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Do Global Production Networks and Digital Information Systems Make Knowledge Spatially Fluid?

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Do Global Production Networks and Digital Information Systems make Knowledge Spatially Fluid?

by

Dieter Ernst∗, Jan Fagerberg∗∗ and Jarle Hildrum∗∗∗

Abstract

Digital Information Systems (DIS) - electronic systems that integrate software and hardware to enable communication and collaborative work - are increasingly used to manage global production networks (GPN). There is a widespread belief that these developments create new opportunities for organizational learning and knowledge exchange across organizational and national boundaries, hence making knowledge more spatially fluid. This would have important implications for the location of knowledge intensive activities worldwide and the global distribution of income. The paper assesses these expectations. We conclude that, despite DIS, the fluidity 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.

1. Introduction

Diffusion of information has traditionally been a time-consuming and costly activity. However, during the last century a series of radical innovations substantially reduced the time and costs of diffusing information. Yet as late as in the 1980s electronic communication was carried over copper wires that carried less than one page of information per second. Today optical fiber cables, as thin as a human hair can transmit the equivalent of over 90000 volumes of an encyclopedia in one second. Similarly, in just one year (from 1998 to 1999) the number of web users worldwide increased by 55 percent and the number of new web address registrations rose by 137 percent (US Department of Commerce 2000). There are no doubts that these changes have radically enhanced the capacity of participants in geographically dispersed networks to access and communicate information fast and at very low costs.

Digital Information Systems (DIS) - electronic systems that integrate software and hardware to enable communication and collaborative work (Chandler and Cortada 2000)- are currently undergoing a technological revolution. Whereas the most commonly used technologies today facilitate *asynchronous* interaction, such as e-mail or non-real time database sharing, rapid increases in data transfer capacity (bandwidth) are currently creating new opportunities for using technologies that facilitate *synchronous* interaction such as real-time data exchange and video-conferencing. There is a widespread belief that these developments create new opportunities for organizational learning and knowledge exchange across organizational and national boundaries, hence making knowledge more spatially fluid (David and Foray 1995; US Department of Commerce 2000).

If these expectations turn out to reflect reality this may have important implications for the location of knowledge intensive activities worldwide and the global distribution of income. As the mobility of knowledge becomes less constrained in space, the competitiveness of existing local knowledge-based clusters may erode with possible negative consequences for income and employment in regions hosting such clusters. On the other hand, there is evidence that newly emerging clusters in low-income regions may now find it easier to upgrade technologically (Ernst 2000, 2002b). But this does not necessarily imply that the spread of DIS will automatically increase the convergence in the global economy. It is not the first time that economists have predicted that some global force will more or less automatically lead to convergence. In fact, following the advent of the neoclassical theory of economic growth (Solow 1956), this was the standard view of economists for a long time (Fagerberg 1994). Today these predictions, and the associated theories, are largely discredited (Fagerberg and Verspagen 2002, Gertler, 2001). There are therefore reasons for being cautious when assessing the consequences of the diffusion of DIS for the global economy.

The purpose of this paper to contribute to a discussion of what these consequences may be, and what new opportunities and challenges arise for actors at different levels in this process[1]. There are several aspects that need closer scrutiny. First the role of globalization in this context: what new ways of doing business across regional or national borders arise, and to what extent are these related to DIS? We deal with this issue in section two of this paper. It is our view that what characterizes the present phase of globalization is the growing dispersion of production factors across borders, and their integration into global production networks (GPNs[2]), coordinated and exploited by leading global corporations (or network "flagships"). There is no doubt that DIS plays an important role in the growth and coordination of such networks and is likely to do so to an even greater extent in the future. But this does not necessarily imply that knowledge flows are becoming universally accessible. On the contrary recent research on GPN indicates that the fluidity 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. It is worthwhile remembering at this point that many authors argue that one of the main reasons why globalization does not lead to convergence has to do with the "tacit" or "sticky" character of much knowledge, knowledge that either has not or

[1] Implications for capability formation in developing countries are addressed in a related paper (Ernst and Kim, 2002)

[2] The concept of a *global production network* (GPN) captures the spread of the value chain across firm boundaries and national borders. It may, or may not, involve ownership of equity stakes. For a more detailed discussion, see Ernst 1997a,b, 1998, 2002b. For empirical case studies see Borrus, Ernst and Haggard (eds.) 2000.

cannot be represented by a set of codes[3] and for which DIS arguably may be of little relevance. Hence it is necessary to consider carefully the character of knowledge in question before drawing conclusions on the potential for knowledge diffusion through DIS. This is the topic to be considered in section three of this paper. We argue that is imperative not to confuse knowledge with information (or data): knowledge is subjective in nature and closely linked to individual or group holding it. This also means that the prospects for communicating knowledge cannot be assessed independently of the capabilities of those taking part in the communication process.

