Why Information Technology Hasn't Increased the Optimal Number of Suppliers

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ABSTRACT

Information technology has generally reduced search and coordination costs. Ceteris paribus, this should lead firms to increase the number of suppliers with which they do business. However, there is little evidence of an increase in the number of suppliers used in the past few years. On the contrary, in many industries, leading firms are working with fewer suppliers. This suggests that other forces must be accounted for in a more complete model of buyer-supplier relationships.

This paper presents a model that shows how a buyer can increase its suppliers' incentives to invest in quality by decreasing their number. This makes it more difficult for the buyer to threaten to switch to alternative sources and thereby expropriate the supplier's share of the value created. As a result, suppliers are more willing to make "non-contractible" investments in quality. Thus, we argue that because information technology often increases the importance of quality, it can lead firms to employ fewer suppliers, and that this will be true even when search and coordination costs are very low. Evidence from several empirical studies of buyer-supplier relationships appears to be consistent with this explanation.

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1. Introduction

The relationship between information technology (IT) and economic organization can be quite complex, but the emerging area of "coordination theory" is beginning to provide a foundation for theory-building and empirical validation. For instance, the hypothesis of Malone and colleagues (Malone *et al.* 1987) that IT will lead to increased outsourcing of activities as it lowers coordination costs, has found some empirical support (Brynjolfsson *et al.* 1991). We are still far from a complete understanding of the organizational impacts of IT; in particular, IT does not appear to have simply increased firms' reliance on market coordination, but rather to have engendered new forms of organization such as "networks" and "value adding partnerships," which involve close links with a relatively small number of suppliers. The combination of these two trends—increased outsourcing but to fewer suppliers—has been identified as the "move to the middle hypothesis" by Clemons and Reddi (1992).

Understanding the interface with suppliers and the potential supporting role of IT has become a major point of interest among managers in their quest for increased efficiency. This topic is often discussed in view of the differences in customer-supplier relationships between Japanese and American firms. Superior supplier relations have been estimated to provide a $300-$600 per car cost advantage to Japanese manufacturers (Cole and Yakushiji 1984).

In this paper we present a theoretical model that explains some aspects of buyer-supplier relations and provides useful guidelines for managers seeking to better understand the role of technology. The remainder of this section reviews previous work in this field and discusses the basic intuition behind our results. Section two discusses the tradeoff between coordination costs and improved supplier "fit". The third section introduces the concept of "incomplete contracts" and presents a model that considers the incentive implications of increasing the number of suppliers. A key result is that the need to provide incentives for quality can limit the desirable number of suppliers. The last section concludes with implications of this analysis and some validating examples.

Transactional factors predict more suppliers

Determining the optimal number of suppliers is a natural extension of the "make vs. buy" or "markets vs. hierarchies" decision. Both questions can be analyzed by focusing on

coordination costs. Malone, Yates and Benjamin (1987) summarize this argument by pointing out that when the buyer can select among many sellers, as in a market, it can secure a low production cost, but in the process must incur relatively high coordination costs. Single supplier relationships, such as hierarchies, on the other hand, restrict a firm's choices, but the resulting tight relationship reduces coordination costs by eliminating the need to gather and analyze information about many suppliers. They further argue that IT will facilitate a move from single-supplier arrangements ("hierarchies") to multiple supplier arrangements ("markets") because it reduces the costs of coordination with suppliers.

Similarly, in studying the impact of technology on the number of suppliers, past research has focused on transactional considerations, examining tradeoffs such as those between the increased search costs necessary to locate a large number of suppliers versus the increased probability of finding a better price or locating a superior product offering as more suppliers are surveyed. According to this logic, any technological developments lowering the cost of acquiring information about prices and product characteristics in a given market should lead to an increase to the number of suppliers considered, especially in markets with differentiated products (Bakos 1991). It has been widely argued that IT in general, and interorganizational systems in particular, tend to lower search costs (Clemons and Row 1989); as these systems are adopted in several sectors of the economy they should lead to an increase in the number of suppliers for most firms.

Evidence of a move to fewer suppliers

While there is evidence of a shift from single supplier "hierarchies" to multiple supplier "markets" (Brynjolfsson *et al.* 1991, Johnston and Lawrence 1988), we have not observed a general increase in the number of suppliers. On the contrary, there is evidence of a reduction in the number of suppliers, both as a recent trend in certain industries, as well as a by-product of IT adoption. For instance, a study of the automobile industry by Helper (1991), found that the average number of suppliers decreased 25% between 1983 and 1988. In a survey of Japanese and American firms, Cusumano and Takeishi (1991) found that American firms were increasingly adopting the Japanese model of supplier relations, which involved relationships with about half as many suppliers per part (1.3 vs. 2.8) and resulted in orders of magnitude fewer defects (0 to 0.01% vs. 0.35 to 2.6%). In some industries the trend has been even more pronounced. Motorola reduced its supplier base from 10,000 to 3,000 in the past few years, prompting one industrial consulting firm to

conclude that "A revolution is going on in the relationships between suppliers and customers" (Emshwiller 1991).

The shift to fewer suppliers is often associated with the emergence of "strategic networks" (Antonelli 1988). In a recent review, Jarillo (1988) concluded that networking, especially in the Japanese Keiretsu model, was a theme in "practically all studies of industrial suppliers and industrial markets". In a similar vein, Johnston and Lawrence (1988) review several case studies and argue that "value-adding partnerships" (VAPs) in which each company "cultivates relationships with only a few (from two to six) suppliers for critical items" are supplanting not only vertically-integrated hierarchies, but also arms-length markets of multiple buyers and suppliers in the economy as a whole.

IT has been linked to these changes in several of the studies. Johnston and Lawrence specifically attribute the rise of VAPs in part to IT, including minicomputers and PCs, improved software, data standards, networking and CAD/ CAM. Helper found a statistically significant correlation between technology use and close supplier relations. Clemons and Reddi (1992) also argue not only that recently there has been a "move to the middle" from both ends of the markets-hierarchies spectrum, but also that IT has been a significant driving force behind this trend. However, this move to fewer suppliers, in the face of the declining coordination costs promulgated by IT, seems to present a paradox.

Explanations for the move to fewer suppliers

One possible explanation for reducing the number of suppliers is that the total costs of coordination have actually increased. For example, if IT results in substantial fixed technological and organizational investments to connect to a new supplier, a firm may wish to limit the number of suppliers it does business with, in order to economize on these fixed costs. Similarly, if investments in electronic integration are specific to a particular supplier, and thus are not transferable to new relationships, they may lead to switching costs limiting the desirable number of suppliers over a period of time. For example, investing in an interorganizational system for the exchange of blueprints in a CAD format used by the firm and a particular set of suppliers, may limit the ability of the buyer firm to explore new suppliers.

While arguments like these may explain why investment in interorganizational information systems could initially reduce the number of suppliers, it is widely believed

that in the long run IT lowers search costs and switching costs (Clemons and Reddi 1992, Malone *et al.* 1987).. For example, once an EDI standard has been adopted in an industry, the cost of basic electronic integration between any supplier and buyer who have implemented this standard will be relatively small. Thus any increase in transaction and coordination costs resulting from the adoption of IT is likely to be temporary. In fact, the increase in outsourcing that has been observed suggests that, on balance, there has not been an increase in transaction costs. Similarly, direct measures of most basic types of computer-aided transactions show rapid cost declines, averaging 25% per year (Brynjolfsson *et al.* 1991). Overall, the theoretical and empirical evidence appears to weigh heavily on the side of *reduced* coordination costs in the past decade.

A second possible explanation is that economies of scale have increased so much that it is only worthwhile to deal with a small number of large suppliers. Although this may be true in a few industries, here again the weight of the evidence does not support this hypothesis in general. Flexible manufacturing is widely acknowledged to have significantly reduced the average size of production runs and overall set-up costs, enabling smaller plants and firms to compete successfully. For instance, in the automobile industry, lot sizes for both production and delivery were smaller in 1989 than five years earlier (Helper 1991). Trends in IT typically favor smaller and cheaper computers, and reduced economies of scale in production. Finally, the average size of firms has decreased during the past decade in the US economy as a whole (Brynjolfsson *et al.* 1991).

If this shift to fewer suppliers is not driven simply by changes in coordination costs or economies of scale, field studies of buyer-supplier relations suggest an alternative explanation. Specifically, they focus on the advantages that smaller, tighter networks of suppliers have in quality (Cusumano and Takeishi 1991) and related characteristics such as innovation and technology adoption (Helper), defect rates (Cusumano and Takeishi), trust (Johnston and Lawrence 1988), information exchanges (Helper; Cusumano and Takeishi), and flexibility and responsiveness (Johnston and Lawrence). Interestingly, all of these characteristics involve investments by suppliers that are difficult or impossible to specify in advance in a contract, that is they are "non-contractible," and they offer benefits which are largely specific to a particular buyer-supplier relationship.

