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Digital Information Systems and Global Flagship Networks: How Mobile is Knowledge in the Global Network Economy

Dieter Ernst

Dieter Ernst is a Senior Fellow and Theme Leader for economic studies at the East-West Center. He is also a research professor at the Center for Technology and Innovation (TIK) at the University of Oslo. His previous affiliations include the OECD, Paris, as senior advisor; the Berkeley Roundtable on the International Economy; the University of California at Berkeley as senior fellow; and the Copenhagen Business School as professor of international management. He is coeditor of *International Production Networks in Asia: Rivalry or Riches?* (2000) and *Technological Capabilities and Export Success in Asia* (1998). He serves on the Committee on Information Technology and International Cooperation (ITIC) of the U.S. Social Science Research Council. He also serves as scientific advisor to the United Nations University's Institute for New Technologies (UNU-INTECH), Maastricht, Netherlands; and the Japan Foundation's Globalization Project.

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ABSTRACT

Two defining elements of the "global network economy" are the evolution of global flagship networks (GFN) and the increasing use of digital information systems (DIS) to manage these networks. Both transformations may gradually reduce constraints to cross-border knowledge diffusion, and hence enhance the mobility of knowledge. We thus need to reconsider and amend the proposition, formalized by agglomeration and innovation economists and network sociologists, that knowledge is less mobile than markets, finance or production facilities. As a first step towards an appreciative theory, the paper explores the role played by DIS for knowledge diffusion within cross-border networks. We highlight opportunities, pressures and incentives that may result from network participation, and explore how they affect the absorptive capacity of local network suppliers.

A few keywords: Networks; knowledge diffusion; information systems; multinational corporations; Internet; industry dynamics; capabilities; global production.

JEL - code(s). D2, F2, L6, L8, M2, 03, R3

INTRODUCTION

Digital information systems (DIS) are electronic systems that integrate software and hardware to enable communication and collaborative work (Chandler and Cortada, 2000). These systems are not developed in a vacuum. They are a response to transformations in economic institutions and structures that determine industrial dynamics. "Globalization" is a widely used short-hand for those transformations.

How does globalization interact with DIS? To answer that question, we need to open the blackbox of "globalization". We define "globalization" as the integration, across borders, of markets for capital, goods, services, knowledge, and labor. Barriers to integration continue to exist of course in each of these different markets, so integration is far from perfect. But there is no doubt that a massive integration has taken place across borders that, only a short while ago, seemed to be impenetrable.

This raises the question: Who are the "integrators"? States obviously play an important role in reshaping institutions and regulations. But at least equally important are private actors, especially large global corporations. We thus need research that explores the link between transformations in international business organization and industry dynamics. A focus on the evolution of cross-border corporate networks allows us to identify what is "new" about the global economy. The approach that I have chosen focuses on international knowledge diffusion through an extension of firm organization across national boundaries. The paper deals with a seemingly innocuous question that however has far-reaching implications for the economic study of industry dynamics: How mobile is knowledge in the emerging Global Network Economy?

At first sight, the answer seems to be obvious. There is a widespread belief, formalized by agglomeration and innovation economists and network sociologists, that knowledge is stickier in space (i.e. less mobile) than markets, finance or production facilities (e.g., Markusen, 1996; Archibugi and Michie, 1995; Breschi and Malerba, 2001). It is argued that this is true in particular for higher-level, mostly tacit forms of "organizational knowledge" required for learning and innovation. Such higher-level knowledge congregates in specialized clusters ("industrial districts"). This reflects the importance of "dynamic agglomeration economies": co-location facilitates a continuous, intense and rapid exchange of new ideas about technical, organizational and production improvements.

In the emerging global network economy, we need to reconsider and amend the "stickiness-of-knowledge" proposition. The defining elements of the "global network economy" are two inter-related transformations in the organization of international business: the evolution of cross-border forms of corporate networking practices, especially global flagship networks (GFN); and the increasing use of digital information systems (DIS) to manage these networks. A central argument of this paper is that the combined forces of DIS and GFN may gradually reduce constraints to cross-border knowledge diffusion, and hence enhance the mobility of knowledge.

