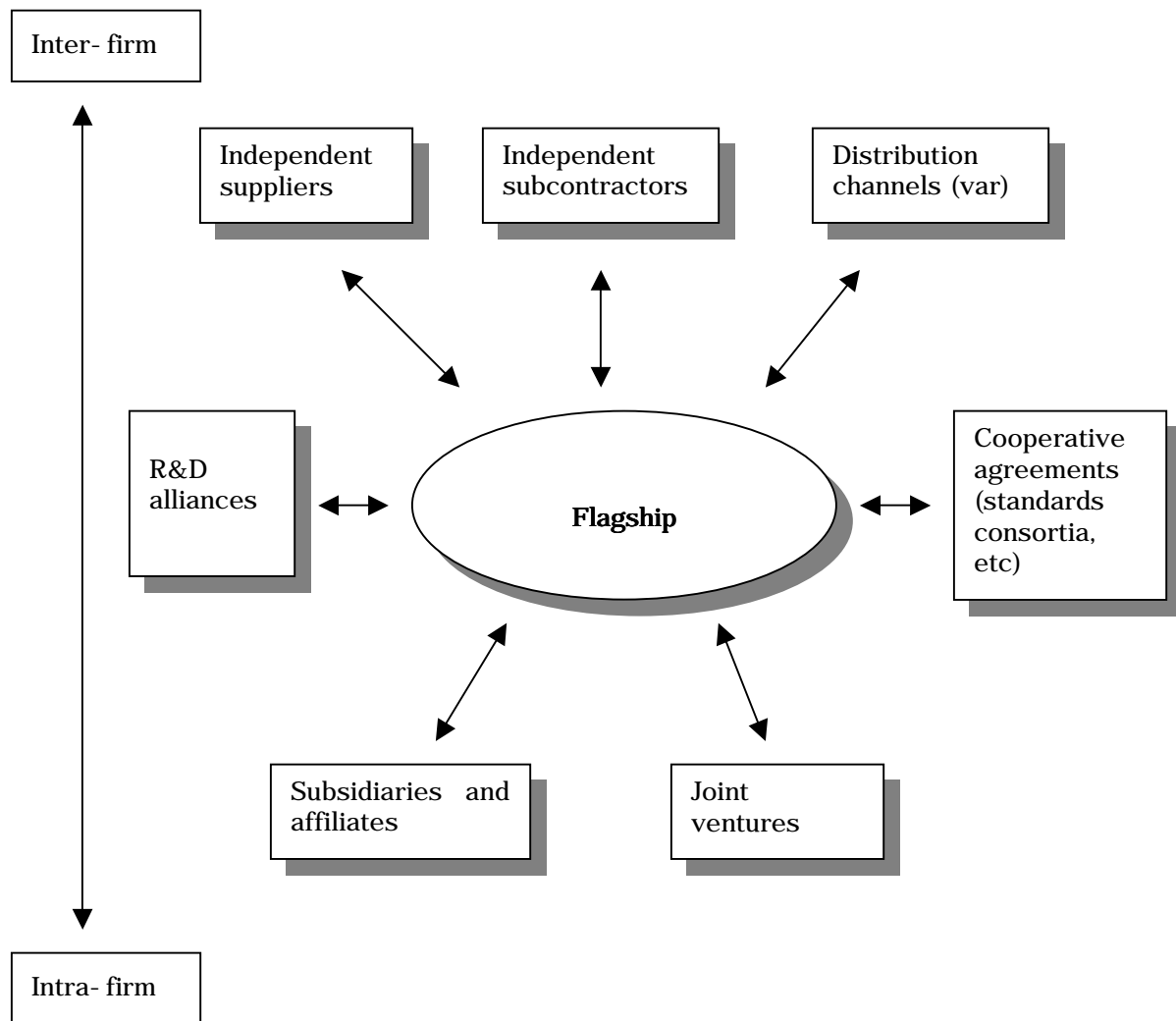


Figure 2: Knowledge transfer mechanisms

		The role of knowledge supplier	
		Active	Passive
Market mediation	Market mediated	Formal mechanisms (FDI, FL, turnkey plants, technical consultancies) (1)	Commodity trade (standard machinery transfer) (2)
	Nonmarket Mediated	Informal mechanisms (flagship provides technical assistance to local suppliers) (3)	Informal mechanisms (reverse engineering, observation, literature) (4)

