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Enabling Massive Coordination in Global Knowledge and Production Networks: Infrastructure, Standards and the Co-Evolution of a Global Supply-Base

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Abstract:

Global-scale knowledge and production networks are now prominent features of the international economy. Many new products and services are developed, produced, and delivered in the context of cross-border networks and lead firms, suppliers, and third-party service providers. Coordination of innovation-related processes under these circumstances requires a mastery of temporal and spatial relationships; a set of competencies that we call "massive coordination." This essay examines the technologies and emergent value chain structures that enable massive coordination. Specifically, we explore transportation and communications technologies, standards and standard setting, the expanding role of information technology, the fragmentation of the value chain, and the emergence of a new global supply-base. These enabling features, and the networks they have helped to spawn, have not appeared overnight, but are the result of long-term, co-evolutionary processes at work in the global economy.

Keywords: Massive coordination, Value chain modularity, Global knowledge networks, Industry co-evolution, Innovation clusters

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Enabling Massive Coordination in Global Knowledge and Production Networks: Infrastructure, Standards and the Co-Evolution of a Global Supply-Base

Martin Kenney/ Timothy Sturgeon

Introduction

Global-scale knowledge and production networks are now a prominent feature of the international economy. Many new products are both developed and produced in the context of cross-border networks and lead firms, suppliers, and third part service providers. These networks have not appeared overnight, but are the result of long-term, co-evolutionary processes at work in the global economy. This paper examines the enabling technologies and emergent value chain structures that underpin and lend character to these global knowledge and production networks. If we consider each of these elements in isolation, none are entirely new, yet it is our view that the scope for efficient coordination of activities they provide companies represents a quantitative and qualitative break with the past.

Obviously, even the simplest of business activities, such as early business fairs in medieval Europe or ancient China, required coordination (Allix 1922; Braudel 1982). The nature of this coordination has been of interest to scholars from broad range of social science disciplines, including anthropology, economics, sociology, and geography. Clearly, value chains used to be simpler, more local, and in need of less elaborate mechanisms for coordination. There is ample evidence for the increasing scale and scope of economic systems and in the degree and complexity of activities being coordinated. In this paper we summarize these changes and point to some of the key enablers of the increasing scale, scope, and complexity of global knowledge and production networks.

Despite a long and eclectic debate about the relationship between firm strategy and the need for coordination in spatially extensive markets, including the contributions of Karl Polanyi et al (1957) on the rise of international markets and Karl Marx's (1981) long disquisition on the drive by capitalist businesses to decrease the time goods remain unsold in transit or inventory[1], it is customary to begin discussions of coordination with Alfred Chandler. Chandler (1977) argued that the rise of the large, multidivisional, and later multinational firm was a response to the deployment of large-scale automated production equipment. In 1884, for example, the installation of two Bonsack cigarette rolling machines by the American Tabacco Company increased daily production capacity to 43 million cigarettes per year, a volume that could easily saturate the entire United States market at the time (Chandler, 1977, p. 291). Faster throughput created an imperative to seek larger markets and to integrate "upstream" into materials and components and "downstream" into distribution in order to reduce bottlenecks and expand control.

Better coordination of larger firms with more dispersed activities, for most of the 20th Century, meant greater vertical integration. For Chandler, the new communications technologies of the day, the telegraph and telephone, were enablers of the geographic expansion of firms and markets because they allowed the far-flung divisions of large corporations to coordinate their activities. This is illustrated in the 1880s with the railroads, which needed to coordinate train schedules to avoid collisions, but later spread to more industries as instantaneous national- and later global-scale communication became possible and affordable. The railroads, along with steam powered shipping and improved road systems, not only demanded better communications systems to function effectively and safely, but themselves became critical to the support the activities of national and global-scale corporations. [2] Improved transportation and communications decreased for firms risk on a variety of dimensions, most notably by improving in demand responsiveness and increasing supply line predictability. But perhaps most importantly, they enabled and expanded the scope of economic activity, not only in terms of enlarged markets, but also by opening up new, lower cost production locations while by allowing an ever-finer global division of labor. Over the latter half of the 20th Century, corporate innovators relied on improvements in communications and transportation technologies to create new business strategies and models that relied heavily on offshore locations. This enabled the organization and operation of the multinational firm.

What is different today is that firms have found ways of coordinating their global-scale activities that do not require direct ownership, even when extremely complex and time-sensitive products and processes are involved. In fact, because of the need to tap specialized capabilities that reside in other firms, global knowledge and production networks are especially relevant when products and process are extremely complex. Because of this, coordinating external networks has become as important as developing the internal capabilities of the firm. The key question for firms is: how can this coordination be achieved? To try to answer this question with some precision, Gereffi, Humphrey, and Sturgeon (2005) offer a set of value chain governance forms that range from high to low levels of explicit coordination. On the high end of this scale is internal coordination (hierarchy), and on the low end is market coordination (coordination based on price). In the middle lie three network forms of organization: captive, relational, and modular.

With captive governance, powerful lead firms dominate their suppliers, and coordination is achieved when suppliers follow instructions. In relational value chains, coordination is achieved through the dense interchange of tacit information and knowledge between lead firms and suppliers. Because of the dense interchange of tacit knowledge and information, spatial proximity between lead firms and suppliers remains quite important. In modular value chains, coordination is achieved when lead firms and suppliers focus on their specific areas of expertise and responsibility (core competence) and exchange information according to well-known standards that have been agreed upon or emerged to structure, simplify and ease the transfer of complex knowledge and information. An example is when a chip design firm in California transmits a computerized design file to a semiconductor manufacturing firm (or foundry) in Taiwan. Because these techniques rely to a substantial degree on information and advanced communications technologies, modularity in knowledge and production networks is a relatively new feature of the global economy. The key point is that value chain modularity eases the coordination of very complex business relationships and processes, even when great distance is involved. Because of value chain modularity, many of the world's most powerful and successful lead firms now demand that their suppliers handle a host of business processes that were previously carried out in-house, including aspects of technology development, parts and materials purchasing, manufacturing, logistics, accounting, and so on.

At the same time, the best suppliers, even some in based in developing countries, now have the capability to make links and provide inputs to lead firms without a great deal of handholding. Communications networks have increased in capacity and dropped in price and now support the transfer of huge volumes of data. And what runs through these pipes is no longer Morse code or just voice conversations, but data that is sent and received by highly sophisticated information technology systems used to design products, run highly automated production equipment, and track complex ever changing information on in-process and finished inventory.

And even in relational value chains, the importance of spatial proximity between value chain activities is decreasing. There are many processes and domains of knowledge that resist codification or are new and thus remain tacit, but nonetheless must be co-developed by firms in bi-lateral or even multi-lateral groupings. While the traditional solution to this problem has been for firms, or the parts of firms requiring tight coordination between value chain activities to cluster in a single location (e.g., Storper and Walker 1989), firms have increasingly developed ways to accomplish collaborative, interactive, and iterative work at a distance. Firms that share and develop tacit knowledge across great distance rely on many of the same enablers of modular value chains, especially low cost voice communications and inexpensive and widely available air travel. People have been trained and worked for decades in countries other than their own, and some of these have now returned home to run firms with the knowledge of how to operate in the new global knowledge and production networks. Technologies such as low cost video conferencing and real time file sharing, while not fully substituting for face-to-face communications, can ease the process of long-distance collaboration while providing the additional benefits of easy access to (lower cost) skilled labor and 24-hour work schedules.

In the realm of innovation and new product development, modular or relational linkages are the most important network governance forms. It is important to note that such global knowledge and production networks are neither binary nor stable, but dynamic. While firms actively seek to move knowledge from the tacit to the codified realm, technological change and competitive re-positioning constantly create new tacit activities and render old codification schemes obsolete. As a result, firms must coordinate with other firms through both modular and relational network linkages simultaneously and navigate the shifting terrain generated by the twin processes of codification and decodification, all while maintaining profitability and market share in the face of rapidly shifting demand. Coordination under these circumstances requires a mastery of temporal and spatial relationships; that is, "massive coordination."