The new mobility of knowledge is an "unintended consequence" (Sassen, 2002) of the evolution of global corporate networks. Global corporations (the "network flagships")

construct these networks to gain quick access to skills and capabilities at lower-cost overseas locations that complement the flagships' core competencies. However, the more

dispersed and complex these networks, the more demanding their coordination requirements. Knowledge sharing is the necessary glue that keeps these networks growing (Ernst, 2002a). Flagships need to transfer technical and managerial knowledge to local suppliers. This is necessary to upgrade the suppliers' capabilities, so that they can meet the technical specifications of the flagships. Originally this involved primarily operational capabilities and procedures required for routine manufacturing and services. Over time, knowledge sharing also incorporates higher-level, mostly tacit forms of "organizational knowledge" required for learning and innovation. In short, knowledge exchange penetrates new geographic areas, and the contents of exchanged knowledge becomes more complex.

The paper demonstrates how the use of DIS as a management tool can enhance the scope for knowledge sharing among multiple network participants at distant locations. But these changes will occur only gradually, as a long-term, iterative learning process. While much of this is still at an early stage of "trial-and-error", international business now faces a huge potential for extending knowledge exchange across organizational and national boundaries. Large bodies of theoretical and applied work exist on the individual topics of GFN, DIS, and international knowledge diffusion. Their mutual interaction however is still mostly uncharted territory. This paper attempts to link together the above three areas of research, as a first step towards an appreciative theory, as defined in Nelson´s (1999) thought-provoking review of economic growth theory.

We first introduce a new agenda for the economic study of knowledge that reflects the co-evolution of DIS and trans-boundary forms of corporate networking practices. We then highlight forces that drive the development of GFN, focusing on the

role of DIS, and look at the economic structure and peculiar characteristics of the flagship network model that foster the new mobility of knowledge. The paper presents robust evidence, based on research in information industries, that the new mobility of knowledge remains constrained in space: while cross-border exchange of knowledge has penetrated new geographic areas, it remains limited to a finite number of specialized clusters and to higher-tier network suppliers. Specifically, we demonstrate that newly emerging "cost-and-time reduction" clusters" in lower-income regions may now find it easier to upgrade technologically from assembly-type manufacturing to the timely provision of supply chain management and design services. In a fourth step, finally, we explore prerequisites for effective knowledge diffusion through GFN. We highlight opportunities, pressures and incentives that may result from network participation, and explore how they affect the absorptive capacity of network suppliers.

1. A NEW AGENDA FOR THE ECONOMIC STUDY OF KNOWLEDGE

For centuries, the main drivers of international production have been multinational corporations (MNCs) (e.g., Braudel, 1992; Wilkins, 1970). Until recently, they have 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, 1998).

A progressive liberalization and deregulation of international trade and investment, and the diffusion of DIS 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. We argue that the combination of these three transformations has substantially increased the mobility of knowledge. First, there is a new divide in industrial organization: a transition is under way from vertically integrated "multinational corporations" (MNCs), with their focus on stand-alone, equity-controlled overseas investment projects, to "global flagship networks" (GFNs) that integrate their geographically dispersed supply, knowledge and customer bases (Ernst, forthcoming). While equity ownership is not essential, network governance is distinctively hierarchical. These networks help the flagships to sustain their competitiveness, by providing them with access to specialized suppliers at lower-cost locations who excel in quick and flexible response to the flagships' requirements.

Second, GFN have acted as a catalyst for international knowledge diffusion, providing a combination of new opportunities, pressures and incentives for local suppliers to upgrade their capabilities. Opportunities include exposure to the flagship`s management practices and technological knowledge, involving a substantial amount of tacit knowledge. Equally important are pressures and incentives for local suppliers to invest in their knowledge base and capabilities (Ernst, 2000a; Ernst and Kim, 2002a).

Third, a long-term process of developing digital information systems (DIS) has enabled the same infrastructure to accommodate manipulation and transmission of voice, video, and data. The use of DIS as a management tool has experienced important transformations (Nolan, 2000). From a machine to automate transaction processing, the focus has shifted to the extraction of value from information resources, and then further to the establishment of Internet-enabled flexible information infrastructures that can support the extraction and exchange of knowledge across firm boundaries and national borders. Compared to earlier generations of DIS, the Internet appears to provide much greater opportunities to share knowledge with a much greater number of people faster, more accurately, and in greater detail, even if they are not permanently co-located (Ernst, 2000b, 2001a, and 2001b). The most commonly used technologies today facilitate *asynchronous* interaction, such as e-mail or non-real time database sharing. But as data transfer capacity ("bandwidth") increases, this is creating new opportunities for using technologies that facilitate *synchronous* interaction such as real-time data exchange, video-conferencing, as well as remote control of manufacturing processes, product quality and inventory, maintenance and repair, and even prototyping. This has created

new opportunities for extending knowledge exchange across organizational and national boundaries, hence magnifying the first two transformations[1].