2. Global Production Networks

A progressive liberalization and deregulation of international trade and investment and the rapid development of digital information systems have fundamentally changed the global competitive dynamics. First, 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*). Second, there has been a compression of speed-to-market through reduced product development and product life cycles (e.g., Flaherty 1986, Stalk and Hout 1990;

[3] By codification we mean the degree to which knowledge can be articulated and represented with a set of developed codes.

Fine 1998): 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. Third, 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 1985; Chandler 1977, Chandler and Hikino 1990) of "multinational corporations" to global production networks (GPNs) coordinated and exploited by leading global corporations (network "flagships", Ernst 2002b).

Until recently, these fundamental changes in the organization of international production were largely neglected in the literature, both in research on knowledge spillovers 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.[4] A GPN[5] encompasses both intra-firm and inter-firm linkages

[4] See, for instance, Bartlett and Ghoshal 1989; UNCTAD 1993; OECD 1992; Cantwell 1995; Ernst 1994 and 1997b; Rugman and D´Cruz 2000; Borrus, Ernst and Haggard 2000.

and integrates a diversity of network participants who differ in their access to and in their position within such networks. 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.[6]

Geographical dispersion across the value chain

GPNs typically combine geographic dispersion with spatial concentration in a limited number of specialized clusters. To simplify, we distinguish two types of such clusters: "centers of excellence" that combine unique resources, such as R&D and precision mechanical engineering (e.g. Dunning 2000), and "cost and time reduction centers" (Ernst 2002b) that thrive on the timely provision of lower-

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[5] For details, see e.g., Ernst 1994, 1997a, 1997b, 1998, 2002a, 2002b. For empirical case studies on diverse GPN, see Ernst and Ravenhill 1999, and Borrus, Ernst and Haggard (eds.) 2000.

[6] GPNs 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. GPNs 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.

cost services[7]. This combination of spatial dispersion and concentration implies two things: First, that some stages of the value chain are internationally dispersed, while others remain concentrated. The degree of dispersion differs across the value chain: it increases, the closer one gets to the final product. And second, the internationally dispersed activities typically congregate in a limited number of overseas clusters. This clearly indicates that agglomeration economies continue to matter, hence the path-dependent nature of development trajectories for individual specialized clusters.

To exemplify these trends, let us look at the electronics industry, a pace setter of GPN (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 a major role as intermediate supply chain coordinators. The same is true for lower-end printed circuit boards. Concentration increases, however, 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

[7] 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 Carribbean locations (like Costa Rica), and a few spots elsewhere in the socalled RoW (= rest of the world).

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.

Coordination of GPNs: The role of global "flagships"

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). 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)[8]. The flagship derives its strength from its control over critical resources and capabilities that facilitate innovation (e.g., Lazonick 2000), and from its capacity to coordinate transactions and knowledge exchange between the different network nodes.

We distinguish between 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"[9]: 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 enables "brand leaders" to combine cost reduction, product differentiation and time-to-market.

"Contract manufacturers" have rapidly increased in importance since the mid-1990s[10]. This represents an acceleration of a long-standing trend towards vertical specialization in the electronics industry (Macher and Mowery 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. 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,

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[8] 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".

[9] Other examples can be found in Ernst 1997b, Ernst and Ravenhill 1999, and in Borrus, Ernst, and Haggard 2000.

[10] With an average annual growth of more than 25% between 1995 and 2000, the so-called *electronics manufacturing services* (EMS) market has been one of the fastest growing electronics sectors, expanding twice as quickly as the total electronics industry.

most flexible solutions to optimize their existing supply chains." (Solectron 2000: 1).

