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Global Production Networks and Industrial Upgrading—A Knowledge-Centered Approach

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INTRODUCTION

Three interrelated transformations in the international economy have fundamentally changed the agenda for development strategies. First, there is 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 geographically dispersed supply, knowledge and customer bases into global (and regional) production networks (GPN) (Borrus, Ernst, and Haggard, 2000; Ernst, 2001a).

Second, these networks provide the flagship with quick and low-cost access to components, subcontracting services and knowledge that are complementary to its core competencies. Yet, simultaneously, GPN disseminate knowledge to local suppliers in low-cost locations, which could catalyze local capability formation (Ernst, 2000a; Ernst and Kim, 2001, and Ernst, 2001b). And, third, a long-term process of "digital convergence" (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.

A central argument of this chapter is that the spread of GPN creates new opportunities for international knowledge diffusion, and that this can enhance the scope for IU, especially in small developing economies. We also argue that the demanding requirements imposed by network flagships on local suppliers create a powerful incentive for the latter to upgrade their capabilities through internalizing transferred knowledge. International knowledge diffusion through GPN can act as a catalyst for developing local capabilities (Ernst, 2000a). 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. 3). After all, investment is only half of the story; it needs to be complemented with knowledge (Nelson and Pack, 1995), which requires international linkages.

Surprisingly little is known about this international dimension of IU. The chapter tries to fill this gap. We develop a conceptual framework for policy-oriented empirical research that integrates insights from research on GPN, knowledge diffusion and capability development[1]. We first describe the new agenda for development strategies. Section 2 introduces an operational concept of IU that can be used as a focusing device. In section 3, we highlight the changing dynamics of competition that has driven the transition from "multinational corporations" to "network flagships", and compare the "flagship model" with other related network theories.

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[1] The impact of "digital convergence" is addressed in Ernst (2000b and 2002a), and Ernst, Fagerberg and Hildrum (2001).

Finally, part 4 explores how three important common features of GPN provide both new opportunities and incentives for knowledge diffusion between flagships and local suppliers. A concentrated dispersion of the value chain across firm and national boundaries creates opportunities for knowledge diffusion to local suppliers in a growing, but still limited number of lower-cost locations (4.1). This goes hand in hand with a parallel process of systemic integration of hierarchical layers of network participants who differ in their capacity to benefit from knowledge diffusion (4.2). And local suppliers are exposed to a combination of pressures and incentives from network flagships to upgrade their capabilities (4.3).

Nothing however is automatic about this process. The key to success are institutions and policies that facilitate the *concurrent leveraging of multiple and diverse sources of knowledge*, through GPN as well as through diverse carriers of regional and 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.

1. A NEW AGENDA FOR DEVELOPMENT STRATEGIES

By enhancing the international mobility of knowledge, GPN and "digital convergence" may provide new opportunities for international knowledge diffusion to small open economies that heavily depend on international trade and investment. However, they also pose a fundamental challenge: What policies and regulations can reduce the global knowledge divide that separates network flagships and lower-tier suppliers of these networks? And what needs to be done to enable the latter to develop the capabilities necessary to reap the benefits of network participation?

Coping with these new opportunities and challenges is simply not possible as long as development strategies continue to stick to the old recipes. After decades of exposure to liberalization, earlier naiv 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: a passive reliance on foreign capital and technology inflows does not guarantee sustainable development. An important shift has occurred, at long last, 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, to provide incentives for learning and innovation (e.g., Evans, 1995; Rodrik, 2000). This is in line with similar debates in major OECD countries (e.g., Kogut, 2000; O`Sullivan, 2000; OECD, 2000).

With some delay, this reconsideration of established doctrines is beginning to take root in economic theory. The neo-classical concept of "market failure" is patently inappropriate for defining the agenda for public policy response to GPN and "digital convergence". Both accelerate the pace of change in technology and markets, and increase uncertainty and the volatility of market structures, industrial organization and firm behavior (Ernst, 2001a). This implies that information is imperfect, "externalities" diffuse and markets are incomplete, with the result that free markets cannot in principle meet the strict requirements of optimal resource allocation (Stiglitz, 1998).

A fundamental weakness of the "market failure" 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 (e.g., Lipsey, 1997). 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.' The concept of "industrial upgrading" (IU) can serve as a superior focusing device.

2. INDUSTRIAL UPGRADING

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 integration through linkages (Hirschman, 1958), 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 (Bell and Pavitt, 1993; Nelson and Pack, 1995; Ernst and Lundvall, 2000)[2].

To operationalize the concept of IU, we first introduce two key components, i.e. specialization and integration. We then construct a simple taxonomy of different forms of IU, and describe peculiar features of our concept. After sketching a stylized model of IU without international linkages, we introduce the international dimension of IU.

2.1. Specialization and Integration

The concept of industrial upgrading (IU) has its roots in Adam Smith´s theory of economic progress through the division of labour, and in Alfred Marshall´s theory of internal and external economies. These insights have been sidelined by an almost exclusive concern with the "maximization-and-equilibrium" paradigm. In the words of Krugman, economists "…explain behavior in terms of an equilibrium among maximizing individuals": maximization and equilibrium are used as "*modelling devices* - as useful fictions about the worlds that allow … (economists) to cut through the complexities."(Krugman, 1996). Yet, such an approach is not very helpful for the study of economic development. By definition, the latter is based on qualitative and largely unpredictable structural change (Loasby, 1998).

[2] This is in line with the leading-edge in economic theorizing, such as endogenous growth theories (e.g., Romer, 1990; Grossman and Helpman, 1991; Helpman, 1998); Lipsey`s structuralist growth theory (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, 2000).

Adam Smith emphasized that growth is shaped by the division of labor which in turn is limited by the extent of the market (1776/1970, book 1, pages 111-126), a proposition which refers to numerous qualitative changes like improved labor productivity through learning (dexterity) and specialized machines, and the expansion of market size through reduced transportation cost. For Alfred Marshall, industrial evolution involves both "differentiation" and "integration". "Differentiation" stands for "the division of labor, and the development of specialized skill, knowledge and machinery". "Integration", defined as " a growing intimacy and firmness of the connections between the separate parts of the industrial organism", shows itself in such forms as the increase of security of commercial credit, and of the means and habits of communications by sea and road, by railway and telegraph, by post and printing-press" (Marshall, 1890/1916, p.201).

2.2. A Taxonomy

In short, specialization and integration define the essence of industrial upgrading (IU). Drawing on Chenery (1960), Ozawa (2000), and Ernst (2001c), one can construct a *taxonomy* of IU that distinguishes five forms:

- *inter-industry* upgrading 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";

- upgrading along *functional* activities within a hierarchy of *value-chain* stages, that proceeds from sales and distribution, to final assembly and testing, to component manufacturing, engineering, product development, and system integration; and

- upgrading within a hierarchy of forward and backward *linkages*, that proceeds from tangible, commodity-type production inputs to intangibles, i.e. a variety of knowledge-intensive support services.

2.3. Peculiar Features

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. 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. And 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. While all five forms of IU matter, we emphasize the last two aspects: *firm*-level upgrading that moves from low-end to higher-end value chain stages, and *industry*-level upgrading through linkages that provides external economies for the individual upgrading firm.

Three additional features distinguish our concept of IU. First, we use a *broad* definition of innovation. In addition to R&D and patenting[3], we include engineering, technology purchases, expenditures on licensing and consultancy, and technology search, as well as the accumulation of tacit knowledge required to absorb imported technology (e.g., Nelson, 1990). Second, we use industrial upgrading as a *context-specific* concept - its characteristics differ across industrial sectors and countries. This is important, as digital convergence and GPN have substantially extended the geographic dispersion of economic transactions, involving diverse economic structures and institutions. Equally important are changes over time. Evolutionary economics has highlighted the importance of history, nationality and industry-specific features for peculiar trajectories of industrial dynamics. Nothing is predetermined about the outcome of these processes (Schumpeter, 1912/1961)[4].

Third, the concept focuses on the *co-evolution of industry structure and firm behavior.* 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[5]. We need to consider the sources of innovation and growth in a broader frame of reference that "includes the firm itself, its relationship with other organizations, and also government policy." (Stopford, 1998: 296)

2.4. Stylized Model Without International Linkages

[3] Most empirical work on IU has narrowly focused on the expansion of R&D-intensive industries. The (usually) implicit notion is that potential rates of productivity growth are higher in "emergent", R&D-intensive industries (Globerman, 1997, pages 98 and 99). Hence, "… specializing in the "right" technological activities directly contributes to faster growth rates of real income". A related notion is that, for R&D-intensive industries, economic rents can be extracted, in part, from foreign consumers. A specialization in the "right" technological activities is expected to contribute to higher levels of national income by promoting more favourable international terms of trade.

[4] There is no guarantee against crises and malignant growth, hence the possibility of truncated upgrading. There are many reasons why a firm can get stuck with obsolete features that once were useful, but now have become barriers to a further upgrading (e.g., Christensen, 1997). The same is true for an industrial district or an economy.

[5] 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 to innovation: capability-based theories of the firm have focused primarily on the internal accumulation of knowledge and skills which underpins its productive activity.

Let us briefly sketch a stylized model of IU. The model is designed to explain how specialization affects market structure and upgrading potential, with no reference to international linkages (**figure 1**[6]). In line with theories of innovation systems and industrial districts, we assume that IU ends at the regional or the national border, and that it occurs only if improved specialization generates pressures to create dense forward and backward linkages *within* the district or the national economy[7]. This "closed economy" assumption is problematic, to the degree that GPN and "digital convergence" increase the international mobility of knowledge.

Specialization is the *explanatory* variable, while market structure and upgrading are the *dependent* variables[8]. The model can also highlight the dynamics of IU, and specify conditions which make it possible to move from a *vicious* to a *virtuous* circle.Industrial economists distinguish specialization patterns that reflect differences in the product composition ("commodities" versus "differentiated" products), and in the types of production process ("mass" production versus "flexible" production). This distinction is based on two criteria: the complexity of technology (complexity), and peculiar characteristics of demand (uncertainty). For "commodities", complexity and uncertainty are low: these products are easy to replicate, changes in demand and technology are predictable, and only limited interaction is required with customers. The reverse is true for "differentiated" products. Similar distinctions can be made for process specialization.

It is argued that different market structures will result from these different product compositions and production processes that account for a different upgrading potential. "Market structure" is defined by entry barriers, mode of competition and value generation[9]. Finally "upgrading potential" covers technological learning requirements and Hirschman-type linkages. For instance, for differentiated products, firms can charge premium prices, while for homogeneous products, price competition and periodic price wars are the over-riding concerns. Differentiated products are associated with high entry barriers and significant value generation, while both are low for homogeneous products.

The purpose of this exercise becomes clear when we look at the last row of our matrix. While homogenous products have only a limited upgrading potential, in terms of

[6] See figures in the appendix.
[7] A national or regional bias is characteristic for much of the literature on national innovation systems (e.g., Nelson, 1993 and Lundvall, 1992), industrial districts (e.g.,Saxenian, 1994; Enright, 1998) and development policies (e.g., Chang, 1994). For a critique, see Ernst, 2001 b, and Ernst, Guerrieri, Iammarino,Pietrobelli, 2001.
[8] Similar models need to be constructed that focus on other forms of IU, as described in the above taxonomy.
[9] Lazonick (1991) argues that, although it is used all the time, "rent" is generally the wrong word analytically. In economics, rent is the return on a resource that is inherently in scarce supply (e.g., the rent that can be charged on a house in a prime location in a major city), irrespective of the quality and the cost of the house. What matters for our purposes are Schumpeter`s "entrepreneurial profits" which derive from the ability of the producers to generate value through higher quality, lower cost products, i.e. innovation (Schumpeter, 1912/1961, 153-4).

technological learning requirements and linkages, the opposite is true for differentiated products. Similar distinctions can be made for production processes: flexible production is linked to premium pricing and significant value generation, giving rise to a substantial upgrading potential. The downside of course are the substantially higher upfront preparatory efforts that are necessary for successful entry.

The conclusion drawn from this simple model is that continuous growth requires a dual shift in specialization: from "commodities" to differentiated products, and from "mass production" to "flexible specialization". It is important to emphasize that causality works both ways: Not only does a narrow specialization on the mass production of commodities fail to provide sufficient pressure to broaden the domestic knowledge base and to develop forward and backward linkages. The reverse is also true: necessary improvements in specialization require a strong and specialized domestic knowledge base and dense linkages. This is precisely what theories of innovation systems and industrial districts suggest, emphasizing the localized nature of knowledge and linkages within a nation or an industrial district. This reflects the importance of "dynamic agglomeration economies"[10]: co-location facilitates a continuous, intense and rapid exchange of new ideas about technical, organizational and production improvements.

This proposition is based on the (frequently implicit) assumption that a fairly homogeneous industry structure exists: "… 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 easily access.

2.5. Introducing International Knowledge Linkages

These assumptions however do not hold universally. Much of the agglomeration economies argument has been developed for a handful for highly sophisticated and tightly networked clusters, such as Silicon Valley, Route 128, Northern Italy, Baden Wuerttemberg, and some industrial districts in Nordic countries. Most other countries are constrained by a narrow domestic knowledge base and limited linkages.

Both constraints are particularly important for small developing economies. One of their primary features is a narrow and incomplete set of domestic linkages (e.g, Lall, 1997; Ernst, Ganiatsos, and Mytelka, 1998). The result is an "inverted production pyramid": a growing final product sector rests on a weak and much smaller domestic base of support industries (Ernst, 2001c). Rapid growth in the final products sector necessitates considerable imports of intermediates and production equipment. We also find a narrow local knowledge base, as expressed, for instance, in low ratios of R&D and

[10] Alfred Marshall´s pioneering concept of "externalities" (1890/1916, p.271) 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. In Marshall´s view, the latter is clearly the decisive advantage.

patenting, a weak public innovation system, and limited interaction of that system with the private sector.

In addition, highly heterogeneous economic structures constrain agglomeration economies; weak and unstable economic institutions obstruct learning efficiency; 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. As a result of this "vicious circle", very limited sharing and pooling of resources and knowledge occurs within the country, and often even within the export-oriented cluster. This implies that our model of IU needs to integrate international knowledge linkages[11]. To compensate for their narrow domestic knowledge base and limited linkages, small developing economies have to rely on foreign sources of knowledge to catalyze domestic capability formation. International linkages need to prepare the way for the development of regional and national innovation systems.

Empirical research supports this argument. As a developing country progresses in its industrial transformation, it reliance on international technology sourcing and knowledge linkages typically increases (e.g., Hobday, 1995; Lall, 1997; and Ernst, Ganiatsos, and Mytelka, 1998). In many cases, successful IU has been based on integration into regional and global production networks established by leading network flagships (e.g., Ernst, 1994; Gereffi, 1999; Ernst, 2000a; and Borrus, Ernst and Haggard, 2000).

3. GLOBAL PRODUCTION NETWORKS

3.1. A New Divide in Industrial Organization

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 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 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,

[11] For an empirical application of such a revised model to the upgrading options for Costa Rica´s Intel cluster, see Hershberg, Monge, and Perez Sainz, 2001.

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).

This growing complexity of competition has changed the determinants of firm organization and growth, as well as the determinants of location. The traditional model of the "multinational corporation", with its focus on stand-alone overseas investment projects, has reached its limits. 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; Chandler, 1977) of "multinational corporations" to the networked global flagship model (Ernst, 1997b, 2001 a).

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, 2001a). The number of such networks, and the intensity of competition varies across sectors, reflecting their different stage of development and their idiosyncratic industry structures.

A GPN covers both intra-firm and inter-firm transactions and forms of coordination: 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 (see **figure 2)**[12]. 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

[12] For details, see e.g., Ernst, 1994, 1997a, 1997b, 2001a, and 2001b. For empirical case studies on diverse GPN, see Ernst and Ravenhill, 1999, and Borrus, Ernst and Haggard (eds.), 2000.

result from the dissemination, exchange and outsourcing of knowledge and complementary capabilities.

3.2. The Network Flagship Model

In short, by integrating their dispersed supply, knowledge and customer bases into global (and regional) production networks, "multinational corporations" are being transformed into "global network flagships". Until recently, 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. This is now beginning to change. There is a growing acceptance in the literature that, to capture the impact of globalization on industrial organization and upgrading, the focus of our analysis needs to shift away from the industry and the individual firm to the international dimension of business networks (e.g., Ghoshal and Bartlett, 1990; UNCTAD, 1993; Rugman and D´Cruz, 2000; Birkinshaw and Hagstrøm)

But our understanding of these networks is limited. Research on GPN is at the formative stage and shares three common weaknesses. Most studies have focused too narrowly on the perspective of the network flagship ("flagship bias"). 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 production, but tells us little about other aspects of global networks ("production bias"). Third, there is also an "R&D bias": research has focused narrowly on the location of R&D and patenting alliances, with a primary focus on the US, Western Europe and Japan. 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).

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. 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. Increasingly, the GCC literature has moved to integrate explicitly an analysis of network flagship behavior.

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 1998; 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 and 1990) 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. 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; they also enhance the network flagships´ capacity for innovation. These considerations are of particular concern for developing countries' integration into GPN, and their capacity to strengthen their local capabilities.

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. Firms must combine product innovation and differentiation, and the learning and acquisition of specialized capabilities that this implies, with high volumes, speed-to-market, competitive pricing, and the ability to penetrate new and uncharted markets (Ernst, 1997 b). Mass production implies large investment thresholds to reap economies of scale, while short product life-cycles imply the rapid depreciation of plant, equipment and R and D. The problems of squaring this strategic circle are compounded by periodic trajectory-disrupting innovations, so that leadership positions cannot be taken for granted.

These market conditions create pressures to move from partial globalization, characterized by a loose patchwork of stand-alone affiliates, joint ventures, and suppliers, to systemic globalization: the effort by a flagship to network its own operations and inter-firm relationships worldwide, across both functions and locations. The demand both for scale and for closer, faster, and more cost-effective interactions between different stages of the value chain have been a driving force in shifting core functions, like production, outside the boundaries of the firm into networks.

4. KNOWLEDGE DIFFUSION THROUGH GLOBAL PRODUCTION NETWORKS

4.1. Concentrated Dispersion

GPN typically combine 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 socalled 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. These different perspectives need to be addressed explicitly by IU strategies. Let us look at some indicators in the electronics industry, a pace setter of GPN (Ernst, 2001b). One important finding is that 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. Most dispersed are Acer`s 19 overseas final assembly and configuration centers that are located in or close to major markets. Dispersion is lower for volume manufacturing sites that produce components or sub-assemblies. Out of Acer´s 21 manufacturing sites, six are large volume manufacturing sites located overseas: two in China, and one each in the Philippines, Malaysia, Mexico and Wales. The location of these manufacturing sites is primarily determined by the fact that 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, 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 (see 4.2.2). 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.

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 IU 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 center 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.

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 IU trajectories for individual specialized industrial clusters.

4.2. 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 returns[13].

"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)[14]. The

[13] 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.

[14] 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

flagship derives its strength from its control over critical resources and capabilities that facilitate innovation, 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.

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 suppliers[15]: 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

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forms of business organization.

[15] 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.

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.

4.3. Prerequisites for Knowledge Diffusion

Under what conditions can GPN generate effective knowledge diffusion? And what needs to be done to strengthen the position of local suppliers? The missing link in our argument is that local suppliers are exposed to a combination of pressures and incentives from network flagships to upgrade their capabilities. This provides important upgrading opportunities for those, mostly higher-tier, local suppliers that possess a critical mass of resources and capabilities.

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.

In short, GPN expose local suppliers to the flagship`s management practices and technological knowledge. International technology transfer has been extensively studied, but research has primarily focused on such formal mechanisms as foreign direct investment and foreign licensing. These formal mechanisms, however, are only the tip of the iceberg. A larger amount of technical knowledge is transferred through various informal mechanisms that involve a substantial amount of tacit knowledge (e.g., Westphal, Kim and Dahlman, 1985; Wong, 1991; Ernst, Ganiatsos and Mytelka, 1998; Ernst, 2000a). This includes early supplier involvement in product design and prototype development; access to proprietary technical and marketing information on end users` requirements and on competitors' products; informal sharing of technical information and ideas between the flagship and different network nodes; and knowledge exchange through informal, transnational peer group networks.

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 (Ernst and Kim, 2001). Much depends on the motivations, resources and capabilities of local suppliers. These issues are at the center of the IU debate. Our focus here is on the other side of the coin: a combination of pressures and incentives, imposed by network flagships on local suppliers to upgrade their capabilities.

Typically, the flagships` outsourcing requirements have become more demanding. Cisco for instance selects suppliers according to three criteria: a solid financial standing; high ratings on a quarterly scoreboard measuring performance in delivery, quality etc.; and speed of response. The latter is of critical importance: suppliers are expected to respond within hours with a price, a delivery time, and a record on their recent performance on reliability and product quality. This implies that local suppliers can only upgrade or perish. To stay on the GPN, local suppliers must develop their capabilities through internalizing transferred knowledge. The only way for suppliers to survive the intense pressures imposed by the flagships is to upgrade from a position of simple contract manufacturers (so-called "box shifters") to providers of integrated, knowledge-intensive support service packages.

At the same time, network participation can also provide an incentive for local suppliers to invest in their knowledge base and capabilities. This requires however that the flagship reduces the perceived risk of such investments through a longer-term commitment; that network participation provides the supplier with a stable source of income to finance the investment; and that the network offers access to superior market and technology information that may reduce the risks involved in the investment decision. These are fairly demanding requirements that not all networks meet. It is now well established that nationality of ownership of network flagships, home country institutions and product mix (specialization) explain why GPN differ in their governance structures, and hence in the incentives they provide for IU investment by local suppliers (Ernst and Ravenhill, 1999; Borrus, Ernst and Haggard, 2000, chapter1).

In short, under certain circumstances, GPN may provide a combination of new opportunities, pressures and incentives for local suppliers to upgrade their capabilities. But they are no substitute of course for domestic upgrading efforts. Take the experience of Taiwanese OEM suppliers to global network flagships in the computer industry (Ernst, 2000a). Taiwan´s involvement in the OEM business[16] has given rise to a peculiar pattern of knowledge diffusion. In line with our IU matrix, Taiwanese firms entered through very simple OEM arrangements, covering low-end desktop PCs and labor-intensive peripherals. This was in line with their initially weak capabilities and narrow domestic knowledge base. Such simple arrangements however generated only limited opportunities for knowledge diffusion, value generation and IU. 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 capability formation in Taiwan´s computer industry. In contrast to a widespread perception (e.g., Hobday, 1995), successful knowledge diffusion 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 (Ernst, 2000a). Taiwanese firms for instance have typically pursued simultaneously different forms and trajectories of integration into GPN, rather than concentrating exclusively on one particular linkage. Also, benefits from network participation did not come automatically. A critical prerequisite were government policies that have created a set of innovative institutions and incentives conducive for continuous IU. Of equal importance were informal peer group networks that Taiwanese "transnational technical communities" have established with Silicon Valley (Saxenian, 2002), and a variety of innovations in industry organization that facilitated inter-organizational knowledge exchange. It is through such concurrent and multiple linkages that a *virtuous circle* was established between international knowledge diffusion and domestic knowledge creation.

CONCLUSIONS

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

Globalization has culminated in an important organizational innovation: "global network flagships" integrate their geographically dispersed supply, knowledge and customer bases into global (& regional) production networks (GPN). For small 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 local suppliers to strengthen their capabilities. This could provide an important boost for IU strategies.

Nothing however guarantees this outcome. Network integration may equally well erode a country´s sources of competitive advantage. It may also sap the strengths of existing clusters and truncate their IU possibilities. Network integration of some "higher-tier" suppliers may well 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.

There is however cause for cautious optimism: network participation may provide new opportunities for effective knowledge diffusion to local firms and industrial districts in developing countries, *provided* appropriate policies and support institutions are in place. Two effects can be distinguished: First, GPN can act as a conduit for knowledge diffusion for state-of-the-art management approaches as well as product and process technologies, including the required tacit knowledge. At the same time, the requirements of network flagships can also provide both pressures and incentives to catalyze knowledge creation and capability development within firms and industrial districts in developing countries.

It is still an open question, however, whether these linkages, over time, may also give rise to joint knowledge creation, with roughly symmetrical contributions from the global network flagship and from the local network participants. We also need empirical research that explores the impact of "digital convergence": How realistic are claims that placing GPN on the Internet provides flexible infrastructures that support not only information exchange, but also joint knowledge creation among distant network participants? And will the Internet create new entry possibilities for local suppliers in small developing countries, providing them with powerful channels for knowledge outsourcing and capability development[17]?

All of this has important policy implications. 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

[17] These issues are addressed in an international policy-oriented research project, coordinated by the East-West Center, on "Placing the Networks on the Internet - Global Production Networks and Local Capability Formation in Developing Asia".

that provide incentives, as well as the necessary infrastructure, support services and human resources.

Implementing such policies however poses daunting political and administrative challenges. Combining participation in GPN with robust IU 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, it requires a deep understanding of sector-specific competitive dynamics, 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 global network flagships, 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 global competition, a handful of flagships 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. What it does imply however is that an openness to foreign ideas and knowledge, and a capacity to absorb these and blend them with existing capabilities is critical for sustained IU. International knowledge linkages can help to broaden the range of options.

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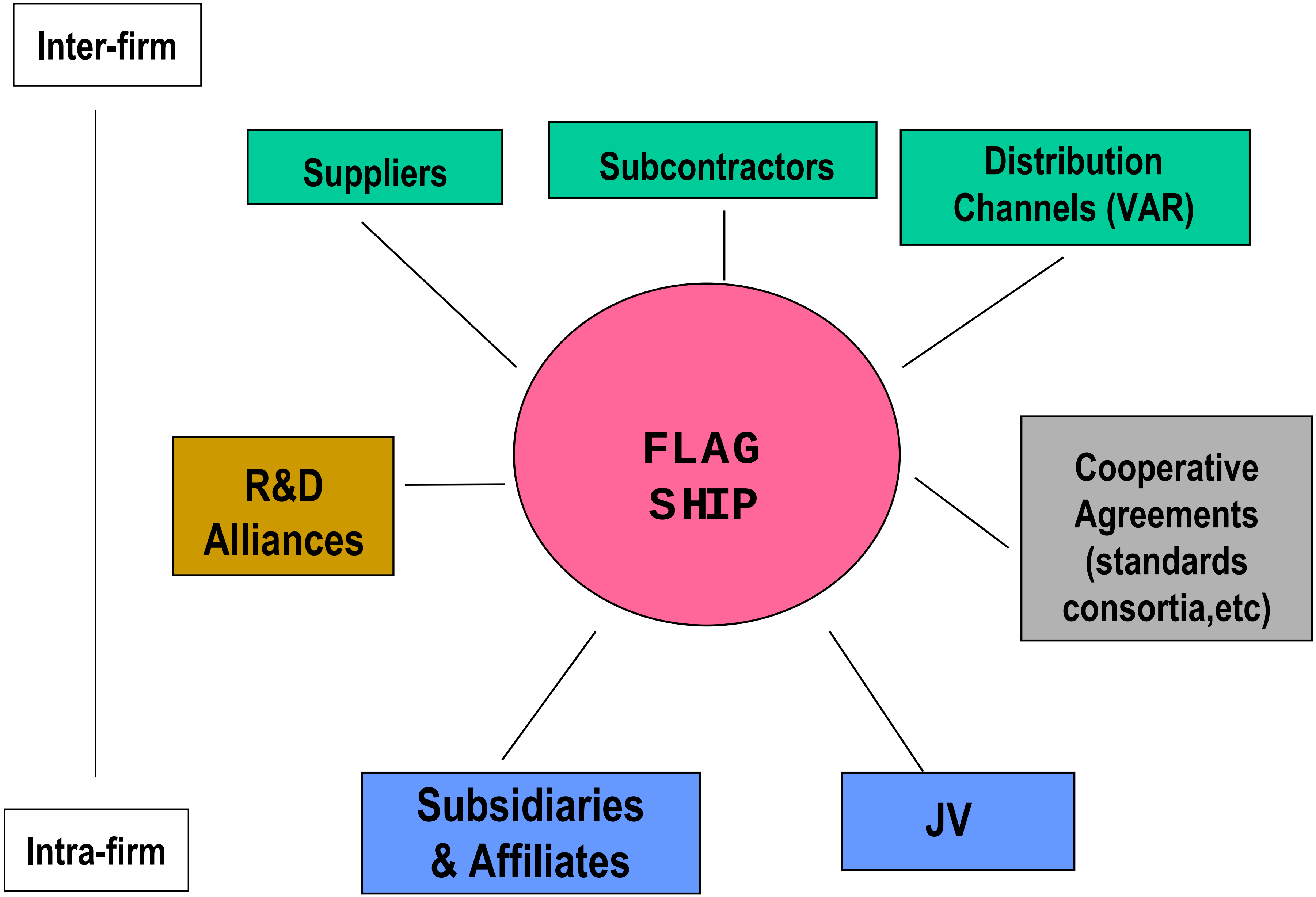
Figure 1. Specialization-upgrading Matrix

Variables	**Complexity/Uncertainty**	
	Low	**High**
Product Specialization	**Homogeneous (commodities)** • Mature technology • Established design • Easy to replicate • Predictable changes in demand & technology • Limited interactions w/customers	**Differentiated** • New technology • Fluid design • Difficult to replicate • Unpredictable changes • Close interaction with customers
Process Specialization	**Mass Production** • Economies of scale & Scope	**Flexible Specialization**
Market Structure	• Low entry barriers • Price competition • Limited value generation: periodic over-capacity & price wars⇒ deflationary pricing pressures	• High entry barriers • Premium pricing • Significant value generation
Upgrading	• Limited technological learning requirements • Limited pressure to develop forward & backward linkages	• Substantial pressure to broaden & deepen local knowledge base • Ditto for linkages

Figure 2. THE NODES OF GLOBAL PRODUCTION NETWORK



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