Suppliers that make investments in quality must depend on their own *ex post* bargaining power (and/or the goodwill of the buyer) to reap a share of the benefits created by their

investments. It has proven difficult to model these considerations for the same reasons that is difficult to specify them in a contract, and as a result they have largely been ignored in the more formal literature on buyer-supplier relations. Notable exceptions include Clemons and Reddi (1992) and Helper (1991). In particular, Clemons and Reddi posit that closer supplier relations can lower operations risk and opportunism risk, and go on to argue that this will be especially true as IT use increases. These approaches, however, do not explicitly address how to provide incentives for investment in quality and, specifically, how the number of suppliers affects the incentives to make such investments. In fact, the idea that limiting the number of suppliers could be a successful competitive strategy runs counter not only to standard neo-classical economic models, but to the widely-used competitive strategy models as well (Porter 1980). As Alan Blinder (1991) put it:

> Keiretsu are often portrayed as exclusionary devices that make Japanese companies unduly clannish and insular. How can such apparently restrictive business practices promote efficiency?

Continuing a stream of thought formalized in our earlier work (Bakos and Brynjolfsson in press), this paper adds incentive considerations to the coordination cost considerations previously addressed. In particular, we use the incomplete contracting ideas developed by Hart and Moore (1990) to show that when it is important to provide incentives to suppliers to invest in quality, it can be optimal to limit the number of suppliers with which a buyer contracts. The intuition for this result is that a supplier will be able to garner more of the benefits resulting from his investment if the buyer does not have too many alternative suppliers. As a result, the supplier will have greater *ex post* bargaining power and therefore greater *ex ante* incentives to invest in quality.

The ability to reduce the number of suppliers to increase their incentives to invest in non-contractibles such as quality, and thus to partially compensate for the problems of incomplete contracting, provides an alternative perspective and an additional explanation for the "move to the middle". Furthermore, while technological progress may help reduce the coordination costs associated with a larger number of suppliers, the incentive considerations are more resistant to technological solutions, and are thus likely to remain in place for the foreseeable future. In view of these considerations, we show that even if search and transaction costs were to go to zero, it can still be optimal for a firm to limit the number of suppliers that it uses.

2. Coordination costs and the optimal number of suppliers

In determining the optimal number of suppliers, it is natural start from the assumption that a firm would benefit by increasing the number of its suppliers thereby broadening its range of choices. However, organizational and technological considerations, such as the cost of setting up a relationship, search costs, and transaction costs, which can be collectively labeled "coordination costs," constrain this strategy.

For example, in trying to determine the optimal number of suppliers for a given input, it may be assumed that suppliers' product offerings differ in some desirable feature, such as price, product characteristics or simply "fit". However, interacting with each supplier entails a coordination cost. After surveying a number of suppliers, the buyer selects the product offering that provides the best value according to its set of criteria. The optimal number of suppliers is determined by trading off the cost of further searches against the expected benefit from identifying a better supplier. Bakos and Brynjolfsson (in press) provide a formalization of this tradeoff between coordination cost and fit, which is illustrated in Figure 1.

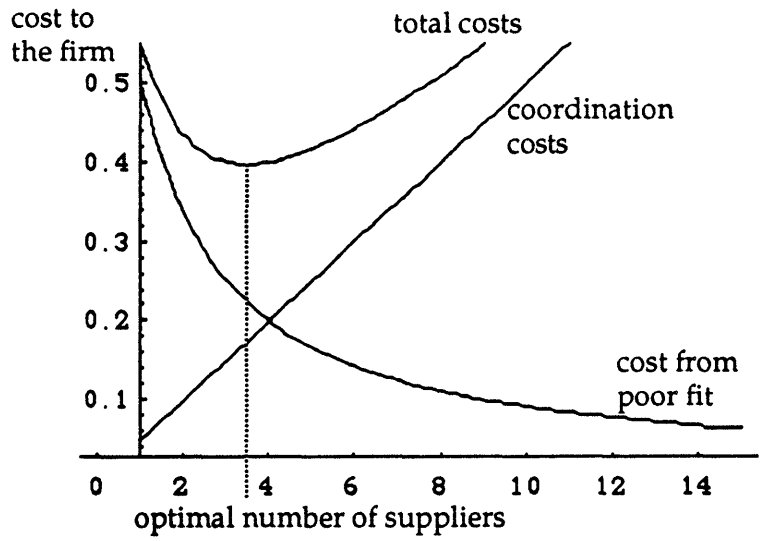

Figure 1: Balancing coordination costs and "fit"

As mentioned earlier, it is widely believed that IT lowers the costs of inter-firm coordination. Figure 2 shows the impact of lower search costs on the curves of Figure 1, thus illustrating how lower search costs can lead to an increase in the number of suppliers. This increase is driven by the lower *marginal* cost of coordination, and would occur even in the presence of a large fixed set-up cost.