If these propositions are correct, the combined forces of globalization and DIS may have serious implications: the competitiveness of existing clusters may erode, as the mobility of knowledge becomes less constrained in space. However, new opportunities may also emerge as enhanced mobility of knowledge may contribute to an upgrading of such clusters. This describes a new agenda for the economic study of knowledge: Do GFN and DIS make knowledge spatially fluid? And how will this affect the spatial distribution of knowledge?[2]

2. FORCES DRIVING GLOBAL FLAGSHIP NETWORKS

What has driven the shift in industrial organization from "multinational corporations" (MNCs) to "global flagship networks" (GFNs)? To answer this question, we introduce a stylized model of globalization drivers, focusing on three inter-related explanatory variables: institutional change through liberalization, information and communications technologies that gave rise to DIS, and changes in competition and industrial organization.

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

[1] While the more sophisticated forms of synchronous knowledge exchange across borders are still exceptional, they illustrate nevertheless a huge potential for reorganizing the global chain of knowledge creation. Once these developments gather momentum, they will have dramatic implications for established localized clusters. But when this happens, it may be too late to start research on this topic.

[2] Policy implications are discussed in a study prepared for the U.S. Social Science Research Council (Ernst, 2002 e).

codes of conduct), and the enforcement characteristics of both. Institutions shape the allocation of resources, the rules of competition and firm behavior. Liberalization affects all aspects of institutions, but at different speed. While changes will first affect formal rules, informal constraints and enforcement mechanisms are more difficult to change. This implies that there is no homogeneous model of liberalization, but many different and often hybrid forms.

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 covers four main areas: trade, capital flows, 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 (*vertical specialization*); and it has reduced the constraints for a geographic dispersion of the value chain (*spatial mobility*).

But there are also unintended consequences: 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" (Dunning, 2000).

Paraphrasing Sassen (2002), "governments have had to reenter domains from which they had withdrawn". Both in industrialized and in developing countries, we are witnessing a renaissance of industrial, technology and regional policies, after a decade of leaving economic growth to market forces. As a result of these changes in policy, a replication of clustering effects at multiple locations may now have greater chances than before.

2.2 Information and Communication Technology: Digital Information Systems

A second important driver of GFN has been the rapid development and diffusion of cheaper and more powerful information and communication technologies (e.g., Sichel. 1997, and Flamm, 1999) that has culminated in the Internet (Naughton, 2000; Mowery and Simcoe, 2002). A combination of technological and economic developments is responsible for the transformation of DIS as a management tool from automation to information resource management, and then on to Internet-enabled cross-border knowledge management (Ernst, 2001c).

On the technology side, the move towards more open standards in DIS architecture (UNIX, Linux, and HTML) and protocols (TCP/IP) enabled firms to integrate their existing intranets and extranets[3] on the Internet, which, by reducing cost and by multiplying connectivity, dramatically extended their reach across firm boundaries and national borders. And while the transition to 3G (=third generation) communication systems is slower than predicted, greater bandwidth implies that there is now scope for experimenting with *synchronous* information and knowledge exchange. Equally important, wireless Internet-based technologies have increased the mobility of DIS.

On the economic side, vertical specialization, particularly pronounced in the electronics industry, poses increasingly complex information requirements (e.g., Chen, 2002; Macher, Mowery and Simcoe, 2002). As firms now have to deal with constantly changing, large numbers of specialized suppliers, they need flexible and adaptive information systems to support these diverse linkages. These requirements became ever

[3] An "intranet" is defined as a private network contained within an organization (a firm) that consists of many inter-linked LANs (= local-area networks). Its main purpose is to share company information and computer resources among employees. An "extranet" in turn is a private network that links the flagship via conventional telecommunications networks with preferred suppliers, customers and strategic partners.

more demanding, as flagships attempt to integrate their dispersed production, knowledge and customer bases into global and regional networks.

In addition, far-reaching changes in work organization have fundamentally increased the requirements for information management and for the exchange of knowledge (e.g., Ciborra et al, 2000). The transition from Fordist "mass production" to "mass customization" requires a capacity to constantly adapt products or services to changing customer requirements, "sensing and responding" to individual customer needs in real time (Bradley and Nolan, 1998). This necessitates dynamic, interactive information systems, and a capacity to rapidly adjust the organization of firms and corporate networks to disruptive changes in markets and technology. Third, real-time resource allocation, performance monitoring and accounting became necessary, due to the short-term pressures of the financial system (quarterly reports) and due to the shortening life cycles of products and technologies. Fourth, to cope with ever more demanding competitive requirements, firms have to continuously adapt their organization and strategy, hence the demand for flexible DIS.

