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Abstract

The theory of incomplete contracts has been used to study the relationship between buyers and suppliers following the deployment of modern information technology to facilitate coordination between them. Previous research has sought to explain anecdotal evidence from some industries on the recent reduction in the number of suppliers selected to do business with buyers, by appealing to relationship-specific costs that suppliers may incur. In contrast, this paper emphasizes the fact that information technology enables greater completeness of buyer-supplier contracts through more economical monitoring of additional dimensions of supplier performance. The number of terms included in the contract is an imperfect substitute for the number of suppliers. Based on this result, alternative conditions are identified under which increased use of information technology leads to a reduction in the number of suppliers without invoking relationship-specific costs. Conditions are also identified when increased use of information technology leads to an increase in the number of suppliers.

1. INTRODUCTION

The access revolution spawned by the emergence of the World Wide Web in the 1990s led to rapid growth in business-to-consumer (B2C) electronic commerce. Business-to-business (B2B) electronic commerce, however, has followed a different path. Until recently, companies had focused on continued development of private networks because of their existing investments in technology, security issues on the Internet, and the lack of a common Web-based interface to support efficient on-line transaction processing. As we move into the new millennium, several industry initiatives are addressing the issues related to B2B electronic commerce on the World-Wide Web, and another Web revolution is expected to transform how organizations interact with each other in new B2B relationships. Our objective in this paper is to analyze how buyer-supplier relationships change as modern information and telecommunication technology (ITT) reduces the costs of search, coordination, and monitoring.

Contract theory has been a useful analytical framework for examining the impact of information systems on organizations. The theory of incomplete contracting, in particular, has been used to explain recent developments in buyer-supplier relationships, following the deployment of modern information technology to facilitate the coordination of activities between buyers and suppliers (Bakos and Brynjolfsson 1993a, 1993b; Clemons et al. 1993). Contract completeness in this context refers to the ability of the buyer to monitor in an economical fashion supplier compliance with activities that benefit the buyer.[1] This paper advances the examination of buyer-supplier relationships in the presence of changes in ITT that affect contract completeness.

Early research suggested that increased use of ITT may reduce the coordination cost of buyer-supplier relationships (Bakos 1991) or the buyer's search cost (Malone et al. 1987), in either case leading to an increase in the number of suppliers the buyer chooses to do business with. Bakos and Brynjolfsson (1993a, 1993b) and Clemons et al. reconciled this theoretical prediction with observed reduction in the number of suppliers in industries such as automobiles. They relied on the assumption that suppliers incur relationship-specific costs that are shared by the buyer in a bargaining game. These costs outweigh the lower coordination and search costs, and lead to a reduction in the optimal number of suppliers.

In contrast to previous work in this area, we do not need to invoke such an assumption about relationship-specific costs. Instead, we posit that improvements in ITT increase the ability to monitor supplier compliance in an economical fashion. A more complete contract with suppliers results in higher benefit for the buyer, but with more suppliers and more contract terms, monitoring costs may increase more than those benefits. Consequently, we show that it may be optimal for the buyer to either increase or decrease the number of suppliers he deals with, depending on how the costs of monitoring increase with the number of suppliers and contract terms.

At the core of this paper is the assumption that while ITT reduces transaction costs (which tends to increase the optimal number of suppliers), it also reduces the cost to monitor certain supplier activities, thus enabling a conversion of these factors from non-contractible to contractible. Bakos and Brynjolfsson (1993a) identify several factors in buyer-supplier relationships that have traditionally been considered non-contractible. These factors include quality, responsiveness, technology adoption, speed, flexibility, and defect rates. Product quality control often requires destructive testing of a sample of received parts. To improve quality of parts and reduce expensive, destructive testing, the buyer may want the supplier to invest in improved process control. Process control, often manifested as vendor certification, involves thorough investigation of many of the factors contributing to the supplier consistently meeting buyer expectations of product quality (Lockhart and Ettkin 1992). Without inter-organizational information systems, the cost to a buyer of monitoring a supplier's processes may be prohibitive, even if the supplier collects the necessary data. The introduction of inter-organizational information systems reduces the cost of monitoring contract compliance (Bakos and Brynjolfsson 1993b) and may thus convert process control as a proxy for product quality into a contractible signal.