This paper offers a description of the new global infrastructure that is both creating the need for and enabling massive coordination in the global economy. Some of this infrastructure is physical in nature, as in the vast improvements we have seen in global-scale transportation and communication systems; some of it is embodied in the technologies that run and run across this new infrastructure, such as the IT systems that have been developed for supply-chain management and business process automation; some if it resides in the firms (suppliers, component producers, and service providers) that have developed the capability to provide lead firms global-scale services and partnerships; and some of is it is conceptual, as in the strategies, routines, and business models that firms have developed to reap the benefits and mitigate the risks associated with global knowledge and production networks.

This vast and dynamic terrain of increasing the scale and scope of capitalist markets and market coordination is explored though a series of brief expositions. We begin by examining the development of the physical and technological aspects of new infrastructure for massive coordination. This is based, in large part, on the unprecedented expansion of global transportation and communications capacity and capabilities. We then take special note of the importance of standards and standard setting in making modular linkages in global knowledge and production networks possible. Standards facilitate global trade in many ways. They simplify the transfer of extremely complex information without a great deal of iterative work. They also can guarantee certain levels of quality through product standards or process standards such as ISO 9000 and 14000 quality process standards (Neumayer and Perkins 2004). The combination of complexity and codifiability enabled by information technology is, along with the increase in industrial capabilities in places other than the most developed economies, one of the few truly novel aspects of the current global economy.

We go on to examine the twin processes of vertical specialization and horizontal integration, known as “deverticalization,” first as a general process and then as it has played out in the electronics industry. The development of specialized firms and industries is a process typical of industrial development, resulting in a deepening division of labor that, over time, has made the advent of global knowledge and production networks possible. In no industry has this process been more pronounced than in electronics and information technology.

We follow with a discussion of the specialized global supply-base that has arisen to support massive coordination. An increasing number of firms, both lead firms and suppliers, now possess the knowledge and capability to take advantage of the new infrastructure discussed in the chapter’s first section. In the simplest of terms, lead firms have learned how to outsource on a global basis and suppliers have learned how to meet their needs. But this is not a one-time learning process. The self-reinforcing but dynamic and uncertain character of these new developments leads us to two important points. The first is that there is much that remains rooted in specific locations, even as spatially clustered activities become increasingly connected to activities in other clusters through global knowledge and production networks. The second is that the processes of codification and automation that make value chain modularity possible are under constant attack from the twin processes of technological change and strategic repositioning by the actors in the network. The frontier will always consist of tacit work, and this tempers the stunning scale and speed at which the global economy now operates, and favors those firms and industries that master massive coordination.

1. The Enablers of Massive Coordination: Transportation and Communications Technologies

The notion of a massive coordination is the key to successful participation in global knowledge and production networks draws inspiration from the observation that the loci of knowledge are dispersed and yet concentrated (Marshall 1890; Storper 1997; Sturgeon 2003; Fields 2004). One hundred years ago firms and industries had ample opportunity to emerge and grow in self-contained local markets. Today, firms are competing in a world in which new knowledge, some of which is of great importance, is emerging in locations that are concentrated in specific locations across the globe. In order to participate in the leading-edge of an industry, a firm must build vertical supply relationships, horizontal alliances, and even in-house operations in some strategically considered subset the all of the locations where critical new knowledge is emerging. As Murtha et al. (2000) show in the case of flat panel displays, the key location for new knowledge creation at the inception of the industry was Japan. Despite policies that tried to spark a domestic industry, the only way for U.S. firms to participate in the industry was to set up substantial development operations and sourcing relationships in Japan and all of the successful firms did so.

As Bruce Kogut (2003) has put it so well, the pull of geography is still very powerful. While centers of both production and knowledge creation have certainly emerged in new places, they are not only unevenly dispersed across the planet, but are instead concentrated in the handful of locations in the world where specialized design, technology development, and standard-setting activities take place. On top of this expanding mosaic of specialized locations, the activities in global knowledge and production networks are becoming much more tightly integrated though reliance on long distance relationships and the broad application of information technology. In this section, we examine two globe-spanning systems that support long distance collaboration, transportation and communications. Within these systems technical change is constantly reordering, but not eliminating, geography's pull.

Transportation and communication technologies form the pathways over which economic actors and specialized value chain activities are interconnected and coordinated. The importance of this infrastructure lies in altering the calculi of price, location, scale, and risk, to name some of the most salient dimensions (Fishlow 1965; Chandler 1977; Cohen et al. 2000). When a new medium of communication or transportation emerges or a previous media is dramatically transformed, such as has occurred when global telecommunication networks shifted from analog to digital transmission, opportunities are created for entrepreneurs to utilize the new media, not only for new products and services, but for organizational and locational innovations as well (Fields 2003).

Transportation

In The Wealth of Nations Adam Smith recognized the importance of transportation for market development. And yet, until the application of the steam engine to locomotion the speed and capacity of transportation was tied to either animate power or the speed provided by harnessing preexisting natural forces such as wind and current. The steam engine began a revolution in transportation, both on land and at sea, by breaking these ties. The electric motor and internal combustion engine dramatically increased the power available for locomotion and further sped the movement of goods and people. As motorized transportation spread to the air, the mobility of productive activity increased further.

The development of a merchant global maritime industry was the result of a long co-evolution of networks that included shipping firms, freight forwarders, ports, insurers, brokers, importers, exporters, and many other actors (Miller 2003). Braudel (1982: 371) reminds us that in the 1400s trade was so risky and difficult that merchants had to own and operate their own ships so as to internalize the large risk/reward equation – there was little opportunity for a division of labor. The development of a merchant shipping industry involved a dynamic between the technological progress that gradually routinized trans-oceanic trade and greater sophistication in international finance (Miller 2003: 4).

The transportation technologies that are the most important to the electronics industry are shipping containerization, which has accelerated and lowered the risks of land and sea transport and air freight. Containerization is at the core of intermodalism, i.e., the ability to move cargo in the same containers by sea, land, and air (Donovan 2004; Taggart 1999). Oddly enough, in maritime shipping containerization first appeared in U.S. inter-coastal shipping, in direct competition with the continental rail system. The bitter resistance of the railroad industry to containerized shipping encouraged the search for maritime alternatives. While containers were first used in international shipping to overseas U.S. military bases (Donovan 2004), the dimensions of the shipping container were soon standardized, thus dramatically simplifying both ship loading and intermodalism. In the process, stevedores were replaced by operators using cranes to load and unload 20- and 40-foot cargo containers from specially designed container ships.

The shipping container so fully dominates world trade today that the volume equal to the twenty-foot container, known as the twenty-foot equivalent unit (TEU), has become the standard measure of cargo capacity. World trade is now measured in TEUs, as is the capacity of ports, warehouses, ships, and cargo aircraft.[3] By packaging physical goods within a standard TEU package, the shipping container brings the container, and the goods they hold, albeit temporarily, into the digital realm, where they can be efficiently routed by the complex algorithms of logistics planning and load optimization software.

The intermodal container shipping provides a base upon which further innovation has been undertaken. For example, "lean" retailers in the U.S. monitor their sales of some products in real-time and reorder goods electronically with extremely short lead-times (Abernathy et al, 1999). When goods are produced in China, for example, telecommunications are used not only to transmit the orders, but also tell the supplier the sequence in which the order should be loaded into the container to allow efficient delivery once the container arrives in the U.S. With this innovation, the entire delivery route of the container can be pre-determined prior to loading eliminating the necessity of sending the goods to a warehouse for either storage or sorting. Intermodalism allows a container to be taken from the hold of a ship at port and placed onto a truck that continues directly to its delivery rounds. In the fluid world of high-tech logistics, a warehouse is like a reservoir, excellent for storage, but is ultimately a waste of money because it creates inventory carrying costs and risks as prices and fashions change.

