THE NETWORK AS KNOWLEDGE

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Abstract

The imputation problem is the puzzle how to account for the sources of the value of the firm. I propose that part of the value of the firm derives from its membership and participation in a network. This network determines not only access to information, but also constitutes itself capabilities that support coordination and learning among member firms. The boundaries of the firm are determined in a dynamic between the development of knowledge in the market and knowledge in the firm. Knowledge in the market grows not only due to the specialization of firms, but also because generative rules of cooperation give rise to an evolving network. However, whereas the value of firm-level capabilities is coincidental with the firm as the unit of accrual, ownership claims to the derived value of a network pit potentially firms in opposition with one another. We analyze the work on network structure to suggest two types of mechanisms by which rents are distributed. This approach is applied to an analysis of the Toyota Production System to show how a network emerged, the rents were divided to support network capabilities, and capabilities transferred to the United States.
The opposition between market and firm is a commonplace belief that yet rests uneasy with particular facts. The common proposition that a viable firm is worth at least the sum of its parts rests on the supposition that organized coordination is a source of economic value. Winter (1987) has coined this problem of valuation as a question of imputation. In his formulation, a firm is the unit of account to which rents accrue. Imputation is, then, the assignment of a firm's value to its constituent parts, e.g. patents, people, and machines. The determination of a firm's value is the result of the uniqueness of these factors, their transferability, and their resistance to imitation by competitors. If these factors, and the knowledge of how to coordinate them, were imitable, then there would be no rent to impute. These conditions are equivalent to concluding that there are no rents to public knowledge.

This reasoning quickly points to the boundary of the firm as representing more than a legal definition of the firm as the unit of accrual, but also as signifying a qualitative barrier between the knowledge held privately and the knowledge that is public. But why should borders of a firm demarcate boundaries to the accessibility of knowledge? Consider the thought experiment in which the activities of a firm are moved to a new location, such as from the Silicon Valley to Atlantic City, or a firm is required to change suppliers over night. If we compensate the firm fully for the incurred costs of these changes, do we expect its value to be nevertheless preserved?

The accounting for knowledge stumbles, consequently, on an important problem: how do we impute the knowledge external to the firm. This puzzle is related to the interpretation of “total factor productivity” in macroeconomic growth accounting studies. After accounting for the contribution of inputs to economy-wide growth, the residual is attributed to exogenous technical change, institutional factors, or externalities. Alternatively, it is possible to specify explicitly the ‘imputed’ source of productivity gains:

$$y_i = a_i + \gamma a_m + \sum \alpha_i X_i + R$$
where $y_i$ is output of firm $i$, $a_t$ is a shift parameter, $\alpha_i X_i$ are weighted inputs (such as the value of capital and labor), $R$ is a residual, and $\gamma_m$ is the weighted value imputed to membership in a network (all terms are in logs). This formulation proposes that “network capability” is a source of imputed value to the productivity of a firm.

To state that the value of a firm is partly derived from the wider network implies that value is accrued net of the payments to other factors and firms. Either this value is gained because other firms have leaky property claims to the knowledge they create, or because firms through cooperation generate joint rents. In this latter sense, the locus of imputation is a firm's relationships in an extended network. This knowledge is not simply the information of who is doing what and at what price. Rather, this knowledge is also expressed in the knowhow or organizing principles by which the network is itself coordinated.

The most tangible expression of the direct value of external knowledge to the firm is the compelling evidence that rapid product development depends on the reliance on outside suppliers. Both Clark et al (1987) and Mansfield (1988) found that time to market was speeded through a policy of outsourcing to suppliers. The capability to commercialize products can in this case be seen to rest on the successful exploitation of the knowledge of other firms. In this sense, the competitive capabilities of a firm rest not only on its own knowledge or on its knowledge of the network. The capabilities of the firm, rather, are dependent upon the quality of the knowledge embedded in the principles by which cooperation among firms is coordinated and supported in the network.¹

This view of the network as knowledge confronts four analytical challenges:

1. What defines the boundaries the network?
2. What is meant by network capabilities?
3. How do network members sort out competing claims to rents?
4. If authority rights are legally assigned to principals and their delegates in firms, then how is the emergent property of network formation transformed into intentional replication of this knowledge through time?

¹ Most, if not all studies of networks treat knowledge as the question of knowing who has knowledge and the access of this knowledge through cooperative relationships. (See Powell, 1990, for example.)
In this paper, we explore the creation of value in the context of firms, markets, and networks. Networks are presented as a type of organization of economic activity that respects specialization and variation of knowledge and at the same time promoting variety. Networks can be emergent and work through the exchange of information (like prices) in markets, or be designed for the exchange and co-development of often tacit know-how between firms.

The contribution of this paper is to understand networks as arising out of generative rules that guide the formation of relationships by organizing principles of coordination. These principles in turn lead to network capabilities that are not specific to a firm, but represent joint gains to coordination and learning. We explain that the structural patterns that emerge in a network define two kinds of rents, one that accrues to a broker, the other more broadly to the members to a closed group. Because these capabilities are quasi-public goods to members, a central issue is how the rents to this coordination are made both exclusionary and sustainable in the face of potential defection.

Our reasoning rests upon three central ideas of what define a firm: unit of accrual, resolution of agency problems through residual claims, and the role of knowledge and social identification to a firm in defining their superior capabilities to organize some activities within its boundaries. While these three ideas are operative in the analysis below, we stress, in particular, the latter property of the firm in order to analyze how capabilities are generated by network coordination. To shift the understanding of networks as simply a resolution to agency conflicts, or as conduits of information, to their capabilities in promoting variety and yet coordination is the primary ambition of this paper.

**Specialization and Variance in Market and Networks**

A definition of an economic network is the pattern of relationships among firms and institutions. In this definition, an idealized market is a polar case in which firms transact at spot prices, are fully connected in potential transactional relations, and have access to public information flows. Few markets exist of this type. Rather, most markets consist of sub-sets of firms and institutions (e.g. universities) that
interact more intensely with each on a long-term basis. These patterns of interactions encode structural relationships that represent the network.

This structural definition fails to convey the observation that the structure of a network implies principles of coordination that not only enhance the individual capabilities of member firms, but themselves lead to capabilities that are not isolated to any one firm. At a minimum, the ability of a firm to access information in a network constitutes an advantage, e.g. the effect of accessing the technology of a research center on its subsequent innovations. Of course, this access is most likely the outcome of a bargain, in which the two parties arrive at an understanding of contribution and compensation. This sort of access, stressed by Powell (1990) among others, exemplifies the informational benefits of enhancing a firm’s capabilities through relationships.  

Cooperation, however, might also engender capabilities in the relationship itself, such that the parties develop principles of coordination that improve their joint performance. Such principles might be rules by how supplies are delivered, such as by just in time or mass production. Or they might involve more complex rules governing the process by which innovations are collectively produced and shared. In this sense, the network is itself knowledge, not in the sense of providing access to distributed capabilities, but in representing a form of coordination guided by enduring principles of organization.

The proposition that part of the value of a firm can be imputed to the capability of its embedded network is implicit in the treatment of the division of labor as handled by Smith through Coase and Chandler. The now classical question in the analysis of the boundaries between markets and firms is to pose the inquiry into the following question: if networks are structured by organizing principles, then why are they not organized with a common governance structure of a firm?

Networks offer the benefit of both specialization and variety generation. The superior abilities of markets to generate variety is a commonplace belief that is, nevertheless, problematic. The converse of this statement is that firms are superior vehicles for the accumulation of specialized learning. To understand variety, we must

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also understand why specialization and variety are antithetical within the firm, but define complements within a network.

Adam Smith (1965) recognized the power of the market to achieve variety through specialization in the division of labor. Smithian efficiencies in specialization were due to the inherent learning by doing by completing repetitive tasks, as well as the reduction in loss time due to changing tools and tasks. (This latter efficiency is particularly striking in light of the tremendous reduction in change-over time for producing variety in auto manufacturing.) At the heart of Smithian efficiencies is the implication that learning by doing, despite the initial endowments of equal competence among individuals, accumulates to lower the costs of subsequent production. Smith saw the division of labor as derived from the dynamic learning through specialization. He posited that people were largely similar in their a priori talents; differentiation into specialized competence was the outcome, not the precursor, to the division of labor. In other words, specialization through a division of labor is the driver of the acquisition of competence and, consequently, of knowledge.

We know, for example, that knowledge accumulates partially through learning by doing, or what is called experience effects. Lundberg (1961) identified the puzzle, called the “Horndal effect,” whereby a plant increased production of 2% annually during a 15-year period without investment in new equipment. Arrow (1962) attributes this effect to learning from doing. These experience effects are captured by individuals assigned by a division of labor to specialize in repeated tasks, or through improvements in coordination among groups. Either source of gain points to organizing principles that generate a division of labor determining the specialization and coordination of knowledge in individuals and groups.

The organizing principles that determine the division of labor determine the patterns of learning. To change these principles by which work is organized, structured, and coordinated is to change the evolution of future learning. The perspective of the firm as a repository of knowledge embraces Smith’s observation on experience-derived learning through a division of labor as posing both a coordination problem as well as determining dynamic paths of knowledge acquisition. Firms are

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3 Horndal was an iron producing firm in the Swedish Fagersta group that was “ignored” in investment terms for a period of 15 years starting in the mid-1930s.
social communities that permit the specialization in the creation and replication of partly tacit, partly explicit organizing principles of work.

The benefits of specialization are limited by the size of the derived demand, but also by contractual and agency hazards. Williamson (1975) observes that specialization through the division of labor creates contractual hazards that may influence a firm to expand its borders beyond its strict comparative advantage. (If a firm has a comparative advantage in an activity, transactional hazards are irrelevant to the boundary decision.) Thus, in this view, a boundary does not represent an etching along an efficient frontier derived from production costs, but is shifted to encompass activities in which a firm should not specialize, if for these contractual hazards of relying on outside suppliers.

The theoretical perspectives of firms as knowledge or as resolutions of governance conflicts are often complementary. In both perspectives, coordination is implicitly a defining attribute of the firm. Knowledge approaches emphasize coordination through implicit rules or authority relationships rooted in common identities. Governance perspectives (e.g. transaction costs, principal-agent) stress the contractual nature of the authority relationship whereby a principal has directive (“fiat”) and monitoring rights over agents who cede a degree of independence over the use of their time.

Where these approaches differ is in their fundamental assumptions regarding the motivations for people to associate within groups to which they attach moral and existential significance. These differences have important implications for the design of work. For example, whereby a governance approach might emphasize the creation of high-powered financial incentives to reveal information and motivate behavior, knowledge-based views of the firm anchor incentives in how social comparisons enforce or destroy the social identities that support cooperation and coordination.

Firms, in general, are built on the inherent property of individuals to identify with larger collectives. These identities serve to anchor perceptions of self in stable cognitive orientations and act as focal points for coordination among individuals and groups. Kreps (1990) has noted that the economic theory of the firm relying on incomplete contracts (i.e. the inability to write contracts on future and uncertain contingencies) implies that managers cannot before hand be told what to decide.
Incentives to decide correctly do not provide the necessary information regarding how to decide. For this purpose, corporate culture serves to dictate particular focal rules by which to coordinate individuals.

But why are firms required to provide this culture? The recursive logic leads to the central issue why should these focal rules be more effective in a firm than between firms? The behavioral sciences provide an important insight. Boundaries to a firm represent more than legal unit of accountability; they provide the cognitive representation of what constitutes the object of membership, that is, of identity. Through identity, individuals anchor their perceptions of self and other, and by this anchoring, they develop the focal rules by which action is coordinated and intention communicated through common categorization. More importantly, through identification to occupation and firm, individuals are guided and motivated along coordinated paths of joint learning. Boundaries matter, because within the cusp of these social membranes, identities are circumscribed. The behavioral foundations to why the knowledge of the firm is bounded are to be found in the basic human motivation of belonging and membership.

The implication of this recursive logic is the conclusion that a Ricardian rent arises out of the scarcity value not only of land or technology, but also of behavioral coordination. We can label this a Penrosian rent, as it is associated with the value of individuals whose activities are better coordinated within the confines of a firm than within the context of a market.

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4 See Kogut and Zander (1996) for a review of supporting studies.
5 The classic portrayal of coordination is as a battle of the sexes, but, as Kreps notes (1990: 101n), the point of coordination is arbitrary; we do not know why different expectations should exist in firms than outside them. Even in the analysis of Hart and Grossman (1986)—which is a theory of ownership—the argument begins with a presumption that one owner values an asset more than another. But why should assets be differentially valued? In other words, ownership is unquestionably influenced by differences in value placed upon firms as units of accrual, but ownership does not inform us as to the sources of the valuation itself.
6 This argument is developed in Kogut and Zander (1996) and draws heavily on cognitive theories of Lakoff, Rosch, and Lave. It shares similarities to the concept of “transactive memory”, with the distinction that this memory is not the discovery of the competence of members to a team, but rather the sharing of a common heuristic by which to categorize events. See Liang, Moreland, and Argote (1995) on transactive memory.
7 Indeed, the very notion of opportunism—which is the engine of the transaction costs explanation of boundaries—is inverted by the recognition that identities serve to label other members as altruistically motivated, and outsiders as opportunistic. In this ascription lies the economic value of membership, but also its costs.
If identity lowers the costs of communication and coordination and drives the path of learning, it comes at a cost. For identities represent a norm which indicates avenues of exploration; by implication, it also prohibits certain paths. Organization by firm is variety reducing. The great power of the market is not only its information properties, but also its function as a generator of variety in innovations and capabilities that are subject to the selection. The “market”, as an assemblage of firms pursuing different visions and organized by distinct identities, generates a variety that individual firms cannot manufacture internally without decrement to the salience of focal rules, i.e. to the organizing principles (inclusive of compensation and incentive schemes), by which work is coordinated.

These observations are important because they force a recasting of the received wisdom on the relative merits of markets and firms. Curiously, the initial statement of Coase is compatible with the view that the structure of external relationships influences boundary between firm and market. Coase (1937) posited that this boundary is determined by the internal costs of production and management relative to the costs of market search and procurement. Market search costs are higher when information is scarce. It is logical to infer that markets, which reduce the costs of this search, decrease the attractiveness of internal production.

Coase, however, left unexamined the issue how structure reduces the costs of search and coordination. Chandler’s (1963) early contribution was to explore how higher-order organizing principles of divisionalization could reduce the costs of internal complexity. His history of the innovation in internal hierarchy pointed to the role that structure plays in reducing the costs of coordination and authority. More importantly, divisionalization increased the internal variety of the firm by separating potentially competing visions into relatively contained units.

Figure 1 presents a simple diagram of the Coasian firm. Since Coase acknowledged market search and management costs, it is reasonable to think of these costs as increasing as the variety of products are produced internally or sourced externally. We index these costs as increasing in relation to a set of products that reflect the identity of the firm. At low variety, a firm produces at lower cost than purchasing from other firms; this condition is simply to guarantee the existence of the firm. At some point, the internal management of increasing variety becomes more expensive than
sourcing variety from the market. It is straightforward to diagram the effect of a Chandlerian innovation; it reduces the costs of managing internal variety.

Stigler (1951) made the important observation that the division of labor is limited by the extent of the market. By pointing out that a firm’s area of specialization is constrained by a downward sloping demand curve, he implied that its competence in one area of work diminishes as it is applied in less related markets. This aspect of knowledge, which has been highlighted by the analysis of Becker and Murphy (1992), is also evident in his prediction that firms integrate early in the life cycle of a market, then disintegrate as the market matures, before reversing this again when the market declines. The reason for this pattern, explained Stigler, is that early in the life cycle of a product, other firms do not have the knowledge or scale to produce the required components. Over time, the external “market” learns and the pivotal firm can outsource in sufficient scale to justify suppliers to invest in the necessary capital assets. This dynamic leads a firm to extend its organizing principles, or knowledge, over a larger terrain of economic activity.

Stigler’s theory of the division of labor is, in consequence, a theory of knowledge in the market. Just as a firm learns, so does the market insofar that suppliers come to substitute for internal production.8 In effect, the variety of the firm decreases as the knowledge diffuses to the market improves. Figure 2 illustrates this idea by showing how improvement in the efficiency of the market reduces the internal variety of the firm.

There is a final consideration of transaction costs in this static portrayal of the boundaries of the firm. Transaction costs has the predictable effect of reducing the reliance of a firm on a market. Demsetz (1988) has argued that the decision to make or buy is determined by the consideration of four factors: (1) internal costs of provision (2) plus the organizational costs of coordination relative to the (3) external price prevailing in the market plus (4) the transaction costs of ex post dependency. Whether the Williamsonian transaction costs critically determine the boundary decision is a question of the magnitude of transaction costs compared to the other factors of price, internal provision, and internal organization costs. Figure 3 illustrates the simple case in which

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8 Stigler also suggests at the end of his article that a firm might have to expand as it internationalizes because foreign markets may have less knowledge. This insight also suggests that in countries with impoverished market knowledge, business groups and highly diversified companies should be relatively more common.
Demsetz organization costs lowers the variety of the firm, while Williamsonian transaction costs leads to increased variety of production inside the firm.\textsuperscript{9} Thus, knowledge and governance views are complementary theories of firm and market boundaries.

**Simple Rules and Emergent Networks**

This static portrayal of the boundaries of market and firm has important implications for the dynamics of learning and competition. Smith’s and Stigler’s emphasis on specialization driving learning is the cornerstone of Hayek’s contention that the market is the engine of variety (Hayek, 1988). Hayek’s contribution is often credited for his observation that markets are superior than hierarchies for embedding information in prices. But Hayek, even in his heralded 1945 article on information, meant something more. Knowledge is held tacitly, raising the problem of how central planners could ever know as much as decentralized firms. Specialization is self-preserving, even if markets generate information as to their valuation and accessibility, because prices can be communicated, but not competencies. The dynamic advantage of the market is the generation of variety through an “extended order” that supports coordination among specialized firms.

Hayek’s notion of the extended order poses the question of what generates the structure of the network. Is the emergence of these network structures random or do they reflect the operation of operating principles that act as genetic rules?

A simple example is a tit-for-tat rule as analyzed by Axelrod and Hamilton (1981). By analyzing the convergence properties in a population in which agents use different rules for cooperating and defecting, they found that particular rules, especially one that rewards for cooperation and sanctions for defections on the next round, tend to dominate. Convergence, however, is frequency dependent and thus vulnerable to tipping in either direction. The implication of this analysis is that structure that isolates “cooperators” tends toward self-organizing communities of cooperation.\textsuperscript{10}

\textsuperscript{9} Walker and Poppo (1990) confirm in an empirical analysis Demsetz’s hypothesis that the marginal costs of internal and external transactions (inclusive of production and opportunism costs) are equal.\textsuperscript{10} For an insightful analysis of how structure influences diffusion (e.g. cooperation), see Boorman 1974.
There are many studies whose results imply the operation of rules. As White suggests, these rules derive from competing identities (White, 1992). For example, the study by Podolny and Stuart (1995) is based on the rule that high status firms do not ally with low status firms. Identity is also revealed in the study by Padgett and Ansell (1993) who infer the rule, based on the analysis of the marriage and economic networks of Florentine families in the fifteenth century, that aristocratic families did not interact socially or economically with the new families. By mild violations of the rule forbidding economic ties, the Medici family influenced the structure such that they were two times more central in the network than the next family (Wasserman and Faust, 1994).

The rule in the biotechnology industry was the following: start-up firms should form alliances with established companies. The origin of the rules lies principally in the lack of financial resources and marketing and distribution capabilities of the start-up companies. Venture capitalists, concerned by the “burn rate” of the initial capital provisions to these companies, required relationships to avoid costly expenditures and to signal the quality of the drug portfolio. (See Shan, Walker, Kogut, 1994). The outcome of these rules is a pattern of alliances that as early as 1983, as shown in figure 4, are marked by the creation of several fragmented star and hub sub-graphs that reveal an emergent structure. (The structure is generated on the basis of the block-model data in table 3 of Walker, Kogut, Shan, 1997.11) Sometimes established companies are central; in a few instances, a new biotechnology company emerges as central.

The rules in the biotechnology industry that generate the relational structure are themselves products of the non-random distribution of capabilities that distinguish start-ups and pharmaceutical companies. Start-ups, consisting of molecular biologists, lacked certain capabilities. But by implication, pharmaceutical companies were unable to integrate the new science, built upon particular professional identities, with their traditional research endeavors. Identification limited, at least initially, the variety of pharmaceutical companies (see Zucker and Darby, 1995). Specialized by differentiated capabilities, their mutual need suggested a rule of relationship formation that generated distinctive patterns in the structuration of a cooperative network.
This dynamic between internal capabilities, ensconced in specific identities and organizational structures, and the external knowledge in the market drives a co-evolution between the emergent properties in the firm and network. Even though markets and firms are organized by different principles, there is nevertheless a correspondence in their structure and properties. We return here to Smith’s and Stigler’s argument that differentiation in the knowledge of the firm and market influence boundary decisions. More radically, the constant dialectic between market and network capability drives a co-evolution that results in a correspondence between their structures.

An example serves to illustrate this correspondence. The excellent study by Annalee Saxenian (1994) in her comparison of the structure of semiconductor and computer industry networks in the Silicon Valley and Route 128. She found that the two regions had very different network structures, even though the technologies and industries were the same. In figure 5, we graph her ethnography. The top panel shows a hierarchical structure in Route 128; a few large firms dominate smaller companies. The Silicon Valley shows a decentralized network. Is it a coincidence that the internal structure of the Silicon Valley is described as flat and that of the Route 128 firm as hierarchical? Why should the internal structure correspond to the external structure?

In the case of the Silicon Valley, there is an institutional foundation that supports the flow of information and matches engineer to project and firm. Obviously, it is rarely in the interest of the current employer to see proven research talents exit their firm, and it is in their interest to discourage involuntary exits. The evolution of a labor market for talent counters potential negative sanctions by the current employer. That is, there are a sufficient number of job opportunities so that in the event the engineer exits in the future (because the hiring firm dies or the new project opportunity ends), subsequent sanctions by former employers are unlikely to be effective. A market consisting of many small networked firms cannot generate effective sanctions on the mobility of engineers. There is, as a consequence of high mobility, less motivation to build a vertical hierarchy by which to promise future rewards.

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11 I thank Jon Brookfield for suggesting this graph.
A labor market that is dominated by a few large firms permits sanctions through refusal of these firms to rehire the engineer or through their signals to other client firms in the area. These sanctions need be no more than the loss of relative ranking in the internal hierarchies of these dominant firms. (Note that the internal labor markets of Silicon Valley are characterized as flat; tall hierarchical ranks are not viable if labor market mobility is high and work is organized by projects.) If a regional market does not support labor mobility, then individual engineers are likely to seek internal advancement, or—and it is important to stress this implication—to migrate from the region. (See Almeida and Kogut, forthcoming, for evidence.)

The link between internal and network structure is the recognition that firms and markets are jointly emergent phenomena. Not only are their boundaries determined by the relative knowledge. Their structure reflects the emergent properties that influence information and incentives, as well as the know-how and coordination, that inform firm and individual strategies. The structural opportunities through labor market has a powerful effect on differentiating the orientation of professional identities. In the hierarchical network of Route 128, engineers identify themselves with internal labor markets; the Silicon Valley encourages identification along professional competence in projects.

The comparison between the Silicon Valley and Route 128 raises the important distinction between emergence and intentionality in network structure. Networks are rarely formed by design, but rather they emerge initially in response to the institutional and technological opportunities of an industry or field. During this process of formation, relationships develop out informational properties that drive a matching process among firms. However, over time, knowledge that is initially information gradually becomes expressed in persisting structures that influence subsequent behavior.

Structures thus are not given by exogenous determinants, but are expressions of multiple and evolving rules that guide the behaviors of interacting entities. Sometimes, governments impose these rules. A rule that establishes monopolies compared to

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12 This line of argumentation comes closest to Coleman (1990: 439ff.), who assumes that external labor markets are competitive markets. He thus does not consider the relationship between the type of external and internal labor markets and its effects on the location of innovation. For an analysis of a related problem, see Anton and Yao (1994).
another that regulates prices has dramatic implications for the emergence of industry structure and organizing principles of coordination and competition. The effects of government discretion generated widely different industrial and relational structures among countries (Hughes, 1983). Sometimes, inherent technological characteristics favor the emergence of particular rules. A technology that enjoys scale economies tends to generate large firms; another technology, such as microprocessors (see below), tends toward network externalities. These characteristics influence size distributions and the structure of a network. Similarly, institutional contexts (e.g. socialist or capitalist, German or American legal environments, etc.) influence the origins and formation of networks. Because markets and firms are not simply given, but vary in their institutional origins and technologies, there are no generic rules that are exogenously constant. Rather, the systemic interaction of technological, organizational, and institutional factors influence the evolution of network structure.

**Capabilities and Rents**

The literature on networks is bifurcated among studies that analyze the effects of network structure on behaviors (e.g. diffusion of an innovation) and those that attribute particular capabilities to network coordination (e.g. flexibility in regional networks to support innovation). In part, this division represents a distinction between content and structure. Yet, most studies suggest a correspondence between structure and content in understanding the capabilities of different kind of network coordination. Clearly, the emergent principles that guide the network formation also effect the capabilities of the network. In other words, we are interested in understanding the conditions in which certain network structures generate value that are captured differentially by participating firms.

The relevant question to ask, therefore, is whether there are rents in networks and to whom to they accrue? An answer to this question requires an understanding of the location advantages to information access in a network compared to membership.

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13 Many studies can be cited to support either line of inquiry. For example, Burt (1987) represents a refined analysis of competing measures of network innovation to understand innovation. More often, articles use cohesion measures (i.e. direct contacts) to describe the network; see Haunschild and Beckman, 1998, and Palmer et al., 1993, for examples. Studies on the capabilities of networks are found in many Italian and German studies, e.g. Lorenzoni and Baden Fuller (1995), Lipparini and Lomi (1996), Herrigel (1993), and Piore and Sabel (1985).
in a coordinated network. Call the first type of advantage a Burt rent. Burt describes the generation of network structure as the outcome of the competitive struggle among egos motivated by envy and self-interest. Individuals, firms, or even industries that have unique (i.e. non-redundant) ties with other entities who are not connected to others in the network are in powerful brokerage positions called “structural holes.” Burt has argued that firms that are positioned in structural holes are more powerful because they arbitrate the information flows between groupings of firms who have dense ties among themselves, but loose ties with each other. Such networks have a hierarchical structure, even if there are many hierarchies. In this network, the rent accrues to the firm bridging the structural hole.

The second type of advantage can be called a Coleman rent. Coleman stressed that dense ties among firms (or actors) result in a resolution to collective action problems. Coordination is improved through repeated exchange among stable members to the group. This network tends to be flatter. In this case, depending upon the quality of the interaction, the rent accrues to membership in the group, with the actual allocation determined by rules of adjudication and relative bargaining power.

For example, Uzzi (1996) describes networks in the textile industry as characterized by problem solving, communication, and trust; Uzzi’s description of a network is, in many ways, identical to the advantages of a firm, as listed above, regarding coordination, learning, and communication. The advantage of a textile network is, however, the flexibility to explore new relationships and opportunities, but within a relatively closed clique that supports long-term trust among members.

Though Burt and Coleman networks are distinct, they both generate potentially a rent to coordination, though with very different implications. The Burt rent is captured by an entrepreneurial broker located in a structural hole. This is an efficient network insofar that information flows throughout the network at the cost of maintaining a minimal number of relationships. Brokers, thus, increase the efficiency of the overall network and capture, as a result, a rent for this service. Just as in studies of monopoly, the calculation of whether the net welfare gain to the system is positive or negative depends upon a comparison of the incentives for the broker to act in collective interests.
Studies by Burt (1997) indicate significant rents to brokers, but do not assess the global welfare benefits. For example, his study on promotion and remuneration of American managers indicates that occupying a structural hole increases the size of bonuses (holding the rest constant) for senior offices increased by $291,000. It could be that individuals who fill structural holes are scarce entrepreneurs who improve internal coordination through control and hence the performance of the system. (Burt’s analysis of their attributes is ambiguous to these effects.) This argument is more problematic in the context of promotion. If we view promotion as a problem of mobility chains, then one person’s promotion is another’s disappointment. In this case, local rent is at best a distributional transfer, ignoring the possibility for dysfunctional consequences and inviting strategic behavior on the part of dominated individuals or firms. Clearly, redistribution is implied in the studies on the structure of input-output activities that indicate some industries occupy structural holes (Burt 1992).

A Coleman rent is associated with the benefits of trust in long-term relationships. This rent is not due to informational efficiency, for as Burt forcefully notes, a redundant network is not a minimal communication tree. However, dense relationships have the attribute of supporting monitoring and coordination by matching incentives to contribution. Coleman (1990) distinguishes between independent and global viability in associations. The former consists of contributions of individuals to an organization (or closed network) with a proportional reward. Global viability, which Coleman believes is dynamically degenerate, rewards people at their reservation price of persistence in the club, while allowing for intra-organizational subsidies to members in an amount that violates rules of proportionality.\textsuperscript{14}

The study by Walker et al. explored both these type types of networks. The early history of this industry revealed a network that was relatively unstructured and more market like. Certainly, while entrepreneurs had important affiliations to sources of ideas (e.g. universities) or finance, horizontal ties among firms were weak.\textsuperscript{15} In this type

\textsuperscript{14} This description is similar to the theory of clubs (and to Olson-type of selective incentives among small groups). There are many rules by which individuals can be rewarded that satisfy their reservation price (i.e. minimum for staying a member). See Cornes and Sandler (1996) for a summary.

\textsuperscript{15} See Powell et al. (1996) on ties.
of network, market-like relationships emerge through firms communicating information regarding e.g. prices and specifications. Coordination in this instance happens through transactions governed by price signals. Learning takes place through the revelation of cooperative or dishonest reputations.

Over time, a more complex network emerges. As shown earlier, figure 4 represents the relational structure that reveals both structural holes and Coleman-type networks. The pharmaceutical company marked II is an isolate that has non-redundant ties with 6 start-up firms; it clearly occupies a structural hole. However, some firms, such as those in group IV, engaged in more dense transactions that are suggestive of formative type of Coleman networks. The analysis of subsequent relationships revealed that Coleman network based on coordination, inclusive of mutual know-how exchange, emerged. Because of this social capital, firms belonging to the same groups tended to cooperate with each other subsequent to their initial cooperation. Network structure began to replicate itself in stable patterns of enduring cooperation. It is not simply that bio-technology relationships are enduring across years that explains this persistence. It is that rather that these formative groups formed progressively more closed cliques; the flow of new relationships were influenced by Coleman-type incentives for cooperating firms to deepen their cooperation. This pattern is also implied in the findings by Gulati (1995) who shows that partners tend to ally with those close in the network and with whom they have previously allied.

The emergent properties of networks imply that self-organizing processes tend to freeze the structure among firms over time into stable patterns of interactions. To explicate this relationship between trust and flexibility as capabilities arising out of a particular relationship, Uzzi proposes that the optimal network structure in the textile industry has a high density of relationships among firms, yet while allowing new entrants and the possibility of further exploration. If the advantage of the market is the generation of variety, this tendency towards self-organization reduces the initial variety. Of course, to the extent those bad firms are eliminated, this reduction is desirable. On the other hand, the constraints on individual experimentation increase due to requirements to orchestrate coordination with other actors. The more networks
take on the properties of firm organization, coordination deprives individual firms of potential avenues of exploration. Thus, neither Burt, nor Coleman structures can be ranked a priori for their welfare merits; additional structure to the analysis is first required.

**Property rights and Networks**

A challenge in studies on networks is to consider jointly the interaction of qualitative differences among individuals or firms and their position in network structures. Burt (1997), for example, sorts out the effect of individual human capital on rank from the effect of network constraint. These efforts do not eliminate the potential that relationships flow to people who possess unobserved human capital attributes. Similarly, the coalition of biotechnology firms with on-going partners might reflect the tendency of high-quality firms to attract high-quality firms.

Of course, if human capital was alienable from the person, it too would flow like a resource through a network, diminishing its value. It is, however, the stickiness of human capital that influences a person’s eligibility to play a brokering role. The tacitness of firm knowledge similarly makes a firm less susceptible to the competitive imitation of its claim to broker.

While this confounding poses an econometric problem of selection bias (i.e. rents are to “quality” people or firms who occupy structural holes), it theoretically returns the analysis to understanding the sources of cooperative structures in a competitive context. The position of a broker, in particular, is liable to competitive erosion through the strategic efforts of competitors to form non-redundant relationships with third parties. Dominated individuals will seek ‘weak ties’ with new actors in order to by-pass control from a structural hole. In the absence of superior capabilities of the broker, structural position in a Burt network appears as non-sustainable.

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16 This analysis is reported in Kogut and Walker (1998).
17 While econometrically selection bias can be addressed, it is also possible to reduce the network to dyadic ties that can be analyzed to determine the attractiveness, expansiveness, and reciprocity among individuals or firms. This analysis leads to an understanding of dyads, it does not aggregate to provide a description of network structure.
18 See the discussion by Walker (1998) on the search models indicating that weak ties proliferate from the objective of maximizing information access. Of course, none of these models constrain search by
In this regard, property right protection has an important influence on sustaining the generation and appropriation of rents among members to a network. Relations themselves reflect frequently agreements to permit the utilization of one firm’s knowledge by another. Examples are the licensing of technology or the decision to cooperate in a joint venture in which firms contribute know-how.

Property rights can have a powerful effect on networks in two ways. First, the degree to which knowledge can be protected (e.g. patents) increases the propensity of firms to license the technology (hence generating a tie) because its use can be contractually restricted. If knowledge cannot be legally protected, nor tacitly bound to a firm, then it spills over to other firms without requiring an agreement. (In some instances, cooperation causes the leak.) In addition to influencing the number of relationships, property rights when coupled with “network externalities” have powerful implications for network structure. These externalities arise when the consumption or use of a good by one person or firm makes it attractive to another to do the same –the classic example being a computer operating system.

Such externalities, for example, exist in microprocessors. Since software is written for microprocessor standards and people want to use the same software, there exist externalities that favor the dominance of one standard over another. For a microprocessor firm, the logical strategy is to grab the largest size of the market. Somewhat counter-intuitively, it would want to induce entry into its market as long as these entrants agreed to license its technology and standards. In fact, cooperation exploded in the microprocessor industry until Motorola and Intel achieved dominance; National Semiconductor did not achieve the same penetration and, interestingly, maintained a higher level of alliance activity. Because all entrants were required basically to cooperate on the standards, these three firms were each centered in the middle of a star of relationships. Centrality thus was the outcome of network externalities coupled with a strong property right regime. Thus, in this case, the strategy to appropriate rents through technology licensing generated the structure, rather than structure simply determining the rents to a broker or Coleman group.
An Illustration: Toyota Production System

To explore holistically the ideas of organizing principles as generative rules and the relationship of rents and structure, the work on supplier chains in the automobile industry provides a rich set of studies that highlight the importance of relational capital through networks. The Toyota Production System, in particular, constitutes one of the most important organizational innovations of recent decades, yet it did not emerge out of a conscious design but out of an emergent process (Fruin and Nishiguchi, 1993). The Japanese market consisted after the war of a demand for high variety, a plethora of auto companies none of which operated plants built to the scale of the mass production facilities of American companies. Furthermore, Japanese suppliers were initially inferior in their capabilities compared to assemblers (Nishiguchi, 1994). Over time, this ‘dual labor market’ evolved into a new division of labor based upon the continuous upgrading of supplier competence and their participation in project design. These new tight supplier relationships created capabilities that increased speed to market, quality, and new model cycle times, with supplier networks as the organizing principle to deliver this capability.

The inter-organizational model emerged in Japan during a period from 1965 to the early 1980s. Over this time period, the production structure shifted toward reciprocal, multilateral relations and a concern with specific rights of transaction rather than residual rights of ownership. From using subcontractors mainly as buffers in the 1950s, assemblers were after 1960 committed to upgrade their subcontractors’ technical capabilities. The composite know-how of assemblers was transferred to suppliers through teaching, along with assembly lines. The emergence of contract assembly and subsystems manufacture noticeably changed the logic of supplier relations toward “collaborative manufacturing”. There were obviously gains to both buyers and suppliers in the form of increased returns of higher order organizing principles.

Though historically emergent, the transfer of the Toyota Production System represents the efforts to create networks by design to other countries (Florida and Kenney, 1991; Dyer, 1996). However, the rules by which supplier networks emerged

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19 This analysis is given in Kogut, Walker, and Kim (1996).
20 This section draws heavily on joint work with Udo Zander.
in Japan are different than the rule that guide its design and transfer. In effect, the emergence of inter-supplier networks were guided by these two rules:

1. The dual labor market is not violated by integrating suppliers into Toyota.
2. Supplier capabilities are improved through the transfer of competence to them.

The first rule grew out of the recognized limits of a Japanese company toward extending the reciprocal agreements among employees to suppliers. Membership in a large company entailed expectations of long-term employment in return for strong identification of the employee with the firm. Contrary to Stigler’s hypothesis of the integration of weak suppliers, the social expectations underlying the employment relationship precluded the integration of suppliers into the core firm. The second rule developed partly as a consequence of the first, as well as through government policy to protect weaker suppliers against the dominance of large assemblers (Nishiguchi, 1994).

Many subcontractors welcomed the new subcontracting system, since it brought with it more stable contractual relations through increased asset specificity, more opportunities for technological learning, and improved growth prospects (Nishiguchi, 1994). From using subcontractors mainly as buffers in the 1950s, assemblers were after 1960 committed to upgrade their subcontractors’ technical capabilities. The composite know-how of assemblers (including the know-how to operate assembly lines) was transferred to suppliers through teaching. The emergence of contract assembly and subsystems manufacture noticeably changed the logic of supplier relations toward “collaborative manufacturing”. There were obviously gains to both buyers and suppliers in the form of increased returns of higher order organizing principles.

Still, these two rules generated initially a network structure that was strikingly hierarchical in structure. In this regard, the Toyota supplier structure was organized along hierarchical lines that were not substantially different than those found among General Motors and its suppliers. However, the rule to respect the dual labor market prohibited the extensive vertical integration. Toyota’s value added contribution to its

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21 This relationship is described in many places, including Aoki (1990) Ablegglen and Stalk (1985), and Nischiguchi (1994).
autos was, and remains, radically less than General Motor’s share of value in its assembled cars. (See also Dyer, 1996, who found the internal value-added of an American assembler to be twice that of a Japanese.)

The dynamic that transformed this hierarchy into a more closed relationship stemmed from the logic of a series of organizational and process innovations that began within Toyota and eventually diffused out to suppliers. The initial innovations of Toyota centered around the introduction of customer-driven production (kanban) manufacturing. The danger of this kind of production system is that working capital increases to provide the flexibility to support changes in customer demand. Almost by contradiction, Toyota also innovated by minimizing inventory levels through the innovation of just-in-time (JIT) deliveries. These systems were coupled with powerful analytical tools, such as value analysis and quality control, which generated information used to minimize costs.\(^{22}\)

If kanban and JIT were powerful, their rapid introduction would be fostered through vertical integration. In fact, through vertical integration, a firm should have more power to enact JIT because it has the authority to do so. Supplier resistance to these innovations clearly frustrated the chief architect of Toyota’s innovations, Ono, who complained bitterly over the resistance to these new methods (Cusumano, 1985). Lieberman had documented the slow diffusion of these methods by tracking inventory levels among suppliers, finding that they continue to decrease for Toyota suppliers through the 1970s (though Nissan and other Japanese firms lagged considerably).

The gradual extension of these new organizing principles of customer-driven production transformed supplier relations from the exploitation of subcontractors to collaborative manufacturing based on multilateral problem solving. Over time, asset-specific contractual relations increased, as exemplified by contract assemblers and system-component producers. Structurally, Japanese subcontractors were reorganized over time into tiers through a concentration of orders, intensified specialization, and increased dependence on particular customers (Fruin and Nishiguchi, 1993). In the new tightly tiered structure, approximately 180 first-tier suppliers contract to several

\(^{22}\) Ohmae’s (1982) early study is a brilliant explanation of the strategic implications of value analysis of Japanese firms.
thousand lower-tier subcontractors that, in turn, contract to tens of thousands third tier suppliers

This tiered structure implies that at a given time, subcontracting philosophies at plants within the same firm vary widely. Nishiguchi compares philosophies within the same buyer firm ranged from “bargaining” subcontractor managers who used subcontractors to protect regular workers when demand fluctuated to pro-subcontracting managers who engaged in intense contacts, training and problem solving. Nishiguchi’s results are consistent with asset specificity not being the cause but the consequence of a particular strategy. (In fact, he finds asset specificity to be a consequence of the supply strategy.) Yet, at the same time, a strategy that points to asset-specific contractual relations needs inter-firm relational mechanisms that enable them to function.

The increased reliance by Toyota on first-tier suppliers generated important organizational innovations designed for the new network. Through repeated interaction between firms in the network, a series of innovations emerged that supported the acquisition of skills specific to the relationships, or what Asanuma has called ‘relation-specific’ capital. (See also Dyer, 1996, and Dyer and Singh, 1998.) These innovations included joint price determination based on objective value analysis, joint design based on value engineering, the target cost method of product development, profit-sharing rules, subcontractor proposals, black box design, resident engineers, subcontractor grading, quality assurance through self-certified subcontractors, and just-in-time delivery circumscribed by bonus-penalty programs. These innovations represented the shift from main purchasing function of the customer shifted from downstream price negotiation to the assessment of subcontractor performance and the coordination of inter-firm functions.

Asanuma’s description of the heterogeneity of the Toyota supplier system indicates a network in which a set of tiered suppliers act differentiate the status of suppliers. Asanuma groups suppliers according to their degree of technological initiative, where DS-suppliers rank the lowest, and suppliers selling standard products to the market rank the highest. An important distinction is between suppliers that work according to drawings supplied by the core firm (DS-suppliers), and those that submit their own drawings to the core firm for approval (DA-suppliers). Over time, DS
suppliers evolve toward greater independence because of an increase in volume produced by a supplier, or an increase in the scope of activities performed by a supplier.

Through monitoring and supplier qualification requirements, the core plant selectively develops relationships with suppliers. Suppliers are evaluated according to how well they have performed on earlier contracts. Often partial ownership is sought in the suppliers that rank the highest in terms of performance and potential capabilities. Moreover, suppliers earn points in the supplier rating system for codifying methods so that they can be used by other suppliers, leading to lower costs for the core firm. By this dynamic, continuous learning lead to improvement in productivity of the whole supplier networks. All types of suppliers have to develop some skills to maintain the relation to the core firm, other than purely technological capabilities.

In effect, Toyota evolved a system that relied upon self-organization to resolve the contradiction between its two rules: the inability to integrate while requiring improvement in supplier skills. The tiered system forced firms to prove their competence and yet also created incentives for them to codify and share their knowledge. Thus, the first two rules were augmented by a third:

3. To participate in the first tier, suppliers are required to prove, codify, and share their competence with each other.

Unlike the operation of the competitive hierarchy to American assemblers, this hierarchy then evolved to move the single locus of innovation from the core assembler (Toyota) to the suppliers as well. Nishiguchi (1994) calls this “clustered control”; in our terminology, it represents a Coleman network of dense ties between the members.

This structure achieved “independent viability” in Coleman’s terms by devising rent-sharing rules that supported decentralized innovations. Initial prices are set in the light of planned production costs, based on the supplier’s and the core firm’s experience with similar parts. If the supplier should improve the process and outpace the planned experience-derived cost reductions, it retains the savings. The pricing mechanism reflects not only an anticipation of learning on part of the suppliers; it provides an incentive to beat the target. However, at the same time, rule three dictates that these improvements flow to other suppliers. As a consequence, improvements at one supplier flow dynamically to others.
Independent viability of membership is a necessary factor in the self-organizing character to the Toyota Supply system. Consider a firm that withheld technology and sought to free-ride on the efforts of others. The intense information flows permit easy monitoring; sanctions need be no more than exclusion from the first-tier club that shares rents. It is important to observe that this system, from the point of view of Toyota, represents a less costly expenditure of time even if it involves a dense set of ties. Because monitoring is coupled with cooperation in technology transfer, it is also occasion to learn from other supplier’s experiences (see Sabel, 1996; Helper, MacDuffie, and Sabel, 1998).

Dense networks provide an important capability of knowledge acquisition, in conjunction with also generating information required for monitoring and enforcement. Thus, monitoring occurs not as a function of an overt sanction mechanism, but rather through the operation of professional identities that support the transfer of technology among suppliers and Toyota.23 Whereas a brokerage role is efficient from the perspective of monitoring and sanctioning, the self-organizing properties of dense relationships benefits from putting the stress on the rapid flow of competencies through frequent and on-going relationships.

The organizing principles of the Toyota System support the capabilities of providing variety and speed to the market. Capable suppliers in a network provide competing variety based upon specialized competence. Black box modularity permits specialization, and yet demands a high degree of coordination. The rapid diffusion of production know how serves to reduce the costs, while the tight coordination of suppliers and assembly in design and production reduces overall time to the market.

The obstacle to Stigler’s solution of vertical integration to overcome inefficiencies in the network was overcome by developing mechanisms to promote learning. These adaptive innovations posed the problem that property claims to this knowledge were weak, hence creating the incentive for suppliers to maintain secrecy. These threats were resolved, though, by two mechanisms. Coordination generated rents that as a positive cycle by inducing cooperation as well as by acting as an efficiency wage to deter defection. Second, the process of technology transfer itself

23 It is not surprising that suppliers are often conflicted in their loyalties, especially at times when these networks are transferred to new locations.
created information that enabled monitoring within the network as opposed as through hierarchical control.

Thus, the Toyota system embodies the irony that these principles of coordination arose due to restrictions on vertical integration. But if the emergence of the Toyota network could not have been foreseen, its transfer by replication in the United States and elsewhere entails intentional coordination among network members. Yet, these intentions do necessarily demand authority for coordination. For growth qua replication implies the possession of capabilities that are rent generating, hence rewarding membership and cooperation. While their origins suggest the operation of unintended consequences, the intentional adherence to these rules suggests a functional understanding of their consequences.

CONCLUSIONS

We began with the observation that value is not a mystical entity. The source of its imputation is not always clear, as witnessed in the lack of consensus over the interpretation of a residual, called total factor productivity. In recent years, we have come to understand better that an important source of value for a firm lies in the capabilities supported by organizing principles of work. These principles constitute what is meant as the knowledge of the firm.

The study of networks as knowledge understands capabilities achieved through coordinated action at multiple levels of analysis. At one level, knowledge is the principles defining coordination in a division of labor that anchor identities of individuals and groups within firms. At another level, the boundary of firm and market are malleable definitions determined by shifting identities and their co-evolving capabilities. Intermediating between these levels is the domain of networks, whose capabilities ride upon the emergent rules of coordination and competition of firms.

The network generated by rules of cooperation differentiates firms by their structural positions. Since firms but not networks are units of accrual and selection, there exists, therefore, a potential divergence between the distribution of these rents and the contribution of individual firms. Sometimes, this divergence is mitigated through the coincidence of structural position and property right claims. However, in
situations in which knowledge is diffuse among a group of firms, coordination can become prey to concerns over cooperation. Embedding a monitoring and sanction mechanism into a cycle of positive returns attached to technology transfer drove the particular success of the supplier system of the Toyota Production System. And by devising credible rules that guaranteed independent viability, Toyota could, by intention, replicate the network (even if particular members changed) in new locations.

Networks are more than just relationships that govern the diffusion of innovations and norms, or explain the variability of access to information across competing firms. Because they are the outcome of generative rules of coordination, networks constitute capabilities that augment the value of firms. These capabilities, e.g. speed to market, generate rents that are subject to private appropriation. It is in the understanding of knowledge as coordination within and between specialized firms that the “missing” sources of value can be identified.
REFERENCES


Almeida, Paul and Bruce Kogut. “Localization of Knowledge and the Mobility of Engineers in Regional Networks.” Forthcoming in Management Science.


Kogut, Bruce, Gordon Walker, and Dong Jae Kim, 1996, Cooperation and entry induction as a function of technological rivalry, Research Policy, 24:77-95.