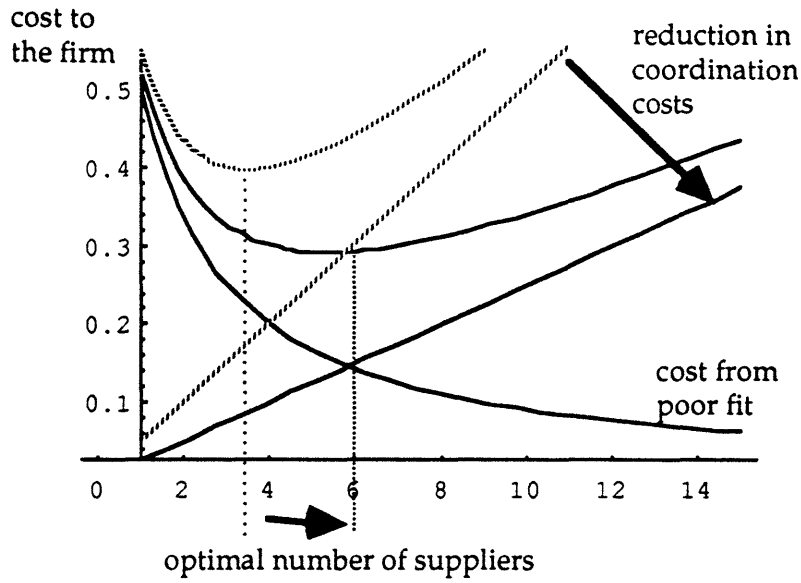

Figure 2: The effect of lower coordination costs

3. Combining incentives with coordination costs

Focusing on coordination costs is appropriate when changing the number of suppliers used has no effect on their incentives. However this is not typically the case. In this section we discuss how incentive considerations can be combined with the coordination cost considerations discussed above to derive a more general model of suppliers relations. Specifically, we assume that the buyer firm and its suppliers can invest in an a characteristic called "quality" that affects the value created by the relationship, but which is not feasible to describe in a comprehensive contract. We continue to incorporate a fixed coordination cost associated with each potential supplier, and to allow for heterogeneous product offerings, thus giving the buyer firm an incentive to search for the "best fit" product in the supplier market.

The incomplete contracts approach

If contracts are "complete" (in the sense that they cover all possible contingencies), then the required level of investment by each party can be explicitly specified. Williamson (1975) has argued that complete contracts are costly or even infeasible. Hart and Moore (1990) sharpen this argument by pointing out that investments in certain variables may

be non-verifiable by a third party (e.g., a court or an arbitrator), even though they may be observed by the parties entering in the relationship (in the sense that these parties can take actions and make decisions based on the outcome of these variables). We use the term "quality" as a short-hand for any such variables. In judging the quality of a good delivered, for example, both the firm and the supplier may be able to observe whether the quality is substandard, but it may not be possible to demonstrate this to the satisfaction of a court.

Without the ability to contractually specify in advance the division of surplus from investments in quality, this surplus will be divided based on the *ex post* bargaining power of the parties involved. Bargaining power, in turn, will be largely determined by what alternatives each party has to the proposed division of the surplus. Based on this principle, we can analyze how changes in the number of suppliers affects the incentives and therefore output.

Specifically, reducing the number of suppliers with whom the firm interacts, will increase the bargaining power of each remaining supplier. This will increase their shares of the *ex post* surplus and, ultimately, their *ex ante* incentives to invest in the relationship. When supplier investments in quality are important, limiting the number of suppliers may be the best way to insure that they have adequate incentives to make such investments. In this section we present a model of buyer-supplier relationships that integrates these incentive considerations with the coordination cost considerations discussed earlier.

An integrated model for the optimal number of suppliers

To capture the incentive effects of the number of suppliers, we model the relationship between a firm and its suppliers by drawing on the incomplete contracting framework discussed above. We show that reducing the total number of suppliers, significantly increases the portion of the marginal returns on investment appropriated by each. This increases the suppliers' incentive to invest, and if this investment is critical, it can result in a better outcome for all parties.