Though the bulk of the world’s physical goods are transported over water by ship, air-freight is the conveyance method of choice for high value-added items that are subject to decay or obsolescence (on obsolescence, see Curry and Kenney, 1999), as it is for people traveling long distance. As the total volume of air-freight has burgeoned the cost of air transport has been decreasing at a rate of 3 percent per annum (Leinbach and Bowen. For memory chips, hard disk drives, fresh fish, fruit, vegetables, and cut flowers, along with many other products that can lose their value rapidly, air-freight has become critical. Specialized firms have emerged at key airports to ensure that goods air transported are not delayed in their movement (Leinbach and Bowen 2004). For locations wishing to become fully engaged in the global economy, a full-service international airport has become an indispensable infrastructural requirement, whether one is exporting cut flowers from Bogotá to Miami or newly packaged semiconductor chips from Penang to Munich. The IT industry is both an advanced user and large market for these advanced transportation services. The fastest growing market of all for air freight is IT goods from Asia to Europe and North America, representing 40% of the total shipments by tonnage and nearly 75% by value (Butterworth-Hayes 2005).

Telecommunications

Technological developments in communication have played a central role in enabling businesses to create, transmit, and alter the location of knowledge creation. For example, the introduction of moveable type for the production of printed books dramatically lowered the cost and sped the production of books. According to the noted Renaissance historian, Lisa Jardine (1996: 177) “The printed book revolutionized the transmission of knowledge, and permanently changed the attitudes of thinking Europe.” Similarly, Febvre and Martin (1976) would title an entire chapter in their treatise on the innovation of the moveable-type book as “The Book as a Force for Change.” The printed book increased the volume of codified knowledge and transmitted information and, by lowering the cost of reproduction, expanded the number of persons capable of accessing the knowledge and information they contained—widening debates and multiplying participants. But, more importantly, the accelerated circulation of information in the form of codified knowledge sped the creation of further knowledge and information, forming a virtuous circle of knowledge creation and dissemination that is continuing to this day. To illustrate, typeset books circulated the heretical views of Galileo and Copernicus far more rapidly than hand copies of an original manuscript ever could have, providing a basis for subsequent astronomical discovery, while contributing to a movement rethinking the old social order.

While there will be enormous improvements in the coming decades, information technology already is altering the world's transportation and communications systems — and the way they are used — almost beyond recognition. The electron-based communication systems began with the telegraph in the 1850s and were followed in the 1880s by the telephone, which further accelerated the expansion of markets and the rate of information flow. Fields (2003), following DuBoff (1980) and others, argues that the telegraph was as important for creating a national market in the U.S. as was the railroad. The creative-destructive power of new communication technologies is revealed by the almost immediate cessation of the Pony Express with the completion of the first transcontinental telegraph line (Standage 1999). Another immediate result was that the transmission of price information about all sorts of commodities was dramatically accelerated. The telegraph and the telephone formed the basic outlines of the early telecommunications industry, allowing firms in other industries to begin to build their strategies around real-time, long-distance communication links. However, in both cases transmission capacity was limited. Though telegraphy was closer to being digital than telephony, the analog transmission system had limited capacity.

Global expansion and dropping costs in voice communications has had a similar impact. Consider only thirty years ago, telecommunications capacity was concentrated in the developed nations of the world. Phone calls to India, China, or even Mexico were expensive and the quality of service was abysmal. Often the telecommunications infrastructure in these nations was operated by government monopolies that had little incentive to improve service. In the 1980s this changed as telecommunications was deregulated and pressure mounted for improved service and lower costs. With the construction of massive new undersea fiber optic cables during the Internet Bubble of the 1990s, a dynamic cycle of price declines for international service was set in motion. In cost terms, any location served by undersea cables experienced dizzying telecommunications price declines. The Internet appears to be writing the final chapter in this story of price collapse in telephony through the arrival of voice-over-Internet-Protocol telephony, which will create always-on connections priced at a low monthly fee. In this respect, Cairncross' (1997) prediction of the "death of distance" will be fulfilled.

India is an excellent example of a traditionally bandwidth-poor nation that has seen its telecommunications infrastructure improve dramatically. India's international submarine cable capacity grew from 31 Gbps in 2001 to 541 Gbps by the end of 2004 (TeleGeography 2004).[4] Though access prices to bandwidth from the U.S. to India are still five to ten times higher than on the U.S. to Hong Kong route, TeleGeography Research predicts that "Inevitably, the increase in capacity and number of competing cable systems will drive down the price of bandwidth to India. In other parts of Asia, prices declined by 60 percent or more in the last year — this could easily be repeated on Indian routes for years to come." In the case of China, the cost of international service has plummeted, for consumers' telephone cards now offer U.S. to China calling for about $.03 per minute.

2. Standards and Standard Setting; Behind the Expanding Role of Information Technology in Global Knowledge and production networks[5]

Information technology is being rolled out across the globe in a wide range of contexts, if unevenly and incompletely. Advances in information technology have been deeply entwined with many of the transformations in physical infrastructure discussed in the previous section, but there are many other aspects of information technology that are altering the prospects for massive coordination in global knowledge and production networks. At the core of this transformation lies the computer.

The concept of building a calculating machine can be traced back at least as far as Babbage, but the true power of the calculating machine came in the understanding that much of (or potentially anything) the analog world could be represented in 1s and 0s provided there was sufficient calculating power available. From the 1950s onwards, the development of the transistor and then the integrated circuit increased the availability of computing power in two ways. First, the development of more capable integrated circuitry, storage devices, and software meant that ever more challenging calculating tasks could be undertaken for the same cost. In contrast to the physical world, where speed and power typically come from larger machines, machines in the digital world tend to shrink and consume less power as their capabilities grow (Cohen et al, 2000). Finally, computing power increased to the point where inherently analog phenomenon such as sound waves or colors could be economically and effectively translated into digital formats, processed by computers, and transmitted across digital communications networks before being rendered back into analog form for the human end-user.

The interconnection of computers was first accomplished in just this way, through the use of a modem, which transformed digital signals to analog sound before sending it across analog networks that were designed for voice communication. On the other end of the line, the modem would then transform the analog sound back to digital form for use by the receiving computer. As the telecommunications system has become fully digitized, the need for this conversion has become unnecessary (Ceruzzi 1998). The combination of digital document creation and communications systems means that has become possible to easily, cheaply, and immediately transmit documents such as blueprints, instructions, photographs, video, the coordinates of three-dimensional shapes, among other things, some or all of whose analog characteristics can be represented digitally, anywhere in the world. For example, a new part can be designed and transformed into a prototype in a General Motors facility in the Detroit area. The design specifications, which are embodied in a data file, can be transmitted directly to a computer numerically controlled machine tool in say, China, to be cut. Or, the geography of the design process can be reversed, with engineers in the Chinese factory designing the part and transmitting the data to Detroit for incorporation into a larger design. Of course, when digital documents or other purely informational objects are fed into computer simulation systems, the physical embodiment of a part or product becomes less critical to the innovation process.[6] Once the design of a product is fully in digital form, it can be viewed, tested, and further manipulated in any place that has sufficient telecommunications bandwidth and labor with the appropriate skills. The point is that digital representations are much more fluid in a geographic sense than their physical embodiments, and this opens up new opportunities for collaboration in global knowledge and production networks.

With "intangible" service products as well, information technology is transforming localized, in-house systems into rapidly evolving global systems that require knowledge networks to create and massive coordination to maintain. In telephone-based customer service, for example, some voice calls are still from point to point, but larger volumes of voice traffic are automatically routed through central IT hubs to a dispersed network of call centers based on real-time decisions made by sophisticated artificial intelligence software. These systems can, among other things, balance the service requirements of an incoming call with the "value" of the caller seeking assistance to determine where the call is routed (e.g., in-house or outsourced call centers in the USA, Canada, or India) and how long the caller has to wait before they are connected to a representative (Gans and Zhou, 2005). The key enabler of modular value chains, as discussed earlier, is the growing ability to codify, transmit, and evaluate complex and rapidly changing information.