The increasing use of DIS has had a dual impact: it has increased the need for globalization, while at the same time facilitating this process. This argument is based on two propositions (Ernst, 2002a). First, the cost of developing DIS 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 developing and implementing DIS, a process that can exhaust the financial means of even the largest global flagships (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, has become the main vehicle for international market share expansion. Of critical importance has been the enabling role played by DIS. These systems substantially increase the mobility, i.e. *dispersion* of firm-specific resources and capabilities across national boundaries. They also provide greater scope for cross-border linkages, i.e. the *integration* of those dispersed resources and capabilities into 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.

There are widespread expectations that the Internet, the latest incarnation of DIS, may further accelerate these transformations (e.g., Department of Commerce, 2000; Litan and Rivlin, 2001). By transmitting information in digital format instantly, and at much lower cost than earlier technology generations (like electronic data interchange, EDI), the Internet substantially broadens the scope for collaboration across organizational and national boundaries. A new generation of networking software provides flexible infrastructures that, computer scientists claim, "support not only information exchange, but also knowledge sharing, creation and utilization." (Jørgensen and Krogstie,

2000).The key is the open-ended structure of the Internet, which allows extra networks to be added at any point, creating almost unlimited opportunities for outsourcing and the diffusion of knowledge.

Surprisingly, the impact of the Internet on business organization is still a largely neglected research topic. Until recently, important contributions to information management neglect and hardly mention the Internet and the world-wide web[4]. Very little research exists on how the Internet reshapes business strategy and organization, and how this affects industry structure[5]. Even less research exists on how the Internet transforms international aspects of business networks[6].

Following Brynjolfsson and Hitt (2000), we argue that the impact of DIS, such as the Internet, on economic performance is mediated by a combination of intangible inputs as well as intangible outputs that act as powerful catalysts for organizational innovation. Intangible inputs include, for instance, the development of new software and databases; the adjustment of existing business processes; and the recruitment of specialized human resources and their continuous upgrading. Of equal importance are intangible outputs that would not exist without DIS, like speed of delivery, the flexibility of response to abrupt changes in demand and technology, and organizational innovations, like "just-in-time" (JIT), "mass customization", the built-to-order (BTO) production model, integrated supply chain management (SCM), and customer-relations management (CRM).

[4] An important book like Strategic Planning for Information Systems (Ward and Griffiths, 1996) mentions the Internet just once, but then as a synonym for the information super highway. And the edited volume Global Information Technology and Systems Management (Palvia et al, 1996) mentions the Internet briefly three times on its more than 600 pages, but fails to provide an explicit analysis.

[5] Noteworthy exceptions are Nolan (2000), Hagstrøm (2000), Brynjolfsson and Hitt (2000), Evans and Wurster (2000), and Litan and Rivlin (2001).

After a while, these induced organizational changes may lead to productivity growth, by reducing the cost of coordination, communications and information processing. Most importantly, these organizational changes may enable firms "to increase output quality in the form of new products or in improvements in intangible aspects of existing products like convenience, timeliness, quality and variety." (Brynjolfson and Hitt, 2000, p.4). In short, we are talking about a complex process that involves a set of inter-related ("systemic") changes (Milgrom and Roberts, 1990): by combining DIS with changes in work practices, strategies, and products and services, a firm transforms its organization as well as its relations with suppliers, partners and customers.

Once we adapt such a framework, it becomes clear that firms that participate in GFN can reap substantial benefits from using DIS as a management tool. There is ample scope for cost reduction across all stages of the production process, both for the flagship company and local suppliers. Procurement costs can be reduced by means of expanded markets and increased competition through Internet-enabled online procurement systems. Another cost-reducing option is to shift sales and information dissemination to lower-cost on-line channels.

The transition to Internet-based information systems can drastically accelerate speed-to-market by reducing the time it takes to transmit, receive, and process routine business communications such as purchase orders, invoices, and shipping notifications. There is much greater scope for knowledge management: documents and technical drawings can be exchanged in real time, legally recognized signatures can be

[6] On the impact of the Internet on GFN, see Chen (2002), Macher, Mowery and Simcoe (2002), Luethje (2002), Ernst and Kim, 2002b, Ernst, Fagerberg and Hildrum (2002), and Ernst (2000b, 2001a, 2001b, 2002e). On Internet-enabled knowledge exchange, see Lerner and Tirole (2000), and Weber (2001).

authenticated, browsers can be used to access the information systems of suppliers and customers, and transactions can be completed much more quickly.

A further advantage can be found in the low cost of expanding an Internet-based information system. While establishing a network backbone requires large up-front fixed investment costs (purchasing equipment, laying new cable, training), the cost of adding an additional user to the network is negligible. The value of the network thus increases with the number of participants ("network externalities"). In addition, the Internet and related organizational innovations provide effective mechanisms for constructing flexible infrastructures that can link together and coordinate knowledge exchange between distant locations **(**Hagstrøm, 2000; Pedersen et al, 1999; Antonelli, 1992).

This has important implications for organizational choices and locational strategies of firms. In essence, Internet-enabled DIS foster 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 networks* that enable a global network flagship to respond quickly to changing circumstances, even if much of its value chain has been dispersed. DIS, especially the open-ended structure of the Internet, substantially broadens the scope for vertical specialization. It allows OEMs to shift from *partial* outsourcing, covering the nuts and bolts of manufacturing, to *systemic* outsourcing that includes knowledge-intensive support services.

2.3 Competition and Industrial Organization

Both liberalization and DIS have 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, 2002b**).** 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 vertical specialization: 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.

The electronics industry 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). Until the early 1980s, IBM personified "vertical integration": almost all ingredients necessary to design, produce and commercialize computers remained internal to the firm. This was true for semiconductors, hardware, operating systems, application software, and sales & distribution.Above all, "IBM was famous (some would say notorious) for the power of its sales force… (and distribution system)" (Sobel, 1986: 37).

Since the mid-eighties, vertical specialization became the industry's defining characteristic. Most activities that characterized a computer company were now being farmed out to multiple layers of specialized suppliers, giving rise to rapid market segmentation and an ever finer specialization within each of the above five main value chain stages An important initial 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). The use of DIS, and more recently of the Internet, has accelerated this process. For the manufacturing of electronics hardware, it facilitated the modularization and geographic dispersion; this was mirrored

during the nineties by similar developments for software design and engineering. The use of DIS has provided new means to improve global supply chain management and speed-to-market. It has also created new forms of interaction between design and manufacturing, and for the exchange of proprietary knowledge. The semiconductor industry provides examples for both developments (e.g., Macher, Mowery and Simcoe, 2002): vertical specialization gives rise to the separation of design ("fabless design") and manufacturing ("silicon foundry"). This creates very demanding requirements for knowledge exchange between multiple actors at distant locations, say a design house in Silicon Valley and a silicon foundry in Taiwan's Hsinchuh Science Park. Vertical separation of design and production of semiconductor devices in turn has created a vibrant trade in "intellectual property rights" among specialized design firms that create, license and trade "design modules" for use in integrated circuits.

In short, DIS and vertical specialization appear to have reinforced each other. Of critical importance is that DIS facilitates the exchange of information and knowledge across firm boundaries and national borders that becomes necessary as a result of progressive vertical specialization. This has given rise to the co-existence of complex, globally organized product- specific value chains (e.g., for microprocessors, memories, board assembly, PCs, networking equipment, operating systems, applications software, and sales & distribution). In each of these value chains consists GFNs compete with each other, but may also cooperate (Ernst, 2002a). The number of such networks, and the intensity of competition varies across sectors, reflecting their different stage of development and their idiosyncratic industry structures.

3. THE FLAGSHIP NETWORK MODEL

3.1. Theoretical Foundations

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, 2000; Ernst and Ozawa, 2002).

A focus on international knowledge diffusion through an extension of firm organization across national boundaries distinguishes our concept of GFN 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). 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 through access to economic rents (e.g., Gereffi and Kaplinsky, 2001; Henderson, Dicken et al,

2001)[7]. Strong complementarities also exist with research on computer-based flexible information infrastructures that frequently uses the terms "extended enterprise" or "virtual enterprise", where the first stands for more durable network arrangements, while the latter for very short-term ones (e.g., Pedersen, 1999; Jørgensen and Krogstie, 2000; and various issues of the electronic journal virtual-organization.net).

As for the dynamics of network evolution, our approach complements 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). The latter approach however 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. This implies that the analysis of the determinants of institutional form must move beyond a 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. Like hierarchies, GFN 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 (Ernst, 1997b; Borrus, Ernst, Haggard, 2000: chapter1) .

[7] Unfortunately, no one has as yet come up with a convincing and robust set of indicators. How should academic researchers, even with the best possible funding, be able to measure distribution of rents across borders, when global flagships like Enron and telecom majors excel in the development of sophisticated off-balance-sheet financial techniques and transfer pricing?

A focus on knowledge diffusion as a major source of industry dynamics 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). This approach also faces less unmanageable data problems.

3.2. Network Characteristics

GFNs differ from MNCs in three important ways that need to be taken into account in the study of industry and innovation (Ernst, forthcoming). First, these networks cover both intra-firm and inter-firm transactions and forms of coordination: a GFN links together the flagship´s own subsidiaries, affiliates and joint ventures with its subcontractors, suppliers, service providers, as well as partners in strategic alliances. 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 can improve the flagship's access to resources and capabilities, and where they are needed to facilitate the penetration of important growth markets.

Second, GFNs differ from MNCs in that a great variety of governance structures is possible. These networks range from loose linkages that are formed to implement a particular project and that are dissolved after the project is finished, so-called "virtual enterprises" (e.g., Pedersen et al, 1999: 16)), to highly formalized networks, "extended enterprises", with clearly defined rules, common business processes and shared information infrastructures. What matters is that formalized networks do not require

common ownership: these arrangements may, or may not involve control of equity stakes.

Third, "vertical specialization" ("outsourcing" in business parlance) is the main driver of these networks (Ernst, 2002b). GFNs help flagships to gain quick access to skills and capabilities at lower-cost overseas locations that complement the flagships' core competencies. Transaction cost savings matter. Yet, the real benefits result from the dissemination, exchange and outsourcing of knowledge and complementary capabilities. Increasingly, the focus of outsourcing is shifting from assembly-type manufacturing to knowledge-intensive support services, like supply chain management, engineering services, and new product introduction. Outsourcing may also include design and product development. This indicates that GFNs also differ from traditional forms of subcontracting: much denser interaction between design and production and other stages of the value chain require substantially more intense exchange of information and knowledge. Network flagships increasingly rely on the skills and knowledge of specialized suppliers to enhance their core competencies.

Two distinctive characteristics of GFN that are enhanced by DIS shape the scope for international knowledge diffusion: a rapid yet concentrated dispersion of value chain activities, and, simultaneously, their integration into hierarchical networks.

3.3. Concentrated Dispersion

GFNs typically combine a rapid geographic dispersion with spatial concentration on a growing but still limited number of specialized clusters. To simplify, we distinguish two types of clusters (Ernst, 2002e): "centers of excellence" that combine unique resources, such as R&D and precision mechanical engineering, and "cost and time

reduction centers" that thrive on the timely provision of lower-cost services[8]. Different clusters face different constraints to knowledge diffusion, depending on their specialization, and on the product composition of GFN. The dispersion of clusters differs across the value chain: it increases, the closer one gets to the final product, while dispersion remains concentrated especially for high-precision and design-intensive components.

Let us look at some indicators in the electronics industry, a pace setter of the flagship network model (Ernst, 2002b). 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 an important role as intermediate supply chain coordinators. The same is true for 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 "centers of excellence" in 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

[8] "Cost & time reduction centers" include the usual suspects in Asia (Korea, Taiwan, China, Malaysia, Thailand, and now also India for software engineering and web services), but also exist in once peripheral locations in Europe (e.g., Ireland, Central and Eastern Europe and Russia), in Brazil, and Mexico in Latin

of Intel, two American suppliers, and one recent entrant from Taiwan (Via Technologies)[9].

In other words, geography continues to matter, even when DIS and high-velocity transportation are used. Rapid cross-border dispersion thus coexists with agglomeration. GFN extends national clusters across national borders. This implies three things: First, some stages of the value chain are internationally dispersed, while others remain concentrated. Second, the internationally dispersed activities typically congregate in a limited number of overseas clusters. And third, agglomeration economies continue to matter, hence the path-dependent nature of development trajectories for individual specialized clusters. In short, the new mobility of knowledge remains constrained in space: while cross-border exchange of knowledge has penetrated new geographic areas, it remains limited to a finite number of specialized clusters.

3.4. Integration: Hierarchical Networks

A GFN integrates diverse network participants who differ in their access to and in their position within such networks, and hence face very different opportunities and challenges. This implies that those networks 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, 1993).GFNs typically consist of various hierarchical layers that range from network flagships, dominating such networks, down to a variety of usually smaller, local specialized network suppliers.

America, in some Caribbean locations (like Costa Rica), and in a few spots elsewhere in the socalled RoW (= rest of the world).

[9] Ernst, 2002e provides a systematic analysis of the diversity of cluster dispersion, using examples from the semiconductor and the hard drive industries.

The flagship is at the heart of the 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, 84)[10]. The 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.

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 (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.

3.5. Taxonomy of Flagships: OEM vs. CM

[10] 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".

To move this model a bit closer to reality, we distinguish two types of global flagships: i) Original equipment manufacturers (OEM) that derive their market power from selling global brands, regardless of whether design and production is done in-house or outsourced; and ii) "contract manufacturers" (CM) that establish their own GFN to provide integrated manufacturing and global supply chain services (often including design) to the OEM. Cisco provides an interesting example of a global brand leader that has pushed vertical integration to the extreme. Cisco outsources much of its manufacturing and support services, including important elements of R&D (Bunnell, 2000). Cisco's GFN connects the flagship to 32 manufacturing plants worldwide. These first-tier international suppliers are formally independent, but they go through a lengthy process of certification to ensure that they meet Cisco´s demanding requirements.

Contract manufacturers (CM) have rapidly increased in importance since the mid-1990s. From 1996 to 2000, capital expenditures grew 11-fold (50% CAGR), and revenues increased by almost 400% (81% CAGR). The percentage of total electronics production being done by contract manufacturers is estimated to be around 22% (courtesy of Technology Forecasters, Inc., April 15, 2002). During the 1990s, global brand leaders (OEM) have put up for sale a growing number of their overseas facilities, and in some cases whole chunks of their global production networks. CM have aggressively seized this opportunity: through acquisition and capacity expansion they have developed, within a few years, their own GFNs that now complement the networks established by the global brand leaders (OEM). For the three leading CM players, these global networks are now larger than those developed by the leading OEM: Solectron has

factories in 70 countries, Flextronics has 62 plants worldwide, and the recently merged Sanmina/SCI has 100 factories around the world (Ernst, 2002d).

4. PREREQUISITES FOR KNOWLEDGE DIFFUSION

Under what conditions can the combined forces of DIS and GFN gradually reduce constraints to cross-border knowledge diffusion? And what needs to be done to strengthen the position of local suppliers? We first distinguish "local suppliers" in terms of their network position and capabilities. We then highlight opportunities: GFNs 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. Finally, we introduce the missing link in our argument: local suppliers are exposed to a combination of pressures and incentives from network flagships to upgrade their capabilities (Ernst, 2002e).

4.1. Local Suppliers

Local suppliers differ substantially in their capacity to benefit from the new mobility of knowledge. Greatly simplifying, we distinguish two types of local suppliers: higher-tier "lead suppliers" and lower-tier suppliers. "Higher-tier" suppliers, like for instance Taiwan´s Acer group (Ernst, 2000a), play an intermediary role between global flagships and local suppliers. They deal directly with global flagships (both OEM and contract manufacturers); they possess valuable proprietary assets (including technology); and they have sufficient resources to upgrade their absorptive capacities. Some of these higher-tier suppliers have even developed their own mini-GFN (Chen, 2002). With the

exception of hard-core R&D and strategic marketing that remain under the control of the OEM, the lead supplier must be able to shoulder all steps in the value chain. It must even take on the coordination functions necessary for global supply chain management**.**

"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.

4.2. Opportunities

GFNs cannot work without some sharing of knowledge. This is true even if the outsourced activities do not involve formal R&D. First, flagships need to transfer technical and managerial knowledge to the local suppliers. This is necessary to upgrade the suppliers` capabilities, so that they can meet the technical specifications of the flagships. It has been argued that flagship- dominated business networks can be a boon rather than a bane for knowledge transfer (Rugman and D`Cruz, 2000: p.58). Their asymmetric distribution of resources, power and decision-making can facilitate trust and credible commitments, enhancing stability, coherence and organizational learning. This, it is argued, reduces the risks that flagships encounter when sharing technology[11] .

[11] The authors acknowledge that this knowledge-sharing is limited to a select group of key suppliers, customers and strategic competitors who collaborate in selective alliances.

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, 2002 b). 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 GFN are plugged into the flagship´s design process on a regular basis.

DIS, and especially the Internet generate new opportunities for improving communication routines, blending old forms of communication (e.g., face-to-face) with new forms (e.g. on-line). This facilitates the integration of local suppliers into the flagship's design process. Of course, the Internet is no substitute for traditional modes of communication. However, it facilitates knowledge exchange without co-location, *provided* that the agents involved know each other through earlier face-to-face informal conversations. Once this basis exists, the Internet provides previously unavailable opportunities for knowledge exchange among distant locations.

In short, GFNs 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., Wong, 1991; Bell and Pavitt, 1993; Saxenian, 2002; Ernst and Lundvall, 2000; 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.

4.3. Pressures and Incentives

Diffusion is completed only when transferred knowledge is internalized and translated into specific capabilities of local suppliers (e.g., Kim, 1997, and Ernst, Ganiatsos, Mytelka, 1998). Important constraints exist that can derail this process (Lam, 1998; Ernst, Fagerberg and Hildrum, 2002).Of critical importance is the absorptive capacity (Cohen and Levintahl, 1990) of the local suppliers, i.e. their resources, capabilities and motivations (Ernst and Kim, 2002a). The absorptive capacity is shaped by pressures imposed by network flagships, and by the existing incentives. The flagships can exert considerable pressure on local suppliers, by threatening to drop them from the networks whenever they fail to provide the required services at low price and world-class quality.

Under certain conditions, these pressures can catalyze local suppliers into concerted upgrading efforts. In response to intensifying global competition, the flagships` outsourcing requirements have become more demanding. Typically, suppliers are selected by 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 GFN, local suppliers must constantly upgrade their absorptive capacity by investing in their skills and knowledge base. Adequate incentives are required to sustain these investments. This requires that the flagship reduces the perceived risk of such investments through a reasonably long-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.

There is a clear need for government policies and support institutions that enable local suppliers to exploit the opportunities and pressures that result from network participation, and that induce flagships to provide the above incentives. Realistically, the focus of such policies has to be on the promotion of local suppliers (as illustrated for instance by countries like Denmark, Taiwan, and Singapore). Most governments (with the exception of quasi-continental economies like China, India and Brazil) are simply to weak to influence flagship behavior. There is however room for policies to exploit existing differences in flagship behavior. It is now well established that nationality of ownership of network flagships, home country institutions and product mix (specialization) explain why GFN differ in their governance structures, and hence in the

incentives they provide for capability upgrading investment by local suppliers (Ernst and Ravenhill, 1999; Borrus, Ernst and Haggard, 2000, chapter1).

CONCLUSIONS

In short, the increasing use of DIS and the spread of flagship-dominated global business networks has increased the mobility of knowledge. GFNs may provide new opportunities, pressures and incentives for local suppliers to upgrade their capabilities, *provided* appropriate policies and support institutions are in place.

Developing a broad domestic knowledge base and specialized skills and capabilities cannot be left to market forces alone. Markets are notoriously weak in generating knowledge and capabilities, as both are subject to "externalities": investments are typically characterized by a gap between private and social rates of return (Arrow, 1962). Reducing this gap requires corrective policy interventions that provide incentives, as well as the necessary infrastructure, support services and human resources.

While the neo-classical concept of "market failure" provides a rationale for policy intervention, it is of limited value for designing its contents (Lipsey, 2001). A fundamental weakness of this concept is its general equilibrium assumption: defined as a deviation from the market clearing equilibrium under conditions of perfect competition, the remedy is to return to a theoretically achievable static optimum. It is now well accepted that perfect competition hardly ever reigns in markets that characterize modern industry. It is thus misleading to think of market failure as something that can, or should, be 'remedied' so that the economy can be brought back to a desired static optimum.

In any case, this concept is patently inappropriate for defining the agenda for public policy response to the new mobility of knowledge. DIS and GFN both reduce the friction of time and space to knowledge exchange. This, in turn, accelerates the pace of change in markets and technology, increasing uncertainty and the volatility of market structures, industrial organization and firm behavior (e.g., Ernst, 2002b). Equally important, almost all aspects of knowledge creation and learning are characterized by market failure: this is true for information and codified knowledge, and even more so for tacit knowledge. Information/codified knowledge is difficult to trade in a market: whenever information is imperfect, "externalities" diffuse and markets incomplete, which is invariably the case with technical change, free markets cannot in principle meet the strict requirements of optimal resource allocation (Stiglitz, 1998).

The design of public policy thus must move beyond the "market failure" rationale. The real question is no longer whether national policies and institutions can make a difference. Instead, it is what kind of policies and institutions will prove most conducive for unlocking new sources of economic growth in the new "Global Network Economy".

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