Increasing vertical specialization is the fundamental driver of this flagship model of industrial organization (Ernst 2002a). 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 (Macher and Mowery 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 need for knowledge-sharing in GPNs

It goes without saying that such outsourcing cannot work without some sharing 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 2002a). 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.

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 exchange of knowledge. Hence, global production networks might be expected to enhance the diffusion of knowledge across firm boundaries and national borders and, arguably, improve the opportunities for knowledge sharing and interactive learning without co-location. However, to assess the relationships between the spread of GPN and knowledge diffusion, it is also necessary to have an understanding of the conditions under which knowledge is created and diffused. This is the topic to which we now turn.

3. Knowledge – mobile or "sticky"?

The traditional approach to knowledge in economics has been to regard it as a so-called "public" good. Being "non-excludable" and "non-depletable" knowledge can be used by everyone, for free and without limitations. This implies that knowledge should be extremely "fluid", that it flows from agent to agent or place-to-place at very high speed, quite the opposite of the sticky knowledge commonly observed. Another long-lasting strand in economics, in the tradition of Alfred Marshall, identifies knowledge creation with learning by doing, using, interaction etc. in the production of a good or service. To the extent that such new knowledge becomes embedded in the local labor force and labor is relatively immobile, this may lead to a clustering of firms around a common pool of skilled labor. This offers a possible explanation of the sticky character of some forms of knowledge but does not take into account that knowledge is not only about local learning but also about R&D.

A fundamental problem with both approaches is that the terms data, information and knowledge are largely treated as synonyms. This is now being challenged by a growing literature arguing that a clear distinction should be made between these terms (Ancori et al. 2000, Cowan et al. 2000). It is pointed out that while data refer to elementary units in communication and message transmission, information is the dynamic process of structuring and economizing on data. Knowledge, on the other hand, is referred to as “what enables people to interpret and give meaning to information” (Boisot 1995 and von Krogh et al. 1994). Furthermore, it is argued that knowledge is subjective in nature and closely linked to the individual or group of individuals generating it (David and Foray 1995, von Krogh et al. 1994, Baumard 1999 and Antonelli 1999).

Tacit versus codified knowledge

There are two reasons why knowledge may remain confined to certain geographical contexts. Firstly, the company or individual holding the knowledge may be unwilling to share it because competitive conditions or intra-organizational cultures favor secrecy (Granstrand 1999, Hansen 1999). Secondly, even if there are no secrecy-related barriers, the knowledge in question may still remain confined to context because its inherent complexity makes it hard to share among the interacting parties. One important reason why some knowledge is found difficult to share between people and organizations is because it has not been codified (or only codified to a limited extent). Knowledge that for various reasons cannot be represented by codes is often classified as "tacit knowledge", a term introduced by Michael Polanyi (1958, 1966). When pointing to the fact that ' we can know more than we can tell'' Polanyi referred to the existence of "a tacit dimension of human knowledge".[11] The reason, Polanyi argues, why we are not able to express all that we know, is that our awareness encompasses a lot more than we are consciously aware of. For instance, we can recognize a face among thousands without being able to articulate exactly how we recognized it (and hence teaching the same skill to others). There are many other examples commonly used in the literature such as, for instance, swimming or biking. Arguably, it is not possible to learn to swim or bike from reading a book. The consequence is that such skills can only by learnt by taking part in the activity in which the skill is exercised.

[11] However, even though Polanyi's writings have had considerable impact on economic theorising, he did not write explicitly about the significance of tacit knowledge for economics. It was Nelson and Winter

How important are these “tacit” aspects of knowledge creation for knowledge transfer and location of knowledge intensive activities? This is a matter of considerable controversy. Some authors hold that much of what is commonly regarded “tacit knowledge” is not really tacit in the sense that it is impossible to codify (David and Foray 1995, Cowan et al. 2000). It may simply be tacit in practice since no codes have yet been developed for its articulation (although this may be possible). Even in cases in which codes have been developed knowledge may appear as tacit to actors who for some reason do not have access to the codes (in the relevant context). Based on these arguments, one might conjecture that further efforts to codify and diffuse the codes widely might ease many of the problems related to the “stickiness” of knowledge and – arguably - that DIS would have a considerable positive impact on this endeavor (Steinmueller 2000).

There is no doubt that we have witnessed during the last hundred years is a massive increase in codified knowledge (and/or information).[12] Still it is possible

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1982 that led the way in bringing the role of tacit knowledge to the attention of economists.

[12] The terms codified knowledge and information are often not sharply separated in economics literature. In Nonaka and Takeuchi 1995 (p.6) codified knowledge is described as something formal and systematic which is possible to express in words and numbers, and easy to communicate and share in the form of hard data, scientific formulae and codified procedures, i.e., not very different from information. Cowan et al. 2000 emphasise that what characterises codified knowledge is that it *can* be stored and communicated by way of information. However, according to these authors, the fact that codes have been developed does not necessarily mean that the knowledge is *universally* easy to communicate and share. A strand of knowledge may appear tacit to some, even though codes have been developed, and explicit to others depending on the agent’s ability to interpret the codes.

to argue that "tacit" knowledge continues to be important. One reason for this, which was pointed out already by Polanyi, is that the knowledge of how to create and acquire new knowledge often is of a tacit character. For instance, studies have shown the importance of having experienced team leaders in knowledge intensive research projects as these often have unique, tacit knowledge of how to initialize and use information sources to the team's advantage (Hansen 1999).

Individual versus collective knowledge

Another reason why it is frequently difficult to spread knowledge from one location to another is that the strand of knowledge to be shared may be of a complex, collective nature reflected by the coordinated actions of large groups of people (Nelson and Winter 1982, Antonelli 2001, Fahy and Smithee 1999). Few individuals, if any, have sufficient breadth and depth of knowledge to grasp the overall performance of an organization. Rather, it consists of the shared knowledge of the employees. Thus, the notion that knowledge can reside between individuals, and not only within these, has been discussed with increasing frequency in economics and management literature in recent years (Lazonick 2000, von Krogh et al. 1994, Nelson and Winter 1982).

Contrary to Polanyi, who writes almost exclusively on individual knowledge, the analysis of Nelson and Winter (1982) focuses on organizational knowledge. Named 'organizational memory', this collective form of knowledge shapes organizational performance. This type of knowledge is embedded in specialized routines that skilled employees perform in a coordinated manner.

Lam (2000) defines “collective knowledge” as the ways in which knowledge is distributed and shared among the members of the organization. It is the accumulated knowledge of the organization stored in its rules, procedures and shared norms that guide the behavior, problem solving activities and pattern of interaction among its members, she claims. Such collective knowledge, it is argued, may have a “tacit” character. For example, Nonaka and Takeuchi (1995) define the organization as an arena in which socialization (through intense teamwork and combination of experiences) makes possible the creation of “collective tacit knowledge” such as shared mental models and technical skills that are hard to imitate for outsiders.[13]

Hence, knowledge, as a topic for economic analysis, must be sharply distinguished from information. While information is seen as merely a representation of knowledge in the shape of general sets of codes, knowledge is regarded subjective in nature and closely linked to the individual or group of individuals generating it. This means that the capabilities of those who hold knowledge, and the contexts in which these capabilities are created and reproduced, emerge as important variables in the analysis of the possible effects of DIS on knowledge diffusion. To what extent does the introduction of DIS change the role of such capabilities (by for instance introducing new or changing existing requirements for successful knowledge diffusion)? Similarly, to what extent do DIS allow for the creation of new contexts that support the

[13] To some extent there is a parallel here to the so-called “ resource based view of the firm” pioneered in the writings of Edith Penrose 1959 in which knowledge is acknowledged as one of several key resources

development and growth of such capabilities? We discuss this in more detail in the following.

4. Mobility of knowledge and Digital Information Systems

As emphasized in the introductory section, recent developments in DIS are often expected to accelerate global diffusion of knowledge. By increasing the quality and lowering the costs of interaction between agents at different locations, DIS are claimed to have created entirely new opportunities for sharing knowledge across organizational and national boundaries. These new opportunities are commonly seen as related to the recently enhanced speed and reach of information flows (enabled by the Internet) and the increased scope for diffusing rich information electronically enabled by a new generation of *groupware* tools.

There is no doubt about the fact that these changes have radically enhanced the capacity of GPN participants to access and communicate information fast, and at very low costs. Thus, if one treats the terms knowledge and information as synonyms, new DIS will undoubtedly appear to impose truly revolutionary effects on the mobility of knowledge within such networks. But it is important to note that, despite the radical changes in terms the of speed and scope of the Internet, DIS are not tools for diffusing knowledge as such, but for distributing bits of data electronically that reach people as information. Hence it is not at all obvious that the effects for knowledge diffusion are the same as for information. As emphasized above, information flows are not the only necessary

making up the competitive advantage of the company.

inputs to knowledge diffusion within a GPN. For knowledge to be created and shared between the nodes it is equally important that the network participants are able absorb the information that they receive, and internalize the knowledge it represents. Keeping the distinction between accessing and absorbing information in mind, we will discuss how DIS impact on knowledge diffusion within GPN under two separate headings. Firstly, we investigate how DIS influence *communication* of information between network participants and secondly, we discuss how DIS impact on the capacity of network participants to *absorb* the information that is being exchanged.

Channels of communication

While personal contact is characterized by parallel use of *sensory* communication channels, impersonal communication deploys *artificial* communication channels such as an optical fiber cable. Traditionally the use of sensory channels has permitted transmission of more and richer information than artificial channels. One reason for this is that sensory channels are normally used in combination. This means that we are simultaneously deploying several senses in communicating, such as touch, sight and hearing, whereas artificial modes of communication, such as a phone conversation, a letter or an email, have normally involved the deployment of one sense only (Boisot 1995). Arguably, if transmission of rich information requires multi-channel communication and personal contact, there may be serious constraints to rapid diffusion of knowledge in GPN through an exclusive reliance on the artificial communication channels offered by DIS.

This argument has been increasingly challenged by a belief that artificial communication solutions can replicate the communicative advantages gained from personal contact. While artificial transmission of information traditionally has reached a large number of people in a short period of time, the scope for direct feedback and interaction (that is possible in personal communication) has been extremely limited. However, the use of web-chat groups, e-mail chains and videoconferencing has allowed much faster feedback and more frequent interaction. Moreover, it has been argued that certain uncodifiable qualities of face-to-face interactions can now be diffused more widely through the use of video mediated communication (VMC). However, one should not overestimate this impact. Research on VMC indicates that video mediated co-presence appear to reveal asymmetries in interpersonal communication that are not found in (co-located) face-to-face interaction. According to Heath and Luff (1992) the camera and the monitor inevitably transforms the participants environments of conduct so that the bodily activity one participant produces, such as gestures or eye-gaze, is different from the object received by the co-participant. The speaker in a video mediated conversation may presume that the recipients are registering his or her body language, while in fact much of this is misinterpreted or not registered at all.[14] This generates a shifting imbalance between speaker and listener and their abilities to influence each other.

Absorptive capacity

Even though increased speed and reach of the Internet, and a wider choice of artificial communication channels make available enormous amounts of information within GPN, it does not follow automatically from this that knowledge is being diffused to a similar extent. For instance, for a local supplier to benefit from the technological information made available by a flagship company, it needs the competence (or the absorptive capacity) necessary to internalize the knowledge that is represented by the information. The fact that a considerable amount of firms (and actually whole regions) are prevented from participating in, or reaping benefits from, GPN because they lack the technical competencies necessary to implement complex network technology (which is a precondition for integration into a GPN) serves as ample proof that dissemination of information is not the only factor determining knowledge diffusion (Macher and Mowery 2001, Lin and Liu 2001).

Borrowing from communication theory we will discuss two aspects of absorptive capacity, *semantic* and *contextual.* The former relate to the fact that, for knowledge to be diffused, sender and receiver must be able to ascribe the same interpretation to the information that is being exchanged (OECD 1992,

[14] For instance, a gentle thrust of one person against another may seem to be a truly powerful gesture while a dramatic shrug to one side can appear miniscule when mediated by a camera and a monitor. Hence the

Shannon and Weaver 1949). The latter refer to the argument that much knowledge is specific to the social context where it was developed (Shannon and Weaver 1949, Boisot 1995, Lam 1996,1997, Antonelli 1999) and is thus difficult to reproduce in locations characterized by other social contexts. Diffusion of such knowledge requires that the network participants share some understanding of these contexts.

Semantic constraints to knowledge diffusion may occur if the network participants lack the skills necessary to give meaning to what is transmitted. For instance, as of today, no single mathematician is able to master more than a single fraction of the discipline's theoretical body of knowledge. In diffusing her knowledge widely the mathematician thus have a communication problem at the *semantic* level since, due to the extensive education required to decode highly abstract codified knowledge, the percentage of the population able to understand the codes are relatively small. Arguably, with the spread of the Internet, manuals for interpreting technical languages and on-line learning courses can be disseminated between network nodes at a faster rate, and more widely, than before. Furthermore, closer interaction between scientific communities, provided by the Internet, may result in higher levels of standardization of technical languages. In addition, databases and intelligent web-browsers can enhance levels of *know-who* (Lundvall and Johnson 1994), meaning social knowledge of network participants that possesses relevant knowledge, which in turn improves the availability of codes within the network. Still, *learning* a new (technical)

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object that is received is not the actual object produced (Heath and Luff 1992, p. 337).

language and developing networks of personal acquaintances continues to be difficult and time-consuming activities for human beings. Hence, one cannot expect such skills to diffuse with anything near the same velocity as, for instance, the diffusion of information over the Internet.

Context and trust

However, even if a person is able to interpret the technical meaning of a coded message may not be enough for knowledge (know how) to be diffused. For instance, even if a group of engineers, working on implementing a foreign technology, are able to decode a set of technical blueprints, this does not necessarily mean that the implementation will proceed in the way intended by the people sending the instructions. This may have to do with *differences in social contexts* between those who send and those who receive the information. Social institutions, such as the judicial system, the educational system, labor market rules and regulations etc., that differ across (and sometimes within) locations influence how network participants organize and hence also how creation and diffusion of knowledge is managed. For this reason, companies situated in different institutional contexts often experience problems in sharing and coordinating their knowledge bases despite shared technical languages (Lam 1997,2000, Antonelli 1999, Gertler, 2001). Alice Lam (1997) illustrates this when pointing to the fact that international alliances, mergers and acquisitions among high-tech companies involving R&D and/or product development are prone to a very high risk of failure due to differences between the interacting parties.

Similarly, according to Luethje (2001), differences of work organization between manufacturing plants of a GPN, may greatly constrain knowledge diffusion within the network.

Another important contextual factor, determining the extent to which knowledge can be diffused in a GPN, is the existence of trust between the participants. If the interacting parts do not know each other, the credibility of the information that is being exchanged is likely be lower than information exchanged between friends or acquaintances, and particularly so if the information represents knowledge codified to a relatively limited extent.[15] These challenges are likely to be specifically serious in Global Production Networks as these imply permeable interfaces and boundaries, project teams that rapidly form, reorganize and dissolve when the needs of the market change (Kristof et al. 1995; Mowshowitz 1997). For instance, studies of collaboration between scientific communities suggest that an initial period involving physical proximity is necessary to build trust and to agree on the focus of the joint project (Carley and Wendt 1991). Similarly, some recommend that global teams perform initial lengthy face-to-face gatherings with repeated same time and same place encounters interspersed throughout the projects (DeMeyer 1991). Even though research has indicated that global virtual teams, interacting only by way of asynchronous and synchronous computer mediated communication, may experience a form of “swift” trust, such trust appears to be very fragile and temporal (Jarvenpaa et al. 1998). Some even doubt whether global virtual teams can ever function without face-to-face interaction, referring to the need for trust and that development of trust requires physical proximity (Handy 1995).

In short, we see that recent developments in digital information systems (DIS) have improved considerably the ability of network participants to source technological information. However absorbing this information, and acquiring the knowledge it represents, may require competencies that are not necessarily available, neither in terms of purely technical knowledge nor knowledge of social contexts. It is of little use to a local supplier to have access to a flagship company's leading product-design debates if it cannot internalize this knowledge and thus extend its own competencies.

5. Concluding remarks

Let us return to the question we started out with: Do globalization and new ICTs make knowledge spatially fluid? In one sense, the answer is yes: The spread of global production networks (GPN) serves as ample proof that knowledge is being diffused more rapidly and extensively than before. By increasing the quality and lowering the costs of interaction between agents in multiple locations, DIS is increasingly enabling large international flagship companies to outsource the various stages of their product value chains to whatever locations can perform

[15] While the feeling of trust exists Boisot 1995 claims, "the power of the transmitter, often charismatic in nature where knowledge is personal and uncodified, will dominate the relationship and keep lines of communication open between the parties" (p.115).

these most effectively. Whereas outsourcing has traditionally been confined to lower-end stages of manufacturing, more high-end stages concerning production and distribution, as well as knowledge intensive business services, are currently subject to global outsourcing.

However, as we have demonstrated there appear to be limits to knowledge diffusion by way of DIS in GPN. For instance, whereas a considerable geographic dispersion of production has taken place in electronics industries, certain high-end value-chain activities tend to cluster in specific locations: The more complex and advanced the activity, the stronger the tendency towards clustering in a few global "centers of excellence". Apparently, and in spite of the radical advances in communication technology (DIS), the knowledge associated with such high-end activities continues to carry a much stronger spatial connotation that many other types of knowledge that GPNs depend on.

We have in this paper discussed several possible explanations for this observed pattern. First, borrowing from communication theory one might conjecture that it has to do with complex and multifaceted character of communication in more advanced and experimental settings. Such more complex and multifaceted types of communication are arguably much more difficult to adapt to DIS than, say, sharing of relatively standard and easily codified production knowledge. Second, following Polanyi one might suggest that it has to do with the fact that such high-end activities are heavily involved in creation of new knowledge, and that the knowledge about how to create new knowledge to a large extent is tacit and cannot easily be codified and diffused through DIS. Third one might point to the contextual character of much knowledge, particularly in advanced environments, as a potential impediment to sharing of knowledge in geographically dispersed, multi-cultural networks. Arguably, DIS may be more efficient in distributing texts than contexts! Finally there is the problem of "absorptive capacity": even if code-books exist, having access to and being able to use these efficiently is sometimes very demanding, particularly in advanced contexts.

It is difficult at the present state of theoretical and empirical work in this area to discriminate between these different explanations of the location patterns that we observe, and it is an important task for further research to increase our understanding about these processes. Moreover, although the arguments considered above all predict that DIS will be more efficient in making knowledge fluid at the lower than at the higher end of the value chain, these arguments do not necessarily explain why such high-end activities increasingly tend to be outsourced to a few global "centers of excellence" (rather than being carried out in, say, the headquarter of the "global flagship" company). A thoroughgoing discussion of this aspect is outside the scope of this paper. Suffice it to say that to explain such clustering there must be strong local externalities associated with such high-end activities. It is, however, quite possible that some of the factors considered above may give rise to this type of externalities. Candidates for this might for instance include the various factors commonly grouped together under the heading "absorptive capacity", some of which may arguably be used over and over again without being depleted. In fact in many cases such capacities tend to improve with use!

On a more general level the discussion in this paper has highlighted some of the problems associated with current analyses of knowledge as an economic phenomenon.[16] The natural inclination of economists has been to treat knowledge as a “stock” (or form of capital) to which private property rights sometimes can - and sometimes cannot - be established (the latter being characterized as so-called public goods). DIS have been regarded as interesting in this context primarily because these technologies dramatically reduce the costs involved with converting new insights to “knowledge stocks” (codification), establish and maintain property rights (markets for instance) and channel knowledge between relevant parties. The problems with fulfilling some of these expectations probably have little to do with DIS as such (or present globalization trends) but with a flawed analysis of knowledge as an economic phenomenon. The main reason for this is, as pointed out previously, is the tendency to conflate the categories of data, information and knowledge to one, thereby ignoring that what is “stocked” is not knowledge as such but data or information. Knowledge, in contrast, has a strong subjective property, and it is this property that makes the “stock” concept deeply problematic. The economics of knowledge, we will argue, cannot be analyzed without taking into account the capabilities of those who hold it and the contexts in which it is created and used. Moreover, it has to be taken

[16] For a good discussion of these problems, see the recent Special Issue of Industrial and Corporate Change on Information and Knowledge (2/2000), particularly Ancori et al. 2000 and Cowan et al. 2000.

into account there may be many different forms of knowledge with widely different requirements. DIS, for instance, may have quite different implications depending on the type of knowledge, the capabilities of those who hold it and the context in which it occurs.

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