The recent adoption of the Internet has dramatically increased the amount and quality of the information that can be shared across great distance. With the explosion of web sites, blogs, and wikis, and improvements of the search engines that sort through them, the communication of information, sounds, images opinions, and even falsehoods has been dramatically eased. The Internet is also a platform for both distributing and running Open Source software, which has lowered information technology costs dramatically. The Internet and the rise of Open Source software have made it easier and less expensive to create new business ventures.

The sophisticated globe-girdling transportation and IT systems in operation today are the result of a chaotic evolutionary process in which governments, firms, and standard setting bodies participated. Massive coordination would have been impossible without the emergence of standards, be they design software programs, data output conventions such as the comma-delimited data, *de facto* standard software packages from Microsoft Office to AutoCAD, Internet protocols such as HTML and Java, or ISO conventions of various sorts. These standards form the basis of interaction within modular and, with technologies such as low cost, high bandwidth video conferencing, relational global networks as well. Though the importance of standards for massive coordination is woven through every aspect of value creation, in this section we focus on IT-related standards.

The evolution of standards in the IT industries is a process by which initial islands of automation and computerization were gradually linked together through the development of a variety of increasingly standardized protocols (Cortada 2004). In large measure, this initially occurred within the firm, but soon the drive for increased efficiency motivated the connection of suppliers and customers to these networks as well. In other instances, groups working to perfect in-house networks left to start firms to sell similar systems on the outside. Though initially many of these linkages were made through proprietary standards, there has been a gradual shift to third-party software systems and open industry standards that have been now been broadly adopted across firms, industries, and national boundaries.

The quest for increased efficiency and ease of use creates pressure for internal data to spread across firm boundaries. For example, access to the forecast data of its customers allows suppliers to make more informed decisions about their own capacity planning, thus increasing overall efficiency. Modern data communications networks, to provide another example, now consist of hardware, software, and transmission lines that are manufactured, installed, and maintained, not by a single, vertically integrated firm, but by a wide variety of firms. When a Nortel technician, for example, tries to fix a problem for a customer, they must have ready access to the detailed technical specifications of hardware and software created by vendors and even competitors such as Cisco, Lucent, and Juniper Networks, in order to do the job. Of course, the traditional obstacles to information sharing remain, such as loss of bargaining power between buyers and suppliers and leakage of sensitive information about products and clients to competitors, but improvements to software and IT systems allow firms to create “firewalls” that protect against the misuse of sensitive or proprietary information.

Data transfer is predicated upon standardized protocols. During the last two decades, certain software applications and hardware has become increasingly ubiquitous in the electronics and IT industry – products made by companies such as SAP, Oracle, Microsoft, Autodesk, Mentor Graphics, and Cadence. Moreover, with the emergence of Internet-based HTML and Java formats, systems from all of these firms can now be accessed through a standardized and ubiquitous user interface: the web browser. Of course, the Internet only transmits digital representations of voice, images, and information; it does not create knowledge nor can it transmit the complex tacit information of physical contextual cues – even seeing a person’s face during a teleconference is not the same as face-to-face interaction, which provides a wealth of rich information coming from both the person and the context. Nevertheless, the richness of the data flowing across the Internet is likely to increase the possibilities for modularity in what have been highly relational linkages in global knowledge and production networks, and to increase the options for long-distance exchange of tacit knowledge in relational linkages that resist codification.

The ease of information exchange that better standards make possible has lowered the bar for firms seeking to create or join global knowledge and production networks. An example is the relationship between semiconductor design firms (a part of the industry that is currently concentrated in the U.S.) and semiconductor foundries (a part of the industry that is currently concentrated in Taiwan). This relationship is possible because semiconductor design firms create chip design files using standardized electronic design software into which the foundry has entered its own parameters, or design rules (Leachman and Leachman 2004). By designing to the foundry’s specifications, the design firm increases the probability that the chip can be produced at a reasonable cost goes up. As the foundry improves its processes, it passes along updated design rules to the companies that create chip design software. While design rules for semiconductors are somewhat specific to the foundry and its processes, the final format of the design file that is handed off to the foundry, called GDS2, is used industry-wide, regardless of which software package the chip design firms uses or which foundry is slated to provide manufacturing services. The GDS2 file shows the geometry of the semiconductor's micro-components, including the vertical (layer) and horizontal position on the chip, as well as the inter-connections between them, but does not reveal the overall logic of the circuitry or explain how the chip is intended to function within larger systems or complete products. Thus the technology of semiconductor production, and the standards that have evolved over time to help coordinate the functioning of the value chain, have helped to generate a clear and relatively stable division of labor between design and manufacturing firms in this industry.

As these examples demonstrated, the electronics and IT industry provides an ideal case for understanding the role of value chain modularity in global knowledge and production networks. Because electronics and IT is has infected business activity in every other industry (Cortada 2004), because digitization has progressed rapidly in its own processes, and because both production and knowledge creation in this industry have become highly dispersed, the industry provides an ideal laboratory for understanding the evolution, importance, and implications of global knowledge and production networks. It provides an example of how far massive coordination can go when value chains have a highly modular character.

3. The fragmentation of the value chain and the co-evolution of a global supply-base

By the 1950s the Chandlerian, vertically integrated, multidivisional firm was the dominant organizational form for U.S. corporations. Transaction costs economists, beginning with Coase (1937), explained the rise of the large multidivisional firm as driven by the need to retain control over critical knowledge. If suppliers accumulated too much critical know-how, they could demand a larger and eventually unacceptably large piece of the pie (Williamson, 1975). The prototypical Chandlerian firm was General Motors, which integrated much of the supply chain within its boundaries. In addition to its multifarious vehicle line divisions, consisting of design and manufacturing, staff functions such as human resources, finance, accounting, etc. were centralized within the office of president. Basic innovation was largely confined to the corporate central research laboratory, which by the 1980s had become almost entirely divorced from the corporate line operations (Florida and Kenney 1990).

The crisis of the Chandlerian U.S. firms began in the 1970s, largely under pressure from Japanese firms that had integrated far less of the entire production process and had different joint knowledge creation relationships with their suppliers (Sako 1992; Nishiguchi 1994). The response of U.S. firms was quite interesting. Reengineering began in manufacturing with the implementation of kaizen and just-in-time systems and these secured significant savings. But the transformation of manufacturing did not stop with the adoption of Japanese-style workflow, inventory management, and quality control. Rather than trying to reproduce aspects of the Japanese system that were based on close ties between lead firms and suppliers, U.S. lead firms tried to retain arms-length relationships with their suppliers while at the same time spinning off internal parts and manufacturing divisions as independent firms and radically increasing outsourcing (Sturgeon, 2006).

In the 1990s, the goal of many important North American lead firms in the electronics industry, such as Apple Computer, Compaq, Dell, Hewlett Packard, Lucent, and Nortel, was to get out of the manufacturing game entirely, or nearly so. For newer firms such as Cisco, Silicon Graphics, and Sun Microsystems, large-scale internal manufacturing was never part of their business model. A similar trend began at the component level with the rise of semiconductor design houses and pure-play (manufacturing-only) semiconductor foundries such as TSMC and UMC in Taiwan that were discussed previously. The goal was not to bring innovation and production closer together, either organizationally or spatially, as the Japanese-style "Lean Production" model suggested (Womack et al. 1990; Florida and Kenney 1990; 1993), but to shed the huge financial burden of carrying so many internal manufacturing divisions, and the machinery, buildings, and workforces that went with them, in the face of newly uncertain demand brought on by intensified international competition.

The imperative for many North American (and later European) lead-firms, then, has been to partition the process in a way that increased outsourcing while limiting the creation of deep interdependencies with suppliers. Sturgeon (2002) saw this trend as enough of a break with past practices, and different enough from the Japanese system, to suggest the emergence of a "new American model of industrial organization," based on value chain modularity. The new digital tools described above, and the standards that went with them, were the best available answer firms had to the vexing question of how to achieve the tricky mix of large-scale outsourcing and limited interdependence between lead firms and suppliers.

But manufacturing was not the only function that U.S. firms sought to outsource. Beginning in the late 1980s, reengineering was also applied to the corporate staff functions. Functions such as legal work and data processing had a long history of outsourcing. However, with the reengineering movement firms began to consider the economics of outsourcing a host of in-house functions, from accounting and payroll to janitorial and food services. Notice that some of these in-house functions, such as accounting and payroll, had been becoming increasingly computerized. Firms from a variety of industries began to offer these functions as services, including incumbent data processing service providers such as EDS and ADP, consulting firms such as Accenture, accounting firms such as PriceWaterhouseCoopers, and enterprise computing firms such as IBM and HP. As corporations mulled over the concept of "core competence" under heavy pressure to increase profits, or at least their stock price, they began to rapidly shed internal functions that could be done less expensively by outside suppliers. Reengineering suggested to managers that every activity and function could, in principle, be considered in terms of the value it generated for the firm. Helping this process along were recommendations from management schools for firms to focus on "core competencies" or assets that reinforced those competencies and to consider outsourcing other activities (Prahalad and Hamel, 1990). The rule of thumb became: if a sufficient number of vendors capable of undertaking the work for less cost were available, and the function was not "core," the firm should probably outsource the function.

A key point that we would like to stress in this by-now-familiar story is that the existence of an adequate number of suppliers with the right capabilities could not be taken for granted, especially when the spatial scale of the business networks expand to include linkages to suppliers, or supplier facilities, located at great distance from buyers. How could lead firms deal with problems arising at a vendor or vendor facility located on the other side of the world? When suppliers in developing countries, where presumably low operating costs make the prospects of outsourcing more attractive, are included in the outsourcing calculus, assuming adequate capabilities in the supply-base is even more problematic. In practice, the development of these global knowledge and production networks has been based on co-evolution of buyers and suppliers and upon various positive feedback loops.

Firms are constantly searching for better options even as they carefully watch the performance of other firms in their industry. Whether firms are satisfiers or constrained maximizers, under the pressure of competition, at least, some are constantly searching for new methods, i.e., creating experiments through which new knowledge is created. Where one of these actions is successful it is likely to be retained by the firm and eventually become a routine (Nelson and Winter 1982). Should firms using these new methods prove successful other firms in the same industry are likely to (and are often compelled to) respond. This is of course not purely an evolutionary story, since management fads can lead groups of firms to make poor choices. But the trend toward using outside vendors for everything from accounting to manufacturing initiated a *co-evolutionary* dynamic between lead firms and the suppliers providing the outsourced functions. Outsourcing helped to drive an increase in scale and competency in the supply-base, which in turn facilitated outsourcing by integrated firms. Importantly, the emergence of highly competent suppliers eventually also provided a supply-base that start-up firms could use to scale up their activities.

For a fascinating illustration of this dynamic, let us return to the example of the fabless semiconductor design firms and what are now known as semiconductor foundries (Leachman and Leachman 2004). By the early 1980s, it was becoming too expensive to establish a new semiconductor firm due to the high-cost of building a semiconductor factory. The electronics boom of the early 1980s, fueled by the sudden popularity of the personal computer, was followed by a severe bust in 1985. This made semiconductor firms extremely reluctant to build factories for their own use. Silicon Valley entrepreneurs and venture capitalists, assisted by the contemporaneous development of venture capital-funded semiconductor design software, developed the concept of a firm that would only design and market semiconductors, and use the excess factory capacity that they knew existing firms had for production. This model worked well through the 1980s, but eventually the growth and proliferation of the design-only firms created enough demand to create a market for a specialized supplier—the "pure-play" semiconductor foundry, a firm dedicated to manufacturing semiconductors designed and marketed by other firms. The pure-play foundry model grew out of the earlier, makeshift solution, and while the success of the foundry business for integrated firms encouraged the formation of more design houses, the market for foundry services eventually grew to create a market large enough to support pure-play foundries such as Taiwan Semiconductor Manufacturing Corporation and United Microelectronics Corporation. The foundry model was given a further shot in the arm as the cost of fabs increased to the point at which it became more economical for the smaller integrated firms to discontinue in-house production. As the foundries learned-by-doing, they became increasingly capable, thereby easing the creation of new design firms.

The same reluctance to invest in new in-house factories, caused by the same boom and bust in the PC industry, drove early moves by lead firms such as Apple and Hewlett Packard to outsource circuit board assembly to Silicon Valley contract manufacturers such as Solectron, Flextronics, and Sanmina, and new start-ups such as Silicon Graphics and Sun Microsystems to make heavy use of these firms from the outset (Sturgeon, 2002). We have already mentioned the important role that the GDS2 standard has played in enabling the foundry model work, and in this part of the value chain it was the "Gerber" file that arose as an industry standard way of describing the physical layout semiconductors on circuit boards.

Global Suppliers

As the 1990s drew to a close, the fragmentation and geographic expansion of supply chains began to spur an apparent counter-tendency toward supplier consolidation. As outsourcing relationships multiplied they became more difficult to manage, and this drove many lead firms to try to simplify and consolidate their sourcing networks. Fewer, larger suppliers have been the mantra at lead firms as diverse as Wal-Mart, General Motors, Dell, and Hewlett-Packard. The result has been the emergence of a new class of huge globally-operating suppliers in a range of industries. Suppliers have aggregated bundles of capabilities and can now provide "one-stop shopping" for lead firms seeking regional and global supply solutions. This new class of suppliers has internalized many of the difficult and costly aspects of cross-border integration such as logistics, inventory management, and the day-to-day management of factories. What is emerging, for the first time, is a global supply-base comprised of large, highly sophisticated and economically powerful transnational suppliers and service providers. Importantly, because large suppliers serve many customers, they can achieve economies of scale that outstrip any single customer. They can also achieve high rates of capacity utilization by balancing the needs of customers operating in different product areas (Sturgeon, 2002).

Examples of global suppliers in electronics contract manufacturing, auto parts, apparel and footwear manufacturing, call center services, clinical trials, and information technology and enterprise computing services are provided in Table 1. What these firms have in common is a recently established global footprint and the fact they sell few, if any products under their own brand names, but instead provide manufacturing, system integration, and other specialized services for their clients, which tend to be well known lead firms in global value chains such as Hewlett Packard, Nike, General Motors, Citibank, and Pfizer. Of course, the U.S. arm's length global supplier model is not without difficulties. For example, in autos, Dana Corporation, Visteon, Delphi, and Lear have recently filed for bankruptcy, even as the strategies of General Motors and Ford appear to be collapsing.

Table 1. Examples of Global Suppliers in Six Industries

1) Electronics contract manufacturing: Flextronics, Solectron, Sanmina-SCI, Celestica, Jabil, Hon Hai, Quanta, Compal
2) Auto parts: Magna, Delphi, Visteon, Bosch, Denso, Yazaki, Lear, Johnson Controls, TRW, Continental
3) Apparel and footwear manufacturing: Pou Chen, Li & Fung, Fang Brothers, Nien Hsing, Texray
4) Call Center Services: Accenture, SNT Group, Atento, Convergys, SR Teleperformance, Wipro BPO, Bertelsmann
5) Clinical Trials and Contract Medical Research: Quintiles, Covance, IMS Health, Parexel
6) IT Services and Enterprise Computing: IBM, Accenture, PriceWaterhouseCoopers, McKinsey, Cognizant

In many cases, the largest suppliers have grown in size and geographic scope very quickly. In the electronics sector the largest five contract manufacturers in 2002 accounted for 70% of the revenues, 63% of employment, 69% of worldwide facilities, and 82% of facilities outside of North America. These high market shares are the result of three modes of expansion: 1) new facility construction, 2) acquisition of smaller, regional competitors, and 3) acquisition of customer facilities. New business has come both from vertically integrated firms seeking to shed internal manufacturing facilities, such as Hewlett Packard, IBM, Nortel, Lucent, Alcatel, and Ericsson as well as rapid growth of younger electronics hardware firms without large scale internal manufacturing, such as Cisco, Juniper Networks, and Silicon Graphics.

Table 2 shows the rapid expansion that these firms achieved in the 1990s. The fastest growing was Flextronics International, incorporated in Singapore but managed from its Silicon Valley, California headquarters. Solectron, also based in Silicon Valley, grew from a single facility in 1989 to a global behemoth with more than 50 plants in 2002. Celestica, which spun off IBM's Toronto manufacturing complex in 1997, established a global footprint in less than five years. Through the 1990s and early 2000s, the top five electronics contract manufacturers were all based in North America, but rapid growth from new business from Japanese lead firms such as Sony pushed the Taiwan-based contractor Hon Hai Precision led them to the number two spot in 2004 [need to update table to reflect this—have the data].

Table 2. Top Six vs. Top 100 Electronics Contract Manufacturers, 1994-2004: Revenues ($M), Compound Annual Growth Rates, and Top Six Share of Top 100 Revenues

	1994	1999	2002	2004	Share of Top 100, 2004	CAGR '94-'04
Flextronics	$211	$1,808	$13,615	$15,355	14%	54%
Hon Hai Precision	UA	UA	UA	$13,190	12%	UA
Solectron	$1,642	$8,391	$12,261	$12,205	11%	22%
Sanmina-SCI	$2,364	$8,624	$10,168	$11,638	11%	17%
Celestica	$1,989*	$5,297	$8,272	$8,840	8%	16%
Jabil Circuit	$404	$2,400	$3,729	$6,577	6%	32%
Top 6	$6,610	$26,520	$48,045	$54,615	63%	24%
Top 100	NA	$46,029	$68,149	$107,534	100%	NA

Notes: *All Celestica revenues in 1994 were from IBM. UA = data unavailable.

Sources: Company annual and quarterly reports; Electronic Business Top 100 Contract Manufacturers, various years.

Global suppliers bundle a wide variety of value chain functions such as manufacturing, component purchasing, and logistics. They tend to make heavy use of leading edge information technology systems and computerized manufacturing systems. They have deep operational knowledge in many areas of the world, and many maintain a rich set of second tier and material sourcing relationships in a wide variety of places.

Since they work for a range of customers, they tend to engage in high volume production that in turn provides them with advantages in the realm of parts and material purchasing and capacity utilization. Global suppliers provide a mix of attributes depending on the locations of a given facility. Facilities in high cost geographies such as the United States and West Europe can provide design assistance, new product introduction services, and low volume production of high cost goods; facilities in low cost locations that are proximate to end markets such as Mexico and East Europe can provide fast turn around and rapid replenishment in the context of "lean retailing," (Abernathy et al, 1999); and facilities in the lowest cost locations such as China can provide low costs, access to local markets, or both.

Global suppliers are key actors in global knowledge and production networks. Their competencies have moved beyond the simple translation of designs into a finished product to the translation of representations and designs into production lines and full product delivery. Ideally, this translation should be entirely modular and routine; and yet, in practice this process is often quite messy, iterative, and interactive. Nevertheless, the fact that there are now suppliers that can take on a great deal of technical, financial, and organizational responsibility for new product introduction, component sourcing, global production, and large portions of distribution as well, has opened up many new possibilities for lead firms in global knowledge and production networks to pursue global strategies with less cost and risk than in the past. Moreover, the deep collaboration between branded lead firms such as Hewlett Packard and global contract manufacturers like Solectron and Flextronics provide a template for a business model that includes global collaboration in the realm of innovation as well. Thus the process of industry co-evolution may once again be extending beyond the intentions of the pioneering firms as it opens up new possibilities for the firms that follow.

Global Infrastructure Providers

A central theme of this book is the need for firms to practice massive coordination to cope with the acceleration and globalization of knowledge creation and transfer. For locations seeking to become better integrated in global knowledge and production networks, the appropriate infrastructure is necessary. Given the rapidity of change, it is not sufficient to wait until the operational knowledge is built locally. Typically, the expertise necessary to design, build, and operate a global-class airport, port, or telecommunications center is not immediately available at the local level. Previously, this was a barrier to developing nations with deficient infrastructure, but today global service firms with knowledge of how to build and operate sophisticated infrastructure projects can be hired to create and manage large infrastructure projects, even in what were formally very remote and isolated locations. These service providers can put places on the map very quickly.

A remarkable example of how these infrastructure managers can deploy their skills globally is China. The Chinese ports of Dalian, Fuzhou, and Nantong are managed by a subsidiary of the Singaporean government, PSA, and the port of Shanghai is managed by the Hong Kong firm, Hutchison International Terminals (World Bank 2003). As a result of this know-how-for-hire, China has created a global-class shipping infrastructure with remarkable speed. In a period of about 10 years, China went from dilapidated ports and airports to a nation with state-of-the-art facilities capable of meeting the demands of firms operating according to the massive coordination paradigm.

Similar trajectories can be observed in the infrastructure for service industries. In less than one decade, India, which continues to suffer from a precarious infrastructure for the production and export of physical goods, has built a strong infrastructure for the exportation of information technology-enabled services. Indian telecommunications is increasingly close to global-class, even as the electrical, water, and sewage systems remain at developing nation levels. Indian facilities that are plugged into global knowledge networks are remarkable in their size and scale. For example, the International Technology Park in Bangalore, built in 1997, now has 1.6 million square feet of office space and houses over 100 firms. It is a joint venture by a consortium of Singaporean firms, the Indian Tata Group, and the Karnataka state government (Choudhury 2003). The Park is managed by a Singaporean firm, which is responsible for the entire complex, from security and building maintenance to utilities provision and telecommunications service. Upon entering the complex, there is the sensation of stepping out of India and into the developed world. The availability on the open market of infrastructure creation skills, and the rise of firms capable of building and operating global-class facilities anywhere in the world, is a powerful stimulant to globalization.

Global Intermediaries

Massive coordination of global knowledge and production networks is not easy, regardless of the sophistication of lead firms and their global suppliers, the robustness of standards, and the quality of the physical infrastructure that supports the coordination between the two. There are a host of functions that are required to make the system work, from match-making, to financing, to human resource recruitment. There are a host of firms that have emerged to help make the linkages between globally-oriented leads firms, global suppliers, and the labor and financial capital that support them both. Because their clientele is now global, it is not surprise that the "intermediary" actors in global knowledge networks such as venture capitalists, executive search firms, and consulting firms now have global operations as well. For example, when a U.S. software firm wants to recruit an executive in India, it can retain an executive search firm that will conduct the search, not only in India or the U.S., but globally. There are globalized venture capital firms that openly tout their ability to assist firms in developing international relationships. So, for example, an entrepreneur with the idea of establishing a semiconductor design firm in Silicon Valley might accept a Taiwanese venture capitalist as an investor because they plan to manufacture the integrated circuit in Taiwan and believe that the Taiwanese venture capitalist might help broker that relationship. In the case of Israeli technology start-ups, participation by a U.S. venture capitalist can prove useful in providing introductions to possible U.S. customers, suppliers, and even potential acquirers.

Multiple skilled intermediaries are typically involved in the formation of global knowledge networks. For example, Kenney et al. (2006) have examined the international entrepreneurial support networks for Chinese technology-based startups that have been listed on U.S. stock exchanges. The majority of these Chinese firms received venture capital from U.S. venture capitalists, had U.S. law firms (Hong Kong branches) prepare their listing documentation, were audited by U.S. accounting firms, and had their public offering managed by a U.S. lead investment bank. In other words, the Chinese firms were able to connect with a global class infrastructure to support their entrepreneurial ambitions.

4. The Pull of Geography

Discussions about the importance of proximity have been schizophrenic. The pull of geography nearly always begins or ends with the discussion of clusters and a quotation of Alfred Marshall's (1890) that in certain locations the "mysteries of the trade become no mysteries; but are as it were in the air." Yet, as Brown and Duguid (2001) point out, Marshall went on to write that the advantages of proximity were "being diminished by the railway, the printing press and the telegraphy." The previous discussions in this chapter have suggested the "death of distance" and increased locational fluidity (Cairncross 1997). And yet, the power of spatial proximity continues to assert itself even in a massively coordinated world. This section reflects upon the role of tacit interactions and the necessity of being "there," especially during the process of knowledge creation. Marshall's brilliant insight still serves as a warning to any suggesting that new technologies are rendering distance meaningless.

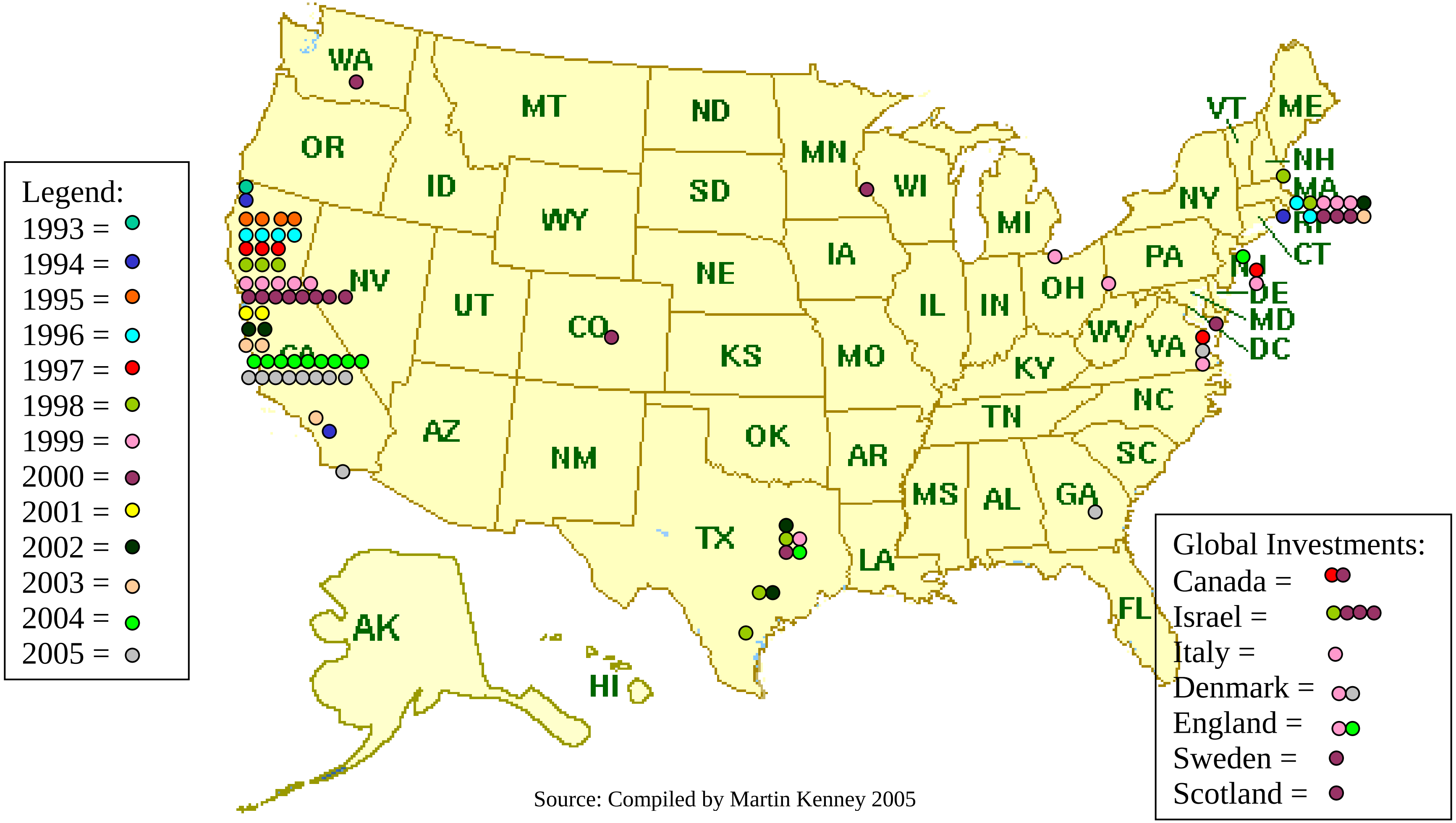
After decades of neglect, economists and business strategy analysts have again recognized the importance of proximity, though the most recent work has tended to focus on economies of scale and scope and concentrations of specialized labor and less on the interactions of co-located firms in the same industry (Krugman). Porter (1998) used his "diamond model" to extend this thinking to include shared institutions such as research institutes and universities. Harkening back to Marshall's "mysteries of the trade," Storper (1997) finds that firms in clusters generate "untraded dependencies" that have economic value, but are not sold in the market. The point is that dense relationships between co-located firms both create value that can be realized and promotes spatial stickiness.

Brown and Duguid (2000) use the metaphors slippery and sticky when they discuss the relationship of the Xerox Palo Alto Research Center (PARC) and its location in Silicon Valley, CA, to its owner, Xerox. Xerox headquarters, located in Rochester, NY, was never able to effectively transfer the knowledge generated by PARC to its scattered operational divisions. However, many of PARC's innovations leaked very readily into the more "prepared" local environment of Silicon Valley. Silicon Valley has what Brown and Duguid term "networks of practice" that provided a locationally-embedded capability to utilize the knowledge being generated by PARC while Xerox's own divisions were unable to either understand nor utilize it. This problem of the role of geography in the appropriation of knowledge is critical for firm strategy in today's global economy. In certain cases, the firm must participate in the life of key regions to remain innovative, but through this participation it may contribute more the region than to its own profitability.

Local knowledge is not only technical knowledge, but also concerns business models and an understanding of how “business gets done.” Cisco utilizes such local knowledge in its acquisitions. John Chambers, Cisco’s CEO, stated unequivocally that “geographic proximity is important” (Mayer and Kenney 2004). An important part of this was the “cultural” fit, which referred to shared understandings. As Figure 1 shows, Cisco does not exclusively purchase local firms, especially when the technology it needs is not locally available, but the vast majority of its acquisitions are made locally in Silicon Valley. Interestingly, in the recent downturn, Cisco became more local in its acquisitions even as its internal operations became more globalized.

Knowledge that is generated within a specialized industrial cluster is one form of inter-firm knowledge transfer. Another is the vertical transfer of knowledge within a supply chain. Gereffi et al. (2005) have considered this in terms of the characteristics of the linkages between firms in the supply chain, but have given less consideration to the influence of location beyond the observation that inter-firms linkages that are complex and difficult to codify are often easier to forge in the context of spatial proximity. Quite naturally, locational decisions are affected by a number of factors. For example, according to Motoyama (2006), when Toyota was designing the hybrid drive train for its Prius model car, a team from Matsushita’s battery division located in the Osaka area worked very closely with the Toyota engineers located in Toyota City. However, as the Prius got closer to introduction Toyota and Matsushita created a joint venture only 35 miles from the Toyota design headquarters to facilitate interaction. It was decided that proximity would enhance close interaction and intimate sharing of information necessary to create an integrated automobile (Motoyama 2006). On the other hand, the “space age” looks of the Prius body was created by Toyota’s design studio located in the Los Angeles area. So, for all-important drive-train technology Toyota worked intimately with Matsushita engineers located in relatively close proximity but who were outside the firm, while the body design was generated internally, but on another continent. The Prius was initially produced only in the Hirose plant in the Toyota City region. In 2006, nine years after the first Prius’ were produced in 1997, production was considered sufficiently stable so that Toyota could produce the Prius in its Chinese factory (Business Week 2005).

Figure 1. The Location of Cisco's Acquisitions, 1993-2005



Source: Compiled by Martin Kenney 2005

As the Prius case underlines, choices about spatial proximity, dispersal, and outsourcing are not static tradeoffs, but interact and change with time depending in part on the capabilities ion the supply-base and on the characteristics and capacity of the global infrastructure supporting collaboration. For example, global electronic contract manufacturers such as Flextronics and Solectron have engineering and production facilities in high-wage locations to enable their engineers to interact with their customer's design engineers on issues such as manufacturability. Once product designs has been refined and manufacturing process validated, however, the product can be manufactured in plants in almost any location, and even to those not owned by the contract manufacturer that helped to specify the production process. This is because there are well-known standards to describe the physical characteristics, or geometry, of electronics products and the components that make them up.

A similar dynamic can be found in the realm of standards. Sturgeon (2003) has argued that the standards supporting geographically fluid modular value chains are often worked out within the spatially concentrated "networks of practice" characterized by Brown and Duguid (2000). With de facto standards, dominant firms such as Intel and Microsoft impose their standard on the industry, and so spatial proximity is less important, but in the case of open standards, co-location can be an important element of successfully hammering out the very codification schemes that then make spatial dispersion possible.

The necessity of spatial proximity between design and manufacturing can differ by product, even within a single "industry." For example, in semiconductors the locational and ownership relationships in random access memory (DRAM) and logic chips are entirely different (Hodges and Leachman, 1995). In logic chips, which do not require cutting edge production technology, it has been possible to separate design from production both organizationally and spatially, as has been discussed in the case of semiconductor design firms can contract foundries. As already mentioned, the largest center for the design of logic chips is Silicon Valley, where there are numerous chip design firms, while manufacturing is undertaken almost entirely in Taiwan. DRAM semiconductors, on the other hand, are largely designed and produced inside large integrated firms in Japan, Korea, the U.S. and, increasingly, Taiwan. The only U.S.-based DRAM producer, Micron, is located far outside Silicon Valley in Boise, Idaho. DRAM process technology is state-of-the-art and requires a constant interaction between engineering and manufacturing, thereby creating great pressure for spatial propinquity and organizational control. At the same time, DRAM designs are relatively straight forward and generic, reducing the necessity for the co-location of chip designers and lead users of the devices.

5. Conclusion

In Joseph Schumpeter's (1939) discussion of the role of entrepreneurs in the formation of "new economic spaces," he remarked upon is how early firms in new industries are often forced to build their own capital goods or even integrate back into creating their own inputs. However, as Adam Smith (1776) first observed, as an industry grows it is often or even usually the case that a community of upstream suppliers will come into existence. There are two common patterns by which these suppliers emerge (Von Hippel 1988). The first pattern is one in which a firm producing a similar good for another industry draws upon its existing knowledge, and, through economies of scope, begins supplying a product to the new industry by leveraging their existing knowledge in another (Rosenberg 1963). For example, Applied Materials originally supplied production equipment to the semiconductor industry, and then began supplying equipment to the silicon flat panel display producers (Murtha et al.). The other common entry pattern is the spin-offs of new firms from the early entrants as the industry grows (Von Hippel 1988; Lecuyer 2006). In semiconductors one of the emblematic pioneering firms for the spin-off of semiconductor equipment and input producers was Fairchild (Stowsky 1987; Von Hippel 1988). This resembles a "self-organizing process." What was initially an industry consisting of a number of horizontal entrants evolves into a value chain with a specialized supply-base as an industry grows (Stigler 1951).

Electronics has undergone its own co-evolutionary process beginning in the Post World War Two period, driven in large part by transformations within the computer industry. The computer industry of the 1950s-1970s evolved in two directions simultaneously. First, with the introduction of each new class of computers, i.e., minicomputers, work stations, personal computers, supercomputers etc., new entrants came to dominate the new segment (Baldwin and Clark 2000). Second, the full implementation in the 1960s of modular system architecture by IBM for market-dominating System 360 opened up opportunities for third-party firms to supply sub-systems and peripheral equipment that were "plug-compatible" with the IBM 360. In this way independent electronics industry sub-sectors were born in specialized product areas such as hard disk drives, computer printers, semiconductors, and application software.

The contemporary world is one within which value creation is becoming dispersed in a world that contains an increasingly rich and variegated division of labor. Richard Langlois (2003) has argued that this division of labor has come to be mediated by the promulgation of open technical standards for processes that were formerly proprietary and contained in the integrated firm. The view here is that standards render the ongoing fragmentation of the value chain unproblematic. Ultimately, this powerful claim is unproven beyond the apparent disintegration of the Chandlerian firm. Also, there is a great deal of counter-evidence. Among global suppliers and service providers there is continual process of bundling underway as these firms seek to realize greater economies of scope or simply to try to capture more of their customer's total expenditures. For example, IBM, which formerly provided IT services only, now provides a wide variety of business services including human resources, finance, and accounting. Contract manufacturers such as Flextronics and Celestica now provide design assistance, circuit board and final product testing, component purchasing, packaging, logistics services, and final assembly in addition to basic manufacturing.

So, the global economy is clearly not moving in the direction of a standards-mediated utopia consisting of small, specialized, single-function firms interacting through transparent, non-coercive markets. Not only are the largest corporations larger than ever, as they seek to build and acquire a global presence, but the largest suppliers and services producers have also become huge global corporations in their own right. In the transportation industry, for example, firms such as UPS and FedEx have moved beyond the simple transportation of packages to also doing some assembly in conjunction with shipping. In the pharmaceutical industry, Quintiles provides clinical trials for clients in the pharmaceutical industry on a global basis. Global call center and BPO service providers such as Client Logic, based in Nashville, TN with 39 call centers and seven fulfillment centers to handle inventory management, packaging, and shipping. Clearly, global value chains and knowledge and production networks are in a state of constant flux and threat of reorganization, by established players in the chain as well as by outside entities trying to leverage new technologies and/or business models to gain advantage.

For firms, coordination of the internal with the external has always been a critical issue. As products and services become increasingly complex, the number, variety, and geographic diversity of organizations and geographies that must be coordinated has mushroomed, sometimes quite suddenly. Firms have been forced to engage in massive coordination as a way to effectively tap the nodes of activity where specific knowledge is both concentrated and is in the process of being dynamically created. These nodes of activity may be within the firm, outside the firm, in the home country or region of the firm, or outside it. Because massive coordination provides the means for developing, maintaining, and expanding global knowledge and production networks, it has become the critical competence for globally operating firms.

Notes:

[1] Marx noted that improvements in communications and transportation technologies served to decrease the time products stayed in inventory, cutting inventory and thus overall costs just as surely as did labor savings or automation.

[2] In fact, the institution of "standard time" in the U.S. was driven by the need of railroads to coordinate schedules—prior to standard time, cities operated on the basis of their own solar time, i.e. noon in Boston, MA was slightly different from Springfield, MA!

[3] The emergence of China as the global workshop can be seen in the rapid growth in the number of TEUs moving through its ports. In 2003, the cargo moving through the ports of Mainland China reached 48 million TEUs, the largest number of containers traversing any nation in the world. From January through September 2004, container throughput was 43.7 million TEUs, a 27.2 percent increase over the same period in 2003. The container throughputs of the ports of Shanghai and Shenzhen were to 10.5 and 9.8 million TEUs and each had a growth rate of about 30 percent (Zhang 2004). Hong Kong, which serves as a major transportation hub for Southern China, is already the busiest port in the world, but Shenzhen and Shanghai are rapidly gaining.

[4] Gbps stands for gigabytes per second.

[5] There is an enormous literature on standards and standard setting. For an overview of the discussions, see Farrell and Saloner (1988), Grindley (1995), Katz and Shapiro (1986).

[6] For a powerful counterargument for the importance of the media, see Brown and Duguid (2000).

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