In today's competitive environment, manufacturers increasingly have to offer their customers product variety and mass customization without increased delivery times. In order to meet these requirements, manufacturers rely on their suppliers to deliver a mix of parts in a timely manner. However, delivery performance depends on many different factors, such as finished parts inventory levels and work-in-process. Suppliers can track these factors inexpensively through the use of information systems (Clemons et al. 1993). Dumond and Newman (1993) outline six ITT-related activities that facilitate valid due dates and supplier schedules that allow a buyer to legitimately hold a supplier accountable for delivery performance. By certifying operating procedures, buyers can ensure that their suppliers are better able to deliver a dynamic mix of parts on a consistent schedule (Inman 1990; Inman and Hubler 1992; Shepherd 1994). In order to contract consistency in delivery times, the buyer has to be able to specify operational procedures and monitor the supplier's performance relative to the specifications. Such monitoring is possible through the integration of information systems across organizations.

The remainder of the paper is organized as follows. Section 2 presents an economic model of contract term and supplier selection when there are no relationship-specific costs. Section 3 provides analysis evaluating the impact of increased use of ITT on the optimal number of suppliers and level of contract completeness. Section 4 extends the analysis by explicitly considering the incentives for a supplier to participate in the contract when he incurs relationship-specific costs to participate. Finally, section 5 concludes the paper with a summary of our principal results.

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[1]Hart and Moore (1990) provided a foundation for the concept that contracts are incomplete. In a follow-up paper, Hart and Moore (1998) further formalized these ideas. Incomplete contracts arise when the contracting parties are not able to specify all contingencies that may affect the outcome of the relationship between the parties (Milgrom and Roberts 1992).

2. BASIC MODEL

Malone et al. (1987) analyze the effect of information technology on outsourcing decisions, focusing on transaction costs incurred in the dealings between a buyer and his suppliers. They find that the increased use of ITT decreases transaction costs and leads to a reduction in vertical integration and to an increase in the reliance on markets for the supply of parts in manufacturing. While this transaction cost-based result has found some empirical support in that information technology investments lead to smaller firms (Brynjolfsson et al. 1994), there is also evidence from the automobile industry that there is a general tendency toward a reduction in the number of suppliers with whom the buyers are doing business (Cusumano and Takeishi 1991; Helper 1991).

Observing this apparent inconsistency in firm response to the introduction of information technology, Clemons et al. (1993) extended the analysis of Malone et al. by adding the concept of opportunity risk. They argue that coordination of economic activities between firms requires relationship-specific investments. Such investments represent a risk to both the buyer and the suppliers, since a breakdown in the relationship will render all or parts of the investments worthless to both parties. Consequently, firms have avoided this risk by either integrating vertically or by under-investing in relationship-specific technology, which leads to a reduction in the number of suppliers. They argue that ITT also reduces operations risk associated with supplier non-compliance and moral hazard by reducing the costs of supplier monitoring. This reduction in operations risk leads to an increase in the number of suppliers.

We formalize some of the reasoning in Clemons et al. in a mathematical model of the buyer's decision of how many suppliers to do business with and how complete to make the supplier contracts. We show that the buyer's choice of level of contract completeness has an impact on the number of suppliers with whom he has contractual relationships.

Following the assumptions in Clemons et al., consider a buyer that is using a number of suppliers to provide intermediate goods for his production activity. He can select from a large number of suppliers. The buyer can choose to include a number of factors in the contract with the suppliers. To be able to enforce a contract term, the buyer has to monitor the suppliers' compliance and such monitoring is costly. The cost of monitoring depends on the amount of ITT available to the buyer. Given the level of available ITT, the decision problem for the buyer involves the selection of the appropriate number of suppliers as well as the number of performance dimensions to include in the supplier contract.

The mathematical analysis of the buyer's problem optimizes the total benefit of contracting with the selected suppliers using the selected monitoring signals, net of the cost of monitoring those signals and the cost of coordinating the suppliers' activities. In this basic model, we assume that there are no relationship-specific costs incurred by the supplier and, therefore, the buyer does not need to provide incentives to suppliers to participate.

The value of the buyer's output, net of the cost of its production, depends on how many suppliers (*x*) the buyer is doing business with and on how many terms (*n*) are included in the supplier contracts. Thus, the buyer's net revenue (or benefit) function is

$$B = B(n,x) \tag{1}$$

which is assumed to satisfy the conditions

$$B_n > 0 \text{ and } B_x > 0, \tag{2}$$

where B_i denotes the partial derivative $\partial B/\partial i$ of function B with respect to the variable i, $i=n, x$. Thus, the more suppliers the buyer is using and the more performance dimensions that are monitored, the higher is the buyer's net revenue. Increasing the number of suppliers increases the ability to find a supplier with a good fit. Similarly, increasing the number of contract terms reduces the risk of variation in the suppliers' delivered product, thereby increasing the probability of getting a supplier with a good fit. Finding suppliers with a better fit implies positive first order derivatives of the benefit function, B, with respect to x and n.

The supplier with the best fit can vary over time as the buyer maintains a stable of suppliers to source in response to stochastic needs for their products. For instance, if suppliers have limited production capacity, their ability to deliver products at a time that is convenient to the buyer may vary with factors such as previous commitments to deliver products to other buyers. Also, if the buyer has multiple plants located in different geographical areas, the best fit may be the supplier that can offer the lowest transportation cost to the buyer's plant that needs a delivery of the supplier's product. Thus, the benefit from having a larger number of suppliers is in enabling the buyer to respond more efficiently to random variations in market conditions. Establishing a relationship with a supplier implies that a contract must be negotiated, blueprints must be exchanged, designs must be provided, and so on, all of which requires time. This time delay until an identified supplier can make delivery limits the reliance on spot markets for outsourcing intermediate goods.

The cost of monitoring the supplier contracts increases with the number of suppliers, the number of contract terms, and the available ITT (t) that facilitates the monitoring of supplier compliance. Therefore, the monitoring cost function is

$$M = M(n,x,t) \tag{3}$$

which is assumed to satisfy the conditions

$$M_n > 0,\ M_x > 0, \text{ and } M_t < 0 \tag{4}$$

We also assume that the marginal cost of monitoring (with respect to the number of suppliers and the number of contract terms, respectively) is decreasing with the level of ITT, i.e.,

$$M_{nt} < 0 \text{ and } M_{xt} < 0 \tag{5}$$

With an increased use of B2B electronic commerce technology, communication of monitoring data can be standardized, which in turn will lead to a reduction in the marginal cost of monitoring with respect to the number of suppliers as well as the number of contract terms.

Further, the cost of coordination of the buyer's and the suppliers' activities increases with the number of suppliers and the level of ITT. Hence, the coordination cost function is

$$C = C(n,t) \tag{6}$$

which is assumed to satisfy the conditions

$$C_n > 0 \text{ and } C_t < 0 \tag{7}$$

The marginal cost with respect to the number of suppliers decreases as the amount of ITT increases, i.e.,

$$C_{nt} < 0 \tag{8}$$

Finally, we assume that the marginal cost of production and relationship-specific costs for both the buyer and the suppliers are zero, so that the total cost of the buyer's activities is captured by the contract monitoring and coordination costs. Investments in B2B electronic commerce technology will standardize electronic transaction processing, thus reducing the need for manual intervention by the buyer as well as the supplier. Thus, B2B technology implementation will reduce the marginal cost of adding a supplier.

The buyer's decision problem can then be formulated as

$$\max_{n,x} \quad B(n,x) - M(n,x,t) - C(n,t). \tag{9}$$

We assume a unique interior solution to the optimization problem. The first order necessary conditions for a maximum are

$$B_n - M_n - C_n = 0 \tag{10}$$

and

$$B_x - M_x = 0 \tag{11}$$

The second order sufficient conditions are given by

$$V_{nn} = B_{nn} = M_{nn} - C_{nn} < 0 \tag{12}$$

and

$$V_{xx} = B_{xx} - M_{xx} < 0 \tag{13}$$

and

$$V_{nn}V_{xx} - V_{nx}^2 > 0. \tag{14}$$

The sign of $V_{nx} = B_{nx} - M_{nx}$ will be of interest in the analysis that follows. The marginal net revenue of adding another supplier is smaller when contracts are more complete (x is large) than when contracts are less complete (x is small), since some of the expected benefit from finding a better fit by adding a supplier will be realized already by greater monitoring. Thus, $B_{nx} < 0$, and in a sense, the number of suppliers used by a buyer and the level of contract completeness are (imperfect) substitutes for one another. Also, the marginal cost of monitoring an additional supplier is likely to be greater when there are more contract terms (x is large).[2] Thus, M_{nx} is likely to be positive and the sign of V_{nx} is likely to be negative.

3. ANALYSIS

An analysis of our model provides insights into the change in relationship between buyers and suppliers when an enhanced level of ITT is introduced.

Proposition 1 *The number of contract terms included in a contract decreases with the level of ITT if and only if*

$$V_{nx} < \frac{V_{nn}M_{xt}}{M_{nt} + C_{nt}} < 0. \tag{15}$$

Similarly, the optimal number of suppliers decreases with the level of ITT if and only if

$$V_{nx} < \frac{V_{xx}(M_{nt} + C_{nt})}{M_{xt}} < 0. \tag{16}$$

Proof *Taking the total derivative with respect to t of equations (10) and (11), respectively, yields*

$$V_{nx}\frac{dn*}{dt} + V_{xx}\frac{dx*}{dt} - M_{xt} = 0 \tag{17}$$

and

$$V_{nn}\frac{dn*}{dt} + V_{nx}\frac{dx*}{dt} - M_{nt} - C_{nt} = 0. \tag{18}$$

On solving for dx/dt from the simultaneous equations in (17) and (18), we obtain*

$$\frac{dx*}{dt} = \frac{V_{nx}(M_{nt} + C_{nt}) - V_{nn}M_{xt}}{V_{nx}^2 - V_{nn}V_{xx}} \tag{19}$$

The denominator is negative by the second order sufficient condition in (14). Also, it follows from conditions (5), (8), and (12) that $M_{nt}+C_{nt}$, M_{xt}, and V_{nn} are all negative. Therefore, dx/dt<0 if and only if*

$$V_{nx} < \frac{V_{nn}M_{xt}}{M_{nt} + C_{nt}} < 0. \qquad \blacksquare$$

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[2]If, however, there is no substantial common random variation in all suppliers' performance, then relative performance evaluation may be useful. In such a situation, the marginal cost of monitoring additional contract terms may be lower when there are more suppliers and, consequently, M_{nx} is likely to be negative.

If V_{nx} is not sufficiently negative (or is positive), then the number of contract terms increases with *t*. However, if V_{nx} is sufficiently negative, an increase in the amount of ITT reduces the number of terms included in the supplier contracts. If the condition in equation (15) holds, then $| V_{nx} |/| V_{nn} |>| V_{xt} |/| V_{nt} |$. That is, the ratio of the magnitude of change in the marginal value of adding contract term to the magnitude of change in the marginal value of adding a supplier when there is an increase in the number of suppliers is greater than the corresponding ratio of change in the marginal value of adding contract term to the magnitude of change in the marginal value of adding a supplier when there is an increase in the ITT.

Similarly, if V_{nx} is not sufficiently negative (or is positive), then the number of suppliers increases with the level of ITT. Since $M_{nx} < 0$ when relative performance evaluation of suppliers is important, V_{nx} is likely to be less negative (or even positive) in this case, and more suppliers may be optimal to facilitate their monitoring. However, if condition (16) holds, then then $| V_{nx} |/| V_{xx} |>| V_{nt} |/| V_{xt} |$. That is, the ratio of the magnitude of change in the marginal value of adding a supplier to the magnitude of change in the marginal value of adding a contract term when there is an increase in the contract size is greater than the corresponding ratio of change in the marginal value of adding a supplier to the magnitude of change in the marginal value of adding a contract term when there is an increase in the ITT.

Intuitively, with enhanced ITT, the buyer is better off if he increases either the number of suppliers (*n*) or the number of contract terms (*x*). However, if $V_{nx} < 0$, then increasing one of the two variables when the other is at a higher level yields less value to the buyer than when the other is at a lower level. In fact, if V_{nx} is sufficiently negative, the buyer is worse off increasing both *n* and *x*, and his best option is either increasing *n* or increasing *x*.

Corollary 1 *If both dn*/dt and dx*/dt are negative, the second order sufficient conditions for an interior solution no longer hold.*

Proof *Suppose that both dn*/dt and dx*/dt. Then, by equation (15)*

$$V_{nx} < \frac{V_{nn} M_{xt}}{M_{nt} + C_{nt}} < 0. \tag{20}$$

Therefore,

$$\frac{M_{nt} + C_{nt}}{M_{xt}} > \frac{V_{nn}}{V_{nx}} < 0. \tag{21}$$

Substituting this relationship into equation (16) yields

$$V_{nx} < \frac{V_{nn} V_{xx}}{V_{nx}} \tag{22}$$

Consequently,

$$V_{nn} V_{xx} - V_{nx}^2 < 0, \tag{23}$$

violating the second order sufficient condition in (14) for an interior point optimum. ■

Corollary 1 implies that either the number of suppliers or the number of contract terms, or both, will increase as the level of ITT increases. It may be optimal for the buyer to decrease either one of the two variables n and x, but not both.

A special case of the above analysis is of interest. If the degree of contract completeness cannot be changed, the buyer's decision problem is simplified to

$$\max_{n} \quad B(n) - C(n,t) \tag{24}$$

The first order necessary condition for the maximum is

$$B_n - C_n = 0. \tag{25}$$

The second order sufficient condition is

$$B_{nn} - C_{nn} < 0. \tag{26}$$

Proposition 2 *If the buyer takes the degree of contract completeness as given and the level of ITT increases, the buyer chooses to do business with a larger number of suppliers.*

Proof *Taking the total derivative of equation (25) with respect to t yields*

$$(B_{nn} - C_{nn})\frac{dn*}{dt} - C_{xt} = 0. \tag{27}$$

This can be rewritten as

$$\frac{dn*}{dt} = \frac{C_{xt}}{B_{nn} - C_{nn}} \tag{28}$$

By assumption, the numerator on the right-hand side is negative, while the second order sufficient condition implies that the same is the case for the denominator. Consequently, dn/dt > 0.* ■

This result is consistent with previous findings in Malone et al. (1987) and in Bakos (1991).

4. RELATIONSHIP-SPECIFIC COSTS

We have so far assumed that the suppliers incur no costs if they seek to contract with the buyer. In this section, we will extend our basic model in a direction similar to that taken by Bakos and Brynjolfsson (1993a, 1993b) to include supplier participation costs.

Bakos and Brynjolfsson (1993a, 1993b) develop a two-stage model in which the buyer selects a number of suppliers in stage 1. The suppliers then make unobservable investments in relationship-specific capital so as to maximize their individual utility. In stage 2, fit is discovered and the suppliers renegotiate their contracts based on the Shapley value measure of their fit. Assuming a parametric structure for the buyer's production function, Bakos and Brynjolfsson analyze numerical solutions to the resultant structured problem. They show that as the importance of relationship-specific investments increases (i.e., the buyer's production function changes exogenously as more ITT is deployed such that the marginal value of the suppliers' incontractible relationship-specific investments increases), the suppliers increasingly under-invest in this type of capital. In response, the buyer selects a smaller number of suppliers to include in his supplier network.

We specify a model that captures the essence of this idea, but alters the negotiation process. In our model, the buyer posts the price he is willing to pay for products purchased from the suppliers. Based on this posted price, suppliers whose relationship-specific costs are sufficiently low will self-select for contracting with the buyer. During the contractual period that follows, the buyer places orders with different participating suppliers that have the best fit for the stochastic realization of the buyer's specific needs.

We assume that there are many suppliers in the market, all with the same marginal cost of production. To simplify the exposition, we assume that the marginal cost of production is zero for all suppliers. Relationship-specific participation cost for supplier *i*, if he decides to enter into a contract with the buyer, has two components: a specific fixed cost $F(i,t)$, which depends on the supplier and the available ITT, and a generic transaction cost $G(x,t)$, which depends on the number of contract terms and the available ITT.

Each supplier knows his fixed cost of participation given the prevailing technology level, *t*, and both the buyer and the suppliers know the distribution of supplier fixed cost. Next, without loss of generality, arrange the suppliers in order of increasing fixed cost so that $F(1,t) < F(2,t) <\ldots< F(n,t) < F(n+1,t) <\ldots$. This redefined function is increasing in the number of a supplier, *n*, and is positive for all values of $n \geq 1$ (see Figure1). We also assume that the fixed cost decreases with the level of ITT, i.e., $F_t(n,t) < 0$. The introduction of B2B electronic commerce technology will standardize many of the functions that were previously relationship-specific. These functions include the set-up of proprietary electronic data interchange and electronic fund transfer systems, as well as the deployment of proprietary middleware for automatic database exchanges. Thus, B2B technology introduction will reduce the relationship-specific supplier fixed costs.

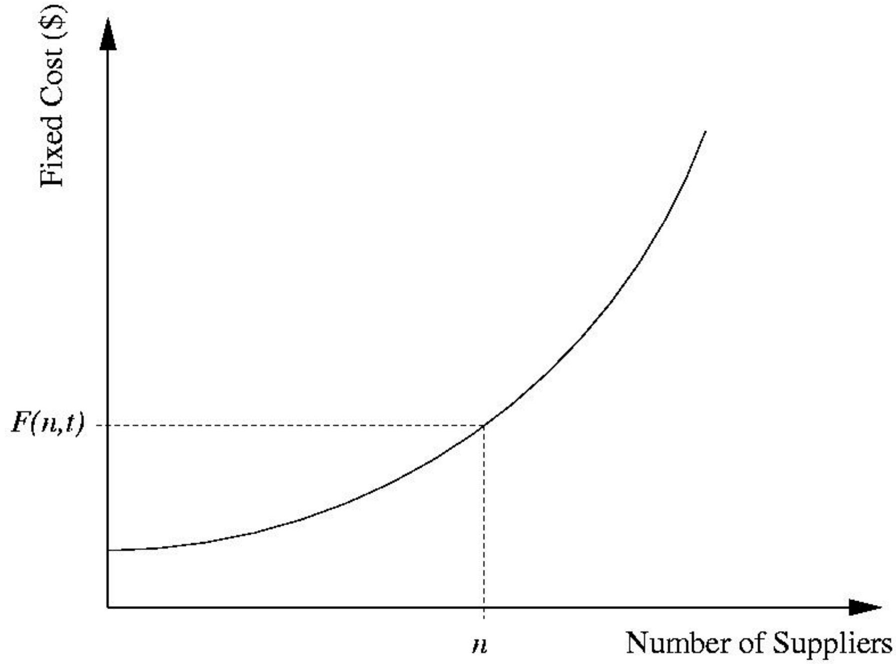

Figure 1. Supplier Fixed Cost Function

At the beginning of period 1, the buyer posts the contract terms, including t, x, and a reward r to the suppliers that choose to participate in the supplier network. Then, each supplier evaluates the offer and decides whether he wants to enter into a contract with the buyer. Thus, supplier i will participate if and only if

$$r \geq F(i,t) + G(x,t). \tag{29}$$

Since the buyer knows the cost distribution, it is optimal for him to choose a reward $r = r(n,x,t)$ given by the following conditions such that exactly n suppliers choose to participate:

$$r(n,x,t) = F(n,t) + G(x,t) \tag{30}$$

Since the buyer does not know each individual supplier's fixed cost, the buyer pays the reward r to all n participating suppliers. The total reward $R = n \cdot r$ paid by the buyer is

$$R(n,x,t) = n\big(F(n,t) + G(x,t)\big). \tag{31}$$

The marginal supplier will make normal profits, while the remaining suppliers will earn rents ($F(n,t) - F(i,t),\ i < n$) based on their lower fixed cost. Also, consistent with Bakos and Brynjolfsson (1993a, 1993b), we assume that the marginal cost of incentives to suppliers to motivate them to make the relationship-specific investment increases with the level of ITT, i.e.,

$$R_{nt} = F_t + G_t + nF_{nt} > 0. \tag{32}$$

Since both $F_t < 0$ and $G_t < 0$, this requires that F_{nt} is sufficiently positive. That is, the marginal cost of motivating an additional supplier to participate increases substantially with a higher level of ITT.

Including the supplier reward function to ensure they participate in the network, the buyer's decision problem is formulated as

$$\max_{n,x} \quad W(n,x,t) = B(n,x) - C(x,t) - M(n,x,t) - R(n,x,t). \tag{33}$$

Assuming an interior solution, the first order necessary conditions for a maximum are

$$W_n = B_n - M_n - C_n - R_n = 0 \tag{34}$$

and

$$W_x = B_x - M_x - R_x = 0. \tag{35}$$

The second order sufficient conditions are

$$W_{nn} = B_{nn} - M_{nn} - C_{nn} - R_{nn} < 0, \tag{36}$$

and

$$W_{xx} = B_{xx} - M_{xx} - Rx_x < 0, \tag{37}$$

and

$$W_{nn}W_{xx} - W_{nx}^2 > 0. \tag{38}$$

Analysis of this extended model yields results that are qualitatively the same as for the basic model without relationship-specific costs. The number of contract terms included in a contract decreases with the level of ITT if and only if

$$W_{nx} < \frac{W_{nn}(M_{xt} + R_{xt})}{M_{nt} + C_{nt} + R_{nt}} < 0. \tag{39}$$

Also, the number of suppliers that the buyer chooses to do business with decreases with an increase in the level of ITT if and only if

$$W_{nx} < \frac{W_{xx}(M_{nt} + C_{nt} + R_{nt})}{M_{xt} + R_{xt}} < 0. \tag{40}$$

However, as before, both *dn*/dt* and *dx*/dt* cannot be negative, or else the second order sufficient conditions for an interior solution will not hold.

Next, we investigate the special case where the degree of contract completeness cannot be changed. The buyer's decision problem is now simplified to

$$\max_n \quad B(n) - C(n,t) - R(n,t). \tag{41}$$

The first order necessary condition for the maximum is

$$B_n - C_n - R_n = 0. \tag{42}$$

The second order sufficient condition is

$$B_{nn} - C_{nn} - R_{nn} < 0. \tag{43}$$

Proposition 3 *If the buyer takes the degree of contract completeness as given and the amount of ITT increases, the buyer chooses to do business with a smaller number of suppliers if and only if*

$$C_{nt} + R_{nt} > 0. \tag{44}$$

Proof *Taking the total derivative of Equation (42) with respect to t yields*

$$(B_{nn} - C_{nn} - R_{nn})\frac{dn*}{dt} - C_{nt} - R_{nt} = 0. \tag{45}$$

This can be rewritten as

$$\frac{dn*}{dt} = \frac{C_{nt} + R_{nt}}{B_{nn} - C_{nn} - R_{nn}} \tag{46}$$

The second order sufficient condition implies that the denominator on the right-hand side is negative. Consequently, dn/dt < 0 if and only if* $C_{nt} + R_{nt} > 0$. ■

Proposition 3 states that if and only if the marginal cost of compensating the suppliers for their relationship-specific investment increases sufficiently with the level of ITT relative to the corresponding reduction in the marginal coordination cost (i.e., R_{nt} is greater than $|C_{nt}|$), then the optimal number of suppliers will decrease. In other words, it is not necessary to have *ex post* bargaining or specify a special structure for the buyer's production function to obtain the result of supplier pool reduction. All that is required is the intuitive assumption that the marginal cost of compensating suppliers for their relationship-specific investments increases sufficiently with the level of ITT to more than offset the reduction in the transaction costs.

5. CONCLUSION

The new millennium is expected to bring with it a revolution in B2B electronic commerce, and companies will have to adjust the way in which they interact with each other when doing business. This research has addressed the specific question of how more efficient ITT will impact the relationship between buyers and their suppliers.

Contradicting predictions offered by transaction cost theory, previous empirical research observed that, as the use of ITT proliferates in buyer-supplier relationships, buyers in some industries choose to use a smaller number of suppliers. This paper developed a simple model in which contract monitoring cost is introduced in addition to transaction cost to capture the complexity in buyer-supplier relationships. If the marginal monitoring cost decreases as modern ITT is introduced, a buyer may choose to include more terms in his supplier contracts, thus making the contracts more complete. As a consequence of the additional contract terms to monitor, depending on the characteristics of the cost functions, the total cost of monitoring per supplier may increase, in spite of the lower per-term monitoring cost. The increase in monitoring cost per supplier may offset or even dominate the reduction in transaction cost brought about by the increased use of ITT, thus leading to a reduction in the optimal number of suppliers.

The paper further investigated the impact of relationship-specific cost on the number of suppliers that participate in a buyer's supplier network. Without invoking any assumptions about supplier opportunism, ex post bargaining or a parametric form of the buyer's production function, the model helps identify conditions under which relationship-specific costs may lead to a reduction in the optimal number of suppliers. Thus, our results demