Industry Co-Evolution and the Rise of a Shared Supply-base for Electronics Manufacturing

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Abstract

This paper develops a co-evolutionary model at the industry level by highlighting the interplay between increased strategic outsourcing and the rise of shared supplier networks. To do so we explore a case where increased strategic outsourcing by *groups* of lead firms has, over time, led to the rise of a *shared* supplier network, one that can be accessed by the industry as a whole, even by lead firms that compete head-to-head in final product markets. The case is the outsourcing of electronics production and the concomitant rise of a pool highly competent contract manufacturers based in the United States and Taiwan. In this case inter-firm relations tend to be neither exploitative nor symbiotic in the classic sense, but flexible, modular, and self-reliant. Our approach postulates an industry-wide virtuous cycle between lead firm strategic outsourcing and the development of supplier competencies. Based on a scope-linkage framework, and a dynamic view of inter-organizational transactions, we seek to expose the key organizational logic that underpins the changing patterns of inter-firm collaboration we have observed in the electronics industry, and expand the co-evolutionary framework to the industry level.

Introduction

This paper develops a co-evolutionary model at the industry level by highlighting the interplay between increased strategic outsourcing and the rise of shared supplier networks. Recent literature (e.g., McKelvy, 1997; Lewin and Volberda, 1999; Lewin, Long, and Carrol, 1999) has advanced co-evolution as a framework for analyzing the dynamics within, and the interplay between, firm adaptation and environmental selection. Simply put, firm learning—micro-level evolution—both conditions and is conditioned by the matrix of organizations, institutions, and more general social forces within which it is situated—macro-level evolution. While this work usefully situates firm learning within its broader competitive and institutional contexts, it fails to elaborate the co-evolution of lead firms with either individual suppliers or their broader supplier networks. More recently, Nishiguchi (2001) has promoted co-evolution as an ideal framework for the study of inter-organizational relations, especially outsourcing. In Nishiguchi's view lead, or convening firms co-evolve with their suppliers as they oscillate between exploitative and symbiotic inter-firm relationships. Competition, the third leg supporting the evolutionary conceptual stool, is left out of his framework because firms in the same value chain are not portrayed as competing with each other but with discrete value chains convened by other lead firms. Supplier networks are portrayed, for analytic purposes, as separate and not shared or overalpping. For example, Toyota and its largely symbiotic supplier network competes against General Motors and its largely exploited supplier network. Network evolution occurs as disturbances both internal and external to the symbiotic or exploitative relationships push lead firms and suppliers alike to adapt and innovate. Co-evolution occurs within each network in a process that might be called *value chain co-evolution*.

This paper explores a case where increased strategic outsourcing by *groups* of lead firms has, over time, led to the rise of a *shared* supplier network, one that can be accessed by the industry as a whole, even by lead firms that compete head-to-head in final product markets. Our case is the outsourcing of electronics production and the concomitant rise of a pool highly competent contract manufacturers based in the United States and Taiwan. In this case inter-firm relations tend to be neither exploitative nor symbiotic in the classic sense, but flexible, modular, and self-reliant. While we agree that firm competencies are powerfully conditioned by the complementary competencies that may or may not reside in the value chains in which it participates, and that the development (or loss) of firm-level competencies exerts a weak effect on the competency of the entire value chain, we observe that, under certain conditions, groups of lead firms can interact with broadly shared supply-bases to drive the evolution of entire industries in a process we call *industry co-evolution*.

The emergence of shared supply networks can be understood as a co-evolutionary process encompassing series of strategic choices and interactions between lead firms and their suppliers that occur in the context of a dynamic environment. While such a conceptualization is in keeping with the line of research that adopts a co-evolutionary view of inter-organization relations (e.g., Nishiguchi, 2001; Madhok, 2000), our approach postulates an industry-wide virtuous cycle between lead firm strategic outsourcing and the development of supplier competencies. Suppliers often increase the quality and scope of their services in response to lead firm requests. Once new supplier competencies are in place, they can be used as a basis to develop relationships with other lead firms, and can influence future lead firm decision making regarding strategic outsourcing if, and this is the crucial element, lead firms and suppliers are not locked into dyadic relationships because of asset specificity, equity ties, geographic propinquity, or other factors. Based on this scope-linkage framework, we seek to expose the key organizational logic that underpins the changing patterns of inter-firm collaboration we have observed in the electronics industry, and expand the co-evolutionary framework to the industry level. While our discussion will be conducted at the level of inter-organization relations in general, our case studies center on the co-evolutionary dynamics of increased strategic outsourcing by lead firms in the electronics industry and the concomitant rise of highly competent set of suppliers that have come to serve a broad range of lead firms.

Our conceptualization the process of industry co-evolution is based on the dynamics of firm capabilities and the characteristics of inter-firm linkages. By contrasting our case with the co-evolution literature that centers on how micro- and macro-level factors enable or limit the firm-level decisions (e.g., Mckelvy, 1997; Lewin and Volberda, 1999), our intent is not to replace micro-level theory or reject the influence of macro-level forces. but to shift the focus to the meso-level processes that occur at the industry level. We view the development of the firm in both its immediate institutional *milieu* and in the context of its industry, that is, the sets of inter-linked and perhaps competing value chains that serve up specific products to consumers. In this way, we look beyond the boundaries of the firm to understand the dynamics of firm capabilities, but not so far beyond as to lose sight of the ways in which the decisions made within the firm might in turn impact what the external environment has to offer.