Following our earlier paper (Bakos and Brynjolfsson in press), we consider a two-period setting with N risk neutral potential suppliers indexed by $i = 1, \ldots N,$. Before the first period, the buyer determines the number of suppliers from which it can purchase.[1] All

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[1] For instance, it establishes an interorganizational information system with $n < N$ suppliers. We assume that the choice of n cannot be changed until after period 1.

suppliers possess identical technology and there are no binding capacity constraints, so the buyer can make a credible threat to shift the order to any other supplier. In the first period, each supplier i makes an investment x_i at private cost $C(x_i)$, to produce an outcome to which we refer as "quality". When the buyer uses supplier i, it creates non-contractible value $v(x_i)$. In addition to potential differences in the value of $v(x_i)$, supplier offerings also differ in a desirable product characteristic which we label "fit". Unlike "quality," the value of "fit" is contractible and provides to the buyer utility ε_i, distributed according to a known density function f_ε.

In the second period, the buyer orders from the supplier with the most desirable product characteristic, production takes place, the goods are delivered, and payments are made. Assets are specific in the sense that a supplier must sell its output to the buyer to create value, and similarly the buyer must gain access to the assets of at least one supplier (e.g., by purchasing from that supplier) in order to create value. We also make the standard assumptions of increasing marginal costs and diminishing marginal returns to investment.

We assume that investments in quality are too complex to include in a contract. Since no contract can be written contingent on firm investments or the value generated by them, the total surplus generated in the second period will be apportioned according the relative bargaining power of the parties involved. Specifically, we follow Shapley (1953) and assume that each firm will receive an amount equal to the value of each potential coalition less its value without the firm, multiplied by the probability that the firm will be in any given coalition.[2] Under this formulation, firms which are not easily replaced will have more bargaining power and thus will be able to garner a larger share of the surplus generated from transacting.

The *ex post* bargaining power of the parties will have a considerable effect on their *ex ante* incentives to invest in quality: each firm will invest until the marginal benefit it can expect to receive equals the marginal cost of investment. Thus, the first order conditions for each of the n supplier firms are given by the following n equations,

$$\frac{dB_i(\mathbf{x})}{dx_i} = \frac{dC(x_i)}{dx_i} \quad \text{for } i = 1, \ldots, n \quad (1)$$

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2 The exact rule for division of the surplus will generally have no qualitative effect on our results as long as each agent's share of output is positively correlated with his access to essential assets via coalitions with other parties.

where $\mathbf{x}$ is the vector of investments x_i ($i = 1,...,n$) and $B_i(\mathbf{x})$ is the share of value received by firm i under investments $\mathbf{x}$. Under the above assumptions, the bargaining power of each supplier, and therefore the value received $B_i(\mathbf{x})$, is inversely related to the total number of suppliers with which the buyer contracts.[3] Thus increasing the number of suppliers will monotonically decrease their individual bargaining power, *ex post* surplus and incentives. Since reducing the incentives of any party will lead that party to invest less in the relationship, a key insight from equation (1) is that increasing the number of suppliers will reduce their investments in "quality."

The buyer's problem in selecting the optimal number of suppliers n is to maximize the benefits from improved fit as the number of suppliers increases, while taking into account the negative impact on supplier incentives and the coordination costs $\kappa(n)$. More formally, the buyer is trying to maximize:

$$B(\mathbf{x}^*) - \kappa(n) + \max_{i \in \{1,2,...,n\}} \varepsilon_i \quad (2)$$

where the first term captures the impact of changing incentives for supplier "quality," the second term reflects coordination costs, and the third term shows the impact of improved "fit". Increasing the number of suppliers n will improve "fit" (i.e., the maximum ε_i) but it will increase the coordination costs $\kappa(n)$. It will also have a negative impact on the incentives of the suppliers to invest in quality. Thus if the buyer wishes to induce significant quality investment from its suppliers, according to equation (1), it must commit to buying from a relatively small number of suppliers.

This model demonstrates that a number of tradeoffs need to be made in determining the optimal number of suppliers. Not only must coordination costs be balanced against improved fit, but the impact of the various arrangements on incentives must also be considered. For example, if suppliers' investment in quality is insignificant, the incentive considerations suggest that the buyer should adopt the maximum feasible number of suppliers. In this case the buyer maximizes its bargaining power and keeps most of the surplus, but no supplier will make a significant investment in quality. On the other hand, if supplier investments in quality are critical, the buyer should work with relatively few suppliers. Although the buyer will be able to keep a smaller fraction of the surplus generated, reducing the number of suppliers will induce each of them to invest in quality, and thus will increase the total surplus to be divided. In other words, as

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3 This is because adding suppliers increases the buyer's bargaining power by making it easier to threaten to shift to an alternative source. See (Bakos and Brynjolfsson in press) for a formal derivation of this result.

the suppliers' non-contractible actions become more important, the optimal number of suppliers decreases. It is important to emphasize that this will be true even if coordination costs become arbitrarily small.