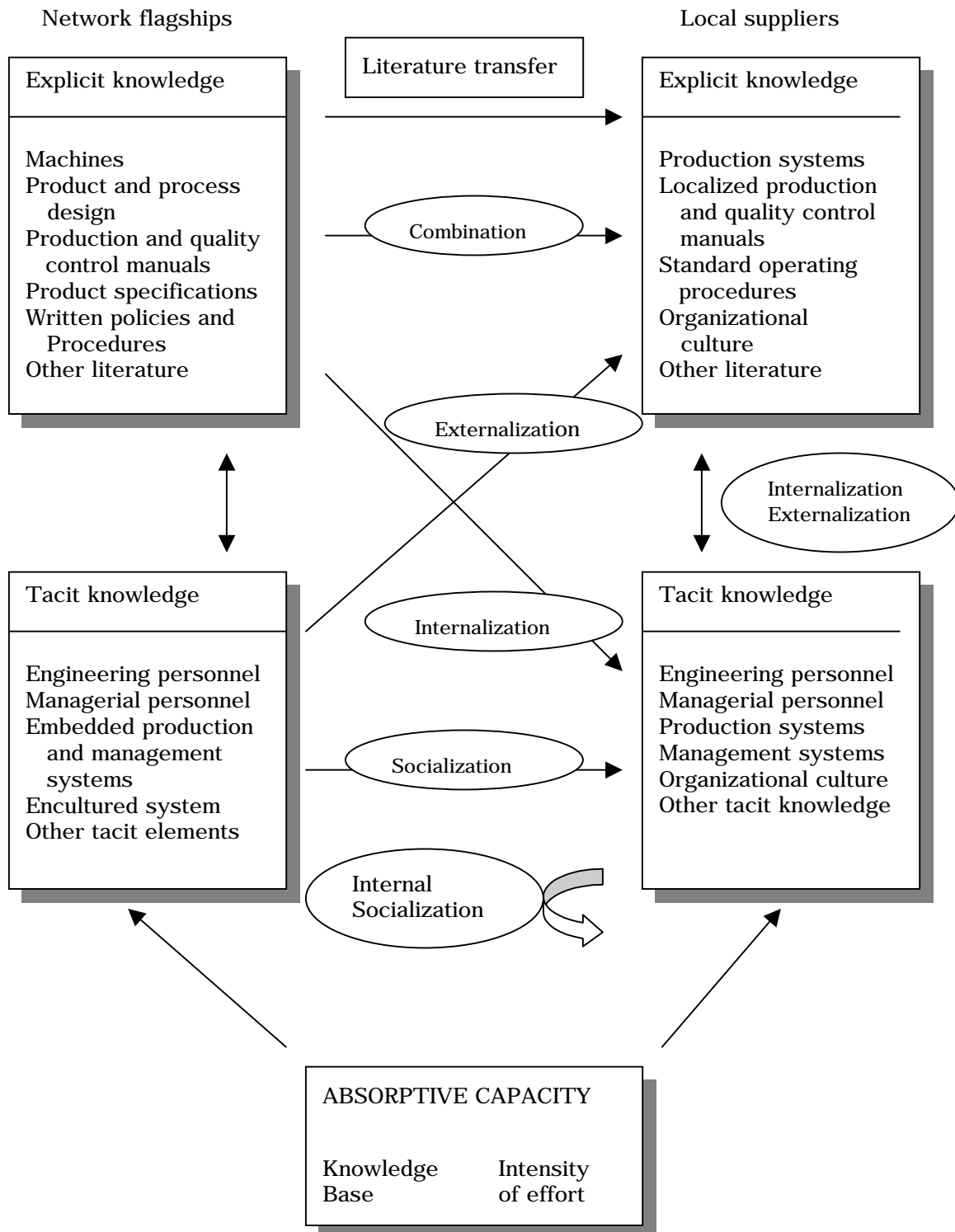
Source: Adapted from Kim, 1997, page 101.

Figure 3: Absorptive capacity of local suppliers

		Intensity of effort	
		High	Low
Existing knowledge base	High	high and rising rapidly (1)	high but falling (2)
	Low	low but rising (3)	low and falling rapidly (4)

Source: Adapted from Kim, 1997, page 98.

Figure 4: The process of local capability formation



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