The proposition of transaction value; a dynamic view of transactions

Prior to elaborating the logic of industry co-evolutionary logic, one premise on the nature of inter-firm collaborations between upstream and downstream firms has to be established. The purpose of engaging in inter-firm collaboration along an industry value chain is to combine two sets of complementary but dissimilar resource configuration in a mutually beneficial manner. The mutual

benefits of collaboration include not only those resulting from *ex ante* resource complementarity but also those that might be generated due to *ex post* investments in relation-specific assets by either party (Bensaou and Anderson, 1999; Dyer and Singh, 1998) and through inter-organizational learning over time, which in turn may help both firms upgrade their competence (Lee and Chen, 2000). Although there might be risks of increased costs associated with relation-specific investments due to the partner's possible opportunistic behavior (Williamson, 1975, 1985), the perceived future value generated from interdependent complementarities might, in practice, overwhelm such risks (Celly, Spekman, and Kamauff, 1999; Heide and Miner, 1992). In other words, basing inter-organizational decisions on transaction costs alone could undermine the realization of collaborative benefits and hence the transaction value of inter-firm collaborations (Dyer, 1997; Madhok and Tallman, 1998; Zajac and Oslen, 1993). Concurring with this line of argument, we assert that the ultimate goal of inter-firm collaboration is to maximize the overall value, not merely limit the costs, of inter-firm linkages. Such a value-creation proposition is particularly valid for analyzing inter-organization initiatives from a co-evolutionary perspective because a certain portion of collaboration value can only be realized through the dynamic process of interaction among economic actors (Madhok, 2000, p. 280).

Specific inter-firm (vertical) relations are a result of strategic choices made by both collaborative parties. For both the lead firm and the supplier then, choices have to be made regarding the scope of competence upon which its competitive advantages are based. Such choices are not random phenomena. Each firm makes strategic choices based on its existing stock of competence, which Levinthal and Myatt (1994) define as initial conditions of co-evolution between firm capabilities and industry. At the same time, the historical development path of firm capabilities may constrain the firm's subsequent strategic decisions on business scope (Arthur, 1989; Teece, Pisano, and Shuen, 1997). Within the transaction value framework, a lead firm will outsource as a way to enhance the value-creation opportunities of its own competence set by utilizing the complementary competencies of potential partners. We regard strategic outsourcing as a value-enhancing initiative that seeks to utilize the linkages between two sets of complementary competencies, rather than initiatives aimed at reducing costs by leveraging low-cost inputs. In other words, lead firm strategic choices about competence scope have to be complementary with those of suppliers before any value-creating collaboration can be realized.

Value chain co-evolution from the supplier's view

The past decade has witnessed large vertically integrated corporations adopting strategic outsourcing measures to remain competitive, especially in highly contested and fast-moving markets

(Quinn and Hilmer, 1994; Fine, 1999). By focusing on the competence areas that are essential to, or have the potential for, the formation of competitive advantage, especially product innovation, marketing, and other activities related to brand development, lead firms have increasingly come to rely upon specialized suppliers for providing best-in-class production services to quickly reap value from innovations while spreading risk in volatile markets (Venkatesan, 1992). The electronics industry is no exception. Firms that develop, market, and sell electronics hardware products, from computers to communications switches to mobile phone handsets, have turned to contract manufacturers for production and even post-architectural design services.[1]

While it has been widely noted that widespread outsourcing results in the emergence of a de-verticalized industrial landscape (Hitt, Keats, and DeMarie, 1999), little attention has been paid to the evolution of the supply-base that has arisen to supply lead newly deverticalized lead firms. This lacunae has led to the erroneous characterization of the deverticalization process as one where industries are evolving toward smaller, highly specialized firms, each of which has shed its "non-core" activities to focus on a few "core" competencies. The deverticalization trend looks very different from the supplier's perspective. To meet the growing demand for full-service, or "turn-key" outsourcing solutions (Sturgeon, 1997), suppliers have in many cases had to add entirely new competence areas, increasing their scope of activities while improving quality, delivery, and cost performance. Increased outsourcing has also, in many instances, vastly increased the scale of suppliers' operations. Thus, increased outsourcing has led to a deepening of competence and an increase in scale at supplier firms. As supply-bases come to be comprised of large, highly capable suppliers the prospects for increased outsourcing are improved. In this way, suppliers and lead firms co-evolve in a recursive cycle of outsourcing and increasing supply-base capability and scale, which makes the prospects for additional outsourcing more attractive, not just to the lead firms that drove the upgrading of the supply base in the first instance, but for those lead firms just beginning to seriously consider large scale strategic outsourcing.

The full range of supplier characteristics has been overlooked in the realm of theory as well. The central question of the transaction costs framework (Williamson, 1975, 1985) is if lead firms choose to make or to buy a particular product, process, or service. Make/buy decisions do depend on the characteristics of suppliers, which are portrayed in the form of a dyad, with suppliers that do not invest in specific assets on one hand (what we call a *commodity supplier*) and those suppliers that do depend on specific assets on the other (what we call a *captive supplier*). The key analytic variable is

[1] The market research firm Technology Forecasters estimates that the revenue of contract manufacturing will share around 15% of the total cost of electronics goods sold in 2001. Moreover, the growth rate of contract manufacturing in the coming five years will be more than 20% a year, which is more than twice as

the degree of asset specificity embodied the inter-firm relationship. Suppliers are portrayed, largely, as either investing in specific assets or not. When asset specificity is present, the organizational field is suddenly reduced and lead firms become locked into using particular suppliers, creating the risk of opportunism and high transaction costs. Most of the literature of the transaction costs framework argues that there are more than transaction costs that matter (such as transaction value, see below), or that there are other solutions (e.g. trust) to problems of opportunism than vertical integration when the long view of repeated interaction is taken into consideration. While we agree with these critics, our view is that there are other important reasons to avoid investing in specific assets, especially in volatile markets. Even where inter-organizational trust can be developed, market volatility can cause disruption to long term relationships that makes investment in assets specific to any single firm's products an unwise proposition since both absolute and relative market positions can change with breathtaking rapidity.