Parametric example

To illustrate the model, we offer an example demonstrating how the number of suppliers affects investment incentives, assuming a production function for quality of $v(x_i) = Ax_i^{\alpha}$, where x_i is the investment of supplier i.. The parameter A characterizes the importance of supplier quality: as A increases, supplier quality becomes relatively more important. We also include a uniformly distributed fit parameter (f(e) = 1) and a constant coordination cost per supplier ($k(n) = kn$).

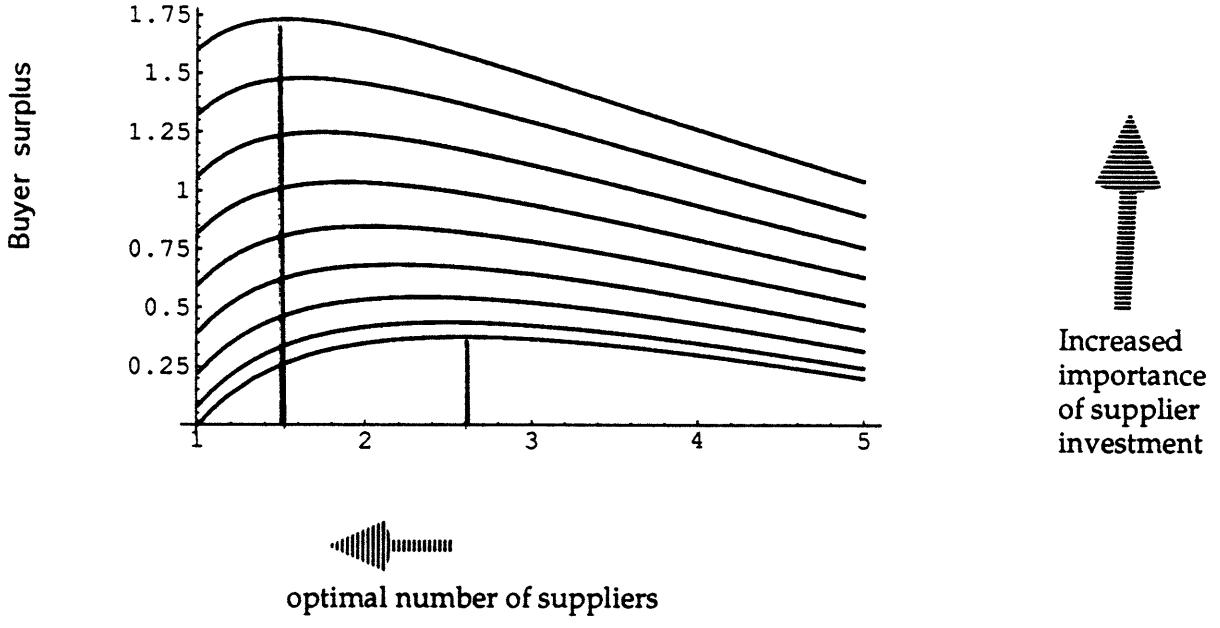

Figure 3: Coordination costs, "fit" and incentives

Figure 3 illustrates the relevant tradeoffs, when coordination costs are positive, for various values of A (larger values of A lead to higher curves). The figure shows how the number of suppliers that maximizes buyer surplus decreases as the importance of quality increases: the optimum when A is high (top curve) is at 1.5 suppliers vs. 2.6 suppliers when A is zero (bottom curve).

Figure 4 illustrates the corresponding tradeoffs when coordination costs are zero. If supplier investment is not important (bottom curve), the optimum number of suppliers is infinite. Each additional supplier slightly increases "fit," at no cost in coordination or

incentives. The top curve is more interesting. It shows that the optimal number of suppliers is finite, (in this case 2) when it is important to provide incentives for quality. The number of suppliers chosen by the buyer to maximize its surplus decreases as the importance of incentives increases, *even when coordination costs are zero!*

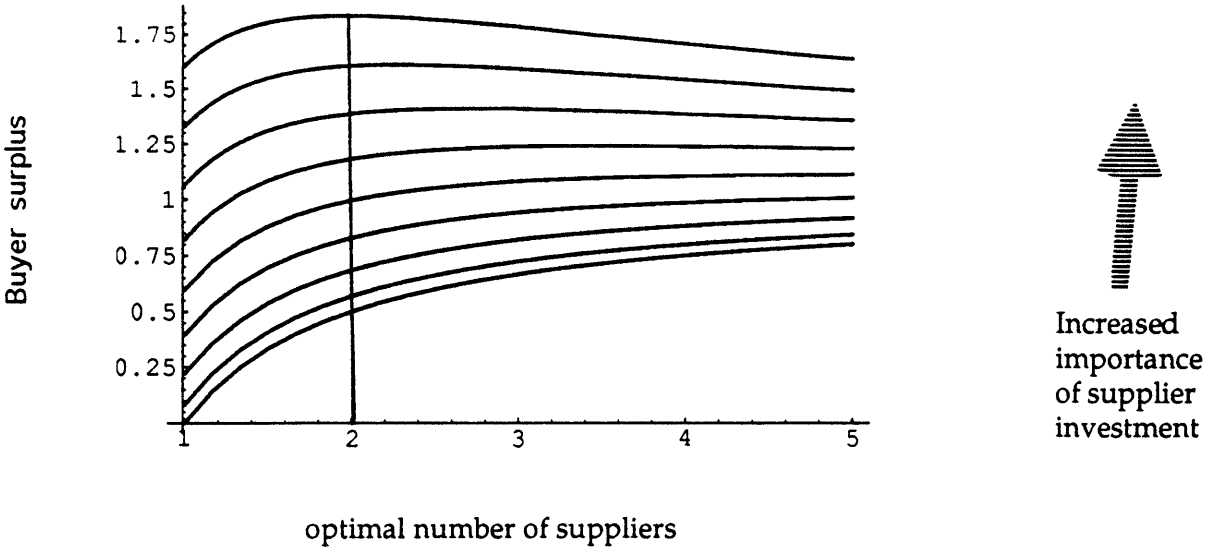

Figure 4: Coordination costs are eliminated

Comparing the two figures shows that for each curve, the optimal number of suppliers is greater when coordination costs are eliminated. However, a shift from an environment of high coordination costs and low importance of quality to one of low coordination costs and high importance of quality is consistent with the reduction in the number of suppliers that occurred in the 1980s.

4. Conclusion

The last decade has witnessed significant changes in both the technology and the organization of buyer-supplier relations, providing an opportunity to reexamine our theories. The persistence and even proliferation of small networks of suppliers as search and transaction costs have declined, suggests that previous theories were incomplete. Drawing on reports from managers that the principal benefits of reducing the number of suppliers lie in the increased incentives for characteristics that are not easy to specify contractually, such as quality, we were able to develop a more comprehensive model.

Implications and Empirical Support

Our model leads to some interesting predictions. First, when incentives for quality are important, it may be optimal to work with only a small number of suppliers, even if coordination costs become negligible. We show that while technological advances that reduce coordination costs can increase efficiency, they may have no effects on increasing the number of suppliers used by a firm if they also increase the importance of investments in quality. Thus our model addresses the apparent paradox identified earlier: information technology need *not* lead to the use of more suppliers.

Second, our model predicts that the number of suppliers will actually be *reduced* when it is important to provide suppliers with incentives to invest in quality. This can explain the finding of Cusumano and Takeishi (1991) of a strong correlation between the number of suppliers and the importance of certain aspects of the relationship, such as the emphasis on quality, the expectation to lower prices over time, and substantial information exchange evidenced by supplier suggestions and involvement in product development. Each of these dimensions of the buyer-supplier relationship is indicative of an important, non-contractible investment on the part of the supplier (which we included under the umbrella term "quality"), and a correspondingly smaller reliance on explicit contracts to govern the relationship. According to our model, the role of quality and other factors in supplier selection, and the suppliers' continuing effort to improve these characteristics even after selection, go hand-in-hand with the reliance on fewer suppliers. By relying on a smaller number of suppliers, a firm increases the incentives of each of them to go above and beyond the "letter of the contract."

This sort of empirical correlation is not unique to Cusumano and Takeishi. The advantages of close buyer-supplier relations such as quality, trust, innovation, information-sharing and responsiveness that are highlighted by other authors (Antonelli 1988, Helper 1991, Johnston and Lawrence 1988, Piore 1989), are exactly those dimensions that are most difficult to explicitly describe in a contract. In particular, our model provides a way of formalizing and explaining the contrasting observations that

> General Motors Corp.'s suppliers enjoy less security [than the Japanese] and hence have less reason to invest in the relationship (Blinder 1991),

and that

> [S]ince an implicit/explicit arrangement of profit sharing is the normal practice in [the Japanese supplier] relationship, underinvestment in transaction-specific assets may be avoided to both parties' mutual advantage (Aoki 1986).

There is empirical evidence that the strategy of reducing the number of suppliers is effective in improving incentives for quality. For instance, Xerox reduced its supplier base to about 500 from 5000, and at the same time it has seen its reject rates on parts go down by a factor of 13 (Emshwiller 1991). Mark V. Shimelonis, a vice president at Xerox adds that suppliers judged mostly on price often didn't focus on pulling substandard parts from the production line.

The traditional view of buyer-supplier relationships stresses coordination costs to the neglect of incentives. It indicates that the appropriate response to lower search costs is always an increase in the number of suppliers. Our analysis provides a contrasting lesson for managers: *When supplier quality is a concern, it can actually be optimal to reduce the number of suppliers.* Thus, it is not necessarily optimal to increase your supplier base just because new technologies make it cost effective; the impact on supplier relationships and their individual incentives must also be considered.

It is worth noting, however, that our models predict that reducing the number of suppliers will not always be beneficial. If there is no importance attached to investments in quality, then it is best to increase the number of suppliers searched until the marginal cost of search equals the expected marginal benefit from improved fit. This suggests that incentive considerations can be effectively ignored for easily specified products such as commodities. For these products, continued reductions in coordination costs should lead to an increase in the number of suppliers considered. The well-documented evolution of the airlines' computerized reservation systems may be indicative of a such a situation. The investments made by individual travel agents and airlines in each other are neither large, nor relationship specific, at least insofar as choosing a flight for a traveler is concerned. Thus, the primary impact of the technology has been to reduce search costs. Consistent with the low significance of "non-contractibles" and incentive considerations, reducing coordination costs has resulted in increasing the average number of suppliers (airlines) considered for each purchase (reservation). There are some emerging "electronic markets," for instance in aircraft parts, used cars, computers and certain information services, that also fit this description.

Why has the number of suppliers declined?

We have seen that the general trend toward fewer suppliers can be explained by the increasing emphasis placed by American firms on supplier attributes such as quality, epitomized by the "Total Quality Management" theme currently popular in management

circles. Furthermore, many related "non-contractible" characteristics are getting increasing attention as well.

We hypothesize that underlying technological considerations play a role in these trends and thus may be driving the "move to the middle". Our model indicates that the mechanism for such a move is that IT combines reduced coordination costs with an increased need to emphasize quality in order to remain competitive. Although the impact of lowering coordination costs has been discussed elsewhere (Malone *et al.* 1987), there are a number of reasons that IT will also have an impact on the importance of quality. For instance, just-in-time (JIT) inventory systems imply a very low tolerance for defects (O'Neal 1989). Milgrom and Roberts (1990) provide a formal model of "modern manufacturing" in which they demonstrate that an emphasis on "quality" is a necessary complement for the successful use of "technologically advanced equipment."

Furthermore, exploiting IT to rapidly respond to changing market conditions may preclude detailed contracts or work rules. For instance, IT tends to automate the more routine tasks, which are typically those which are easiest to detail in a contract, leaving behind a residue of tasks that are neither automatable, nor contractible (Brynjolfsson 1990). This would increase the need to rely on institutional mechanisms, such as reducing the number of suppliers, to provide appropriate incentives.

More generally, we suggest that IT has contributed to the increased expectations for speed, flexibility and responsiveness throughout the economic environment. Any comprehensive contract between a buyer and a supplier would have to consider and provide for an increasing number of future scenarios. Thus it has become relatively more cost-effective for both parties to share the benefits of their relationship relying on trust and *ex post* bargaining. In such an environment, a good partner is one who does not adhere merely to the "letter of the contract," but one who does whatever reasonably needs to be done. This results in increased reliance on the institutional incentives available to deal with incomplete contracts, such as partnerships with suppliers, leading to long-term relationships and reduced numbers of suppliers. In effect, IT has lead to a situation where the technology of production has outrun our ability write contracts that keep pace.[4]

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[4] Indeed, if the growing number of lawyers employed is any indication, we are far from automating the writing and enforcement of comprehensive contracts.

In a related stream of thought, Huber (1990) has pointed out the distinction between knowledge-intensive and product-intensive relationships and activities. Knowledge-intensive activities are not as easily contractible, because of the difficulty of writing complete contracts that define them precisely in a way that allows legal description of the contingencies. As the widespread adoption of IT increases the share of knowledge-related activities in the relationship between a firm and its suppliers, our model predicts that the significance of incomplete contracting considerations will increase.

Of course, it is possible that this new emphasis on quality is unrelated to IT, and is simply due to a belated realization that quality ultimately affects profits, or to an increasingly fierce competitive environment. Whatever the forces driving the increased emphasis on quality, the end result will be an increased reliance on institutional factors to provide the right incentives, as we model in section 3 of this paper. This leads us to conclude that, even as technological developments continue to reduce the magnitude of coordination costs, the need to provide incentives for quality is likely to limit the number of suppliers a firm uses.

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