A key factor facilitating the growth of outsourcing is the lead firm's desire to achieve greater strategic flexibility and lower risk by reducing fixed investments, especially in manufacturing facilities. Such considerations are especially important when the technological change is rapid and market volatility is high, contingencies which make effective capacity planning and efficient capacity utilization of in-house or externalized specific fixed assets extremely difficult. Suppliers, then, are used to ramp output up and down according to changes in demand. For their part, suppliers are able to achieve relatively stable demand profiles, high capacity utilization rates, and low costs by pooling demand from a large number of customers *if* process technology depends not on specific assets, but on *generic assets*, assets that are widely applicable to the entire customer pool, *and* suppliers have the capacity to capture complex requirements from multiple customers and transform that data into a format usable by their generic processes.

Because complementary competence scopes exist in inter-firm collaboration, co-evolutionary processes are driven by each firm's managerial discretion, and the performance feedback of existing inter-organization relations. But contingencies that are external to the inter-firm relationship matter as well. For example, external contingencies serve as critical sources of influence on managerial decisions when frequent technological changes increase the cost of investments required to keep existing capabilities, the flexibility of operations can be diminished, especially in the face demand fluctuation. In addition, the competitive pressures in end markets may force lead firms to seek cost advantages through scale, scope and learning effects in critical competency areas, which further enhances the advantages vertical specialization. Moreover, time-to-market becomes a key survival

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quickly as the electronics industry as a whole (*Economist*, 02/12/2000).

(not success) factor when rapid technological change combines with competitive pressure to shorten product life cycles (Curry and Kenny, 1999). Yoffie (1997) highlights the criticality of both technological changes and competitive pressure in driving many electronics-related industries to toward a horizontal industry configuration, where competition occurs among firms that have become specialized in specific stages of the value chain. These two external contingencies then serve as a significant impetus for lead firm decision makers to focus the firm's competence scope and continuous investments a specific area of expertise while leveraging suppliers' competence. In brief, the lead firm's proactive response to a changing environment induces suppliers to enhance their competence scope and increase strategic outsourcing, actions that have the result of reinforcing a horizontal industry structure.

The lead firm's increasing reliance on the competence of its suppliers will often be balanced by an effort to exert some degree of control over inter-firm transactions. Specifically, any conflict of interest resulting from the supplier's aggressive expansion of competence scope into areas deemed core to the lead firm will weaken collaborative activities. This potential damage to future business can in turn become a powerful feedback to the supplier's competence development. In addition to the use of asymmetric competence levels to exercise external control, a lead firm can implement either multiple sourcing (e.g., McMillan, 1990; Porter, 1985) or parallel sourcing (e.g., Richardson, 1993) to enhance its bargaining power over suppliers.

Facing the lead firm's strategic motivation to maintain flexibility and control, a supplier has to structure its businesses in a strategic manner. As mentioned earlier, a supplier has to define its competence scope as an initial condition and make it as a bet on a co-evolutionary process with its customers and potential customers (Levinthal and Myatt, 1994). The choice of competence scope will be made concurrently with the decision regarding which lead firm(s) the supplier is going to serve. Two critical decision rationales, among others, are risk reduction and learning opportunities, which in turn constitute feed-forward factors in the co-evolutionary process.

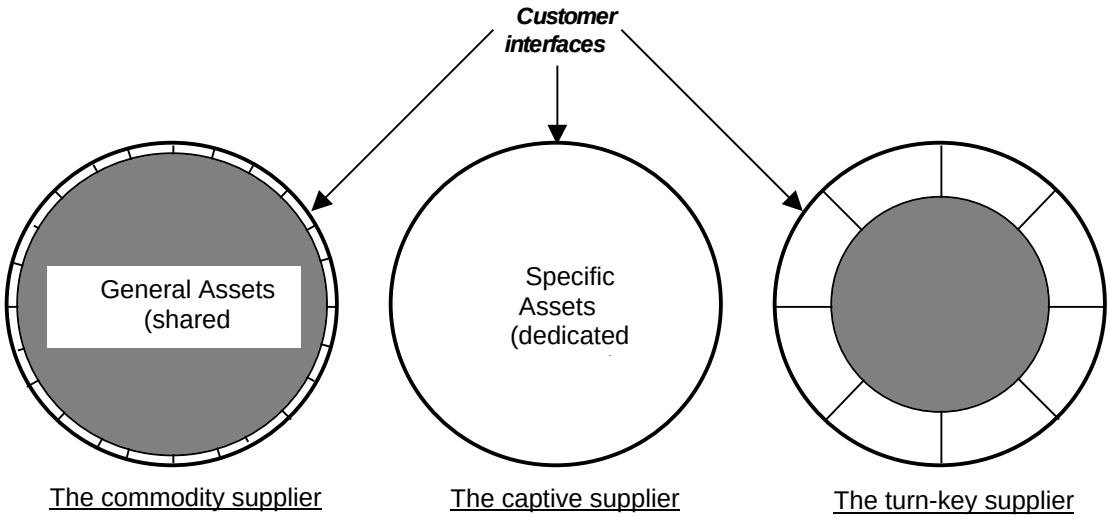
Take, for example, a supplier's focus on manufacturing competencies. The supplier has to continually upgrade its manufacturing competence to ensure its competitiveness. However, there are risks associated with continuous investments in manufacturing competence. Transaction cost theory suggests that the implementation of safeguards for relation-specific investments are required to reduce costs due to potential transaction hazards. Long-term supply contracts or captive supply relationships may suffice for this purpose. Nevertheless, as already discussed, transaction costs are not a sole concerns that organizing inter-firm relations. Instead, future value creation through relation-specific investment could also sustain a healthy development of inter-firm relations (e.g., Zajac and Oslen, 1993; Madhok and Tallman, 1998). In fact, modern manufacturing knowledge, e.g.,

modularization or design proliferation (Baldwin and Clark, 1997; Sanchez, 1996), could substantially help suppliers to reduce the degree of asset specificity while maintaining its capability to offer customized manufacturing services. Having such capabilities, the supplier could further expand its customer base and serve new application areas. In other words, given the right mix of capabilities, a supplier could reduce its business risk through structuring a multiple-customer and/or multiple-business profile.

Figure 1 compares the standard supplier archetypes, which we refer to as *the commodity supplier* and *the captive supplier*, with the supplier having a strong multiple-customer and/or multiple-business profile, which we refer to as the *turn-key supplier*. Commodity suppliers depend on generalized assets (and often produce standard products), and because they connect to customers largely via arms-length market transactions, only a very thin customer interface is needed, such as a telephone order or a mailed or faxed order form. As price is the key factor structuring outsourcing decisions, and since thin linkages and standardized products make supplier switching easy, commodity suppliers are often found in what Nishiguchi (2001) would refer to as exploitative supplier networks. Captive suppliers depend on dedicated assets, and in extreme form would serve only one customer and therefore have a single, extremely thick customer interface optimized for high levels of collaboration. There is general agreement in the literature that parties to transactions in networks comprised of captive suppliers would be protected from opportunism by reliance on long term relationships, trust, equity ties, or some other form of thick linkage (Richardson, 1972; Thorelli, 1986; Johanson and Matson, 1987; Lorenz, 1988, 1992; Jarillo, 1988; Bradach and Eccles, 1989; Powell, 1987, 1990). In Nishiguchi's framework, captive suppliers would tend to be found within symbiotic supplier networks.

In our view, this dyadic view of suppliers is misleading. In practice, many suppliers seek to limit interdependence with customers and to diversify their business profiles, while at the same time building up generalized assets *and* thick customer interfaces relative to the commodity supplier archetype. We refer to such suppliers as *turn-key suppliers*(Sturgeon 1997, 2000) because of their relatively independent stance toward their customers, their high level of competence, and their leveraging of generalized assets to serve multiple-customers and/or multiple-businesses (hereafter MC/MB). A core competence of turn-key suppliers is an ability to use their generalized assets to serve the very specific needs of their customers, which are understood and monitored via relatively thick customer interfaces (comprised, for example, of customer-specific program and product management teams). Turn-key suppliers represent more than a point on a continuum between commodity and captive suppliers because their existence can change the character of entire industries by creating supply bases that are shared by a wide range of lead firms while allowing a great deal of non-price data to flow across the inter-firm linkage.

Figure 1. Comparison of Dyadic Supplier Archetypes with the Turn-key Supplier: General vs. Specific Assets



A MC/MB customer profile not only reduces a supplier's risks of high fixed investment but also can create industry-wide learning opportunities. Competence-building through learning from partners has been indicated as one of the strategic goals of inter-organizational collaborations in general (e.g., Hamel, 1991; Lei and Slocum, 1992; Khanna, Gulati, and Nohria, 1998; Madhok, 2000), and vertical relations in particular (e.g., Bettis, Bradley, and Hamel, 1992; Lee and Chen, 2000). Depending upon the strategic intent (Hamel, 1991) and absorptive capabilities (Cohen and Levinthal, 1990) of respective partners, both explicit and embedded knowledge can flow through collaborative initiatives and be internalized by partner firms. In the case of upstream/downstream alliances, a turn-key supplier can acquire, among others, market information, design concepts, technical specification, quality standards, and process parameters through working with contracting partners of a higher level of competence.

Two of the key pitfalls of strategic outsourcing are creation of new competitors via supplier upgrading and loss of critical resources through suppliers that might be shared with competitors. There is substantial research that highlights the potential threat to the buying firm from suppliers' aggressive learning and subsequent entry into the buyer's business territories (e.g., Bettis, Bradley, and Hamel, 1992; Makides and Berg, 1988). However, we argue that within the context of shared supply networks supplier learning is often consistent with the achievement of collaboration value. When the supplier's existing competence leverages a MC/MB structure, it can add value to the buyer

from which it acquires knowledge while maintaining its value chain specialization. For example, a supplier of manufacturing services can lower its prices and widen its field of learning by spreading its fixed investments across a broad business portfolio. A more capable supplier could further improve its service by leveraging its existing product or process competencies learned from other buyers. In other words, the common benefits accrue to each partner by using a shared supply network will be no less, and often greater, than the benefits the supplier could realize unilaterally (Khanna, Gulati, and Nohria, 1998). Eventually, learning from working with multiple lead firms contributes to a significant feed-forward dynamic (Levinthal and Myatt, 1994), guiding the supplier's initiatives to expand its competence scope.

Similarly, because they rely to a high degree on a core of generalized assets, turn-key suppliers can often leverage knowledge gained from one customer in serving others. Since the supplier's core assets are by definition generic, there is little danger that the improvement of services for other customers, even those who might be direct competitors, will seriously erode lead firms' core competitive advantage. Advantages from access to generic assets—low cost, high quality, and highly responsive manufacturing for example—are further reduced when product life cycles are extremely short, as they have become in a broad range of sectors.

Beyond industry- and firm-level factors underlying the co-evolutionary process, different institutional arrangements in which firms are embedded will affect strategic choices concerning competence scope and inter-firm linkages. Institutional factors serve both as facilitating and restricting forces on a firm strategic and organization adaptation (Lewin, et al., 1999). Among others, geographic proximity may play a nontrivial role in facilitating inter-firm resource exchanges and the fulfillment of customization needs (Porter, 1998). Further, differential capacities of capital market could limit a firm's strategic options in constructing new inter-organization relationship through acquisitions. The existence of efficient multiple-tier supply networks constitutes a supportive infrastructure that could render first-tier supplier less of a threat and more of an asset for lead firms.

Industry co-evolution

The key micro-level features that allow suppliers to become widely accessible are the quasi-merchant nature of inter-firm transactions and the generic nature of the products and services that suppliers provide to lead firms. At the macro-level, the system requires widely accepted standards to describe components and finished products, and process technology that resists the build-up of specific assets and thus remains effectively generic. At the meso-level, which is the level we would like to stress here, the emergence of significant numbers of turn-key suppliers can create a capacity pooling effect, in which lead firms can easily connect to—and disconnect from—production and

service capacities that reside externally in the supply-base. The existence of high bandwidth inter-firm linkage mechanisms allow for the build up of specific assets to the degree that inter-organizational collaboration and learning can take place (creating transaction value), while the generic nature of the core products and services provided puts limits on the build-up of asset specificity and keeps the threat of opportunism from hindering inter-firm collaboration. Pooling effects and low barriers to relationship exit are created by the generic nature of the products and services provided and the MC/MB profile of turn-key suppliers.

An industrial supply structure of this kind can be regarded as a *modular production network*. Within modular production networks the forces of symbiosis and exploitation are so entwined as to render the dualism less than useful. Furthermore, competition becomes part of the analysis because lead firms can compete head to head while sharing the same set of suppliers and in some cases, even the same facilities. We argue that shared supply-bases, as they come into existence, exert profound effects on entry conditions, the nature of subsequent competition, and future outsourcing decisions. These effects are distinct from those that can be expected to arise from cases where production networks are discrete and evolve along classically exploitative or symbiotic lines. Shared supply bases, as in the modular production network, tend to generate a powerful self-reinforcing dynamic—a classic network effect—because pooling effects create large external economies of scale and scope and powerful learning effects that induce an increasing number of lead firm to tap the network, which in turn further enhances the competence, scale, and scope of the turn-key supply-base and induces more lead firm to participate.

A tale of two supply-bases: the co-evolution of electronics contract manufacturing in Taiwan and the United States

To illustrate the heterogeneity of supply-base/lead firm co-evolution in the electronics industry, we conduct a comparative analysis of two types of electronics contract manufacturers which have emerged from heterogeneous institutional environments, namely "original design manufacturers" (ODM, hereafter) based largely in Taiwan, and "electronic manufacturing service" (EMS, hereafter) firms based largely in the United States. These two sets of contract manufacturers have played a vital role in setting new patterns of global production and hence in altering the dynamics of competition in electronics and computer-related industries. We make our comparison of ODM and EMS contract manufacturers by mapping three dimensions of competence scope in each group of firms: value chain scope, product/customer scope, and geographic scope.

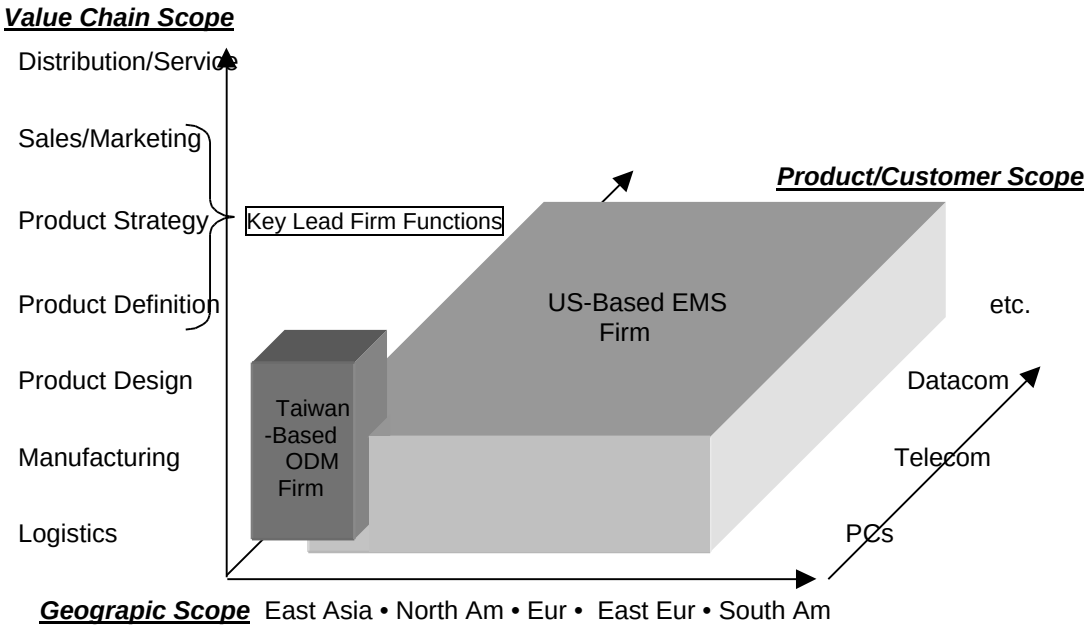
The ODM contract manufacturers are closely associated with a cluster of personal computer-related hardware producers based in the Taipei-Hsinchu corridor in Taiwan, but have increasingly

moved production of the most price sensitive products, particularly desktop computers, to Mainland China. The percentage of total manufacturing output in China was estimated to be around 35% in 1999, and is expected to increase up to 50% in 2001 (MIC, 2000). EMS firms exist in many places throughout the world, but have over time come to be increasingly dominated by firms based in North America (the largest five firms are based in Silicon Valley, CA; Huntsville, AL; Toronto, Canada; and St. Petersburg, FL).

ODM and EMS firms show significant differences in all three dimensions of business scope mentioned above. ODM firms provide wider range of value-chain activities than do EMS firms, especially in the area of post-architectural product design and development. Lead firms such as Compaq and Dell have retained marketing, product strategy, and much of conceptual design; and ongoing innovation by component producers Intel and Microsoft dictate most of the standard personal computer architectures that post-architectural product design must adhere to; but the ODM firms have become world leaders in bringing personal computer products to market quickly by joining product concepts developed by personal computer companies with the changing product architectures dictated by the component makers. EMS firms concentrate on the base manufacturing processes that are common to most of the electronics parts or subsystems, particularly circuit board- and product-level assembly, and have been much slower to develop design competence. This difference in value chain scope is related to their differences in product scope. EMS firms are able to leverage the same production processes across a wide range of product categories, including computers, communications equipment, consumer electronics, electronic instruments, industrial electronics, medical electronics, and electronics for military and aerospace applications; while ODM firms concentrate their product portfolio in personal computer-related categories, an area where they have built up design capabilities.

ODM and EMS firms are also different in regard to the geographic scale and scope of their production facilities. Owing to their aggressiveness in acquiring the divested production assets of lead firms and their response to customer requests provide on-stop global manufacturing services, the largest EMS firms have many more manufacturing locations than do ODM firms. As EMS firms have set up global operations, logistics and supply-chain management have become important competencies. ODM firms, on the other hand, have their manufacturing sites located almost entirely in Taiwan and Mainland China. The differences between ODM and EMS contract manufacturers are summarized by Figure 2.

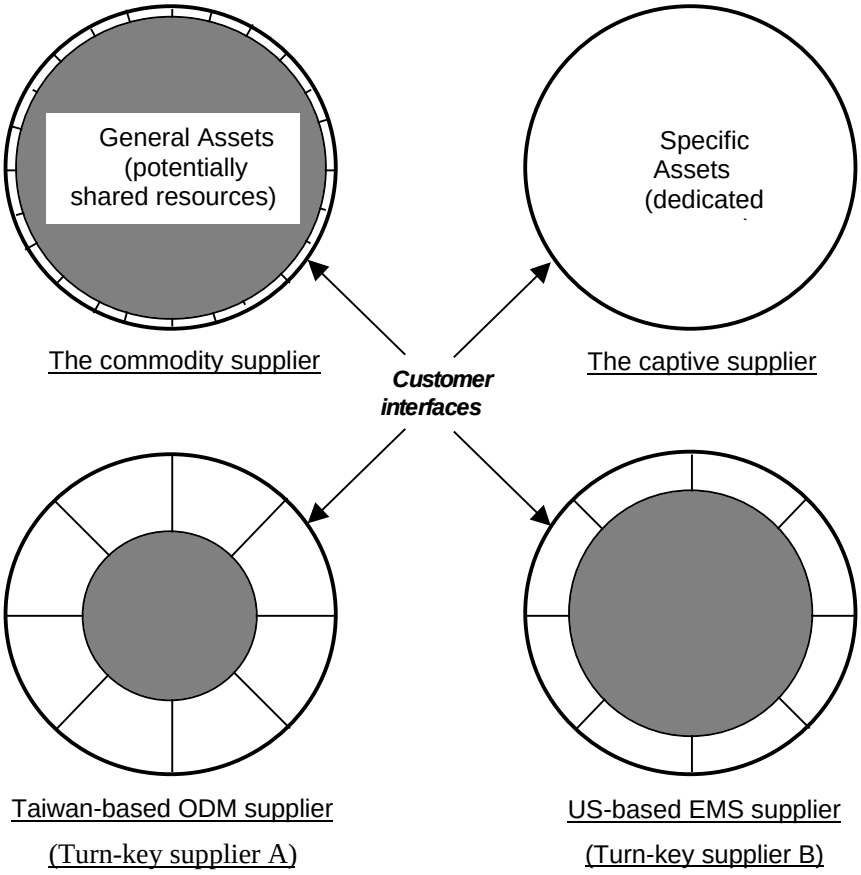
Figure 2. Comparison of Typical ODM and EMS Electronics Contract Manufacturers: Value Chain Scope, Product/Customer Scope, and Geographic Scope



The difference in value chain scope between ODM and EMS contract manufacturers alters the character of the inter-firm linkage. The ODM supplier's involvement in post-architectural design requires a thicker linkage mechanism than EMS suppliers. By adding design and development competencies to highly competitive manufacturing capabilities, ODM firms help their customers, the large branded computer systems firms such as Compaq and Dell, to speed time-to-market and increase cost competitiveness. Still, even when product design services are provided, the buying-supplying relationships with customers are largely not captive or exclusive. Lead computer firms rely upon a multiple sources in order to enhance their purchasing power and operating flexibility. Modular design and manufacturing capabilities (Baldwin and Clark, 1997; Sanchez, 1996) are therefore a vital element of an ODM firm's competence profile. Figure 3 builds on Figure 1 above to include typical ODM and EMS electronics contract manufacturers, also denoted here are turn-key supplier types A and B). The main difference between the two is in the thickness of the customer interface, indicating a higher degree of asset specificity among ODM suppliers related to their design services. Asset specificity in EMS firms is generally limited to customer specific program and project management activities that strive to give the customer the impression that EMS production is "an extension of the customer's organization." At the center of both EMS and ODM firms, however, lie a core of general assets that can quickly be used to serve away from any one customer and toward

other existing and new customers. The specific assets that do exist in both the ODM and EMS firms, since they are much shallower than those of the captive supplier and are combined with a core of general assets, actually facilitate customer switching because they ease the process of initial collaboration. This points again to the unique character of modular production networks: that they are not simply a middle ground between exploitative and symbiotic production networks, but something entirely different.

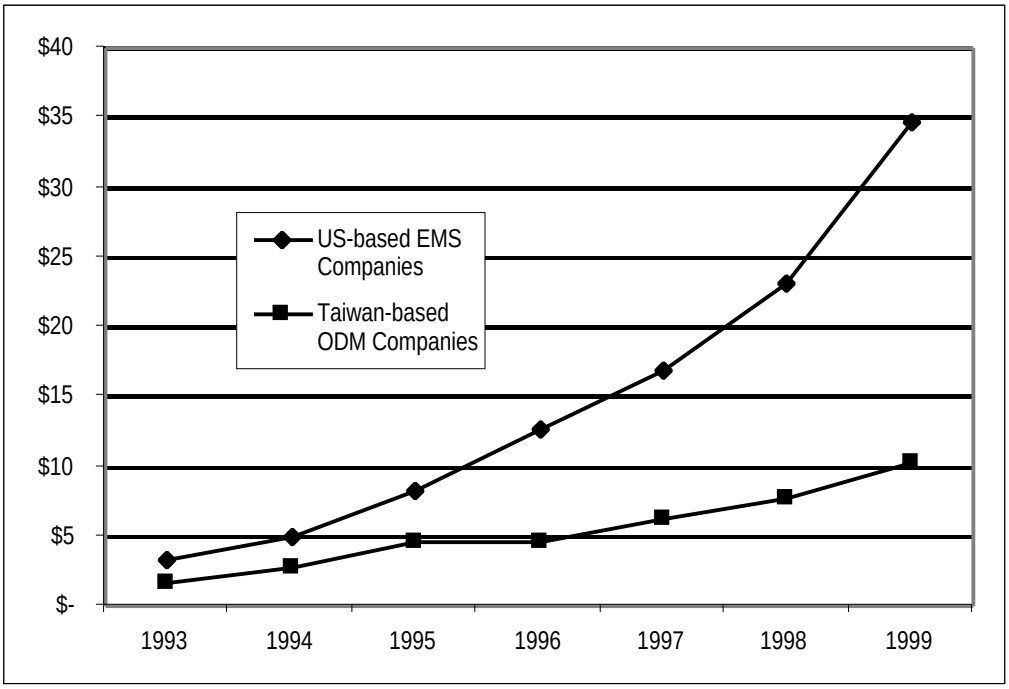
Figure 3. Comparison of Typical ODM and EMS Electronics Contract Manufacturers with Dyadic Supplier Archetypes: General vs. Specific Assets



As we have discussed and presented in Figure 2, the main differences between ODM and EMS firms fall along the lines of value chain, product/customer, and geographic scope. The implications of these differences for firm performance must await further research. One thing that is clear, however, is that revenue growth at the largest five EMS firms have outpaced revenue growth at the largest five ODM firm by a significant margin. Between 1993 and 1999 total revenues of the top five ODM firms

increased 35.5% annually from $1.7B to $10.3B. In the same period, total revenues of the top five EMS firms increased 47.7% from $3.3B to $33B.

Figure 4. Revenue Comparison of Largest Five ODM and EMS Electronics Contract Manufacturers: 1993-1999, Billions of Current US Dollars



Source: Company annual reports.
Note: Largest five EMS firms are Solectron, SCI, Celestica, Flextronics, and Jabil. Largest five ODM firms are Acer, Quanta, HonHai, FIC, and Mitac.

This differential may have to do with business scope differences. For example, the ODM firms' focus on a single electronics sub-sector, personal computers, may have limited their growth relative to the EMS firms, which have been able to expand into a wide spectrum of electronics subsectors, especially the burgeoning data communication and medical electronics fields. Another possible scenario has to do with value chain scope. Because ODM firms have expertise in product design, lead firms may have been wary about granting them too much business as they increased their strategic outsourcing, instead choosing EMS firms which, because they do far less design work, were perceived as less of a potential threat. Similarly, ODM firms may have fallen into a "competency trap" of sorts (Levitt and March, 1988). Because of their higher degree of specific assets related to design, ODM firms may have necessarily had to move more slowly into non-computer sectors because of the time required to build up the requisite design expertise. There are of course, possible causes of the growth differential between ODM and EMS firms that do not have to do with business

scope. Macro-level environmental factors, such as financial rules in Taiwan that make growth through acquisition extremely difficult, share price increases in the US in the 1990s that provided capital for the largest EMS firms to acquire dozens of customer facilities and smaller competitors, long experience by American managers with international operations, and perhaps a desire on the part of American electronics systems firms for spatial and social propinquity with their increasingly important outsourcing partners—at least on the headquarters level.

Despite differences both ODM and EMS supply-bases have contributed to the emergence of modular production networks in the electronics industry because they share the following key features:

1. Macro-environmental factors in the electronics industry that facilitate and encourage value chain modularity, including good product and component standardization; a highly codifiable design process; rapid technological change at the component, process, and final product levels; product and market proliferation; and rapid industry growth.
2. An overlapping set of customers, initially consisting largely of American electronics systems firms, which have proved willing to cede control over manufacturing to outside service providers.
3. A quasi-merchant, non-captive (MC/MP) stance toward customers and markets.
4. Reliance on a generic, easily transferable, widely applicable core of fixed assets.
5. Reliance on mechanisms to support a thick customer interface (relative to commodity suppliers).

Implications for strategy and further research

Our exploration on the emergence of shared, modular supply-base from a co-evolutionary perspective suggested a useful framework for understanding the changing nature of the modern industrial landscape, especially to the extent that it coming to be characterized by abundant strategic outsourcing and inter-firm specialization. Questions about the dynamics and evolutionary development of inter-firm vertical relationships across different value chains have implications for both the formulation of competitive strategy and for future research.

First, the argument presented in this paper suggests that the key organizational transformation that is underway is less a process of de-verticalization than a de-linking of production-related activities from innovation-related activities (Sturgeon, 2000). In Schumpetarian competition, innovative firms that gain market share build up large productive assets specific to the product in question, creating barriers to new entry. Building on Schumpeter's conception of innovation, Nelson and Winter (1982) show that the dynamic process of industrial evolution tends to create larger firms

and more concentrated market structures over time because successful innovations lead to higher profits and greater investments in productive capacity that put innovative firms ahead of their competitors and then protect them from new market entry. However, the emergence of modular supply-bases alters our thinking about the relationship between innovative capacity, firm size and scope, and entry conditions. Firms that outsource a large share of their manufacturing no longer have to carry the financial, administrative, and technical burdens of fixed capital related to production, allowing them to focus on innovation and become more organizationally and geographically flexible (Sturgeon, 2000: 16). On the other hand, the market position of dominant firms are no longer protected by large-scale firm-specific investments in plant and equipment, making market entry more feasible because existing firms are no longer buffered from competitive pressure by large, in-house fixed capital. Barriers to entry are lower because competitors can tap the same modular supply-base and therefore gain access to leading-edge production capacity. Thus, competition between lead firms becomes more tightly tied to product-level innovation, increasing the pressure on firms to execute in the areas of product development, brand development, and marketing. The rising costs associated with an intensified focus on innovation and marketing in turn makes it less likely that lead firms will invest in in-house productive capacity in the future, speeding the shift toward modular industry organization.

Second, our research on the emergence of contract manufacturing in general, shared supply-base in particular, creates a fruitful arena to explore the relationship between organizational capabilities and production routines. To be capable of providing turnkey production services at competitive prices, a contract manufacturer has to specialize in a set of generic production routines that can be efficiently applied across a wide range of customers. By doing so, a supplier can effectively elevate the level of capacity utilization and hence reduce overall costs. On the other hand, a contract manufacturer may have to accommodate various degrees of customer-specific needs for differentiation purposes. Furthermore, an increasing demand of providing services on a global scale requires a supplier to replicate and/or integrate its existing routines across national borders while maintaining service integrity. To be competitive and effectively managing its inter-organizational relationships in the such a setting, a contract manufacturer has to achieve organizational flexibility through carefully designed and implemented modular operational routines that allow the constant adjustment of its business scope along various dimensions. By including managerial intentionality and strategic heuristics (Nelson and Winter, 1982), our view of the contract manufacturer's evolutionary development can help to "provide a bridge between the predominantly descriptive concerns of evolutionary theory and the prescriptive analysis of firm strategy." (Dosi, Nelson, and Winter, 2000: 12)

Third, research on the changing patterns of industrial outsourcing and the emergence of electronics production network offers a great opportunity to examine the determinants of a firm boundary decisions. The traditional analytical angle for explaining boundary decisions lies in the transaction cost theory (Williamson, 1975, 1985). This theory requires decision makers to consider the costs that may be incurred due to transaction-specific investments made by either party in order to decide whether to outsource or produce in-house. However, as even complex transactions become by and large commoditized, and the buyer-supplier relationship within the context of modular production network become quasi-merchant in nature (Sturgeon, 2000), the outsourcing firm's concern over the costs of governing external transactions with suppliers becomes less important than its desire to benefit from access to capabilities that are costly to develop internally impossible to acquire through arms-length market transactions (Barney, 1999). In other words, the potential level of value that can be added by the production network becomes a critical determinant to the vertical boundary decisions between transacting firms and the extent of outsourcing activities (Zajac and Oslen, 1993). By opening up this line of inquiry, our research leads us to postulate an analytical framework of value creation based on the supply base's business scope and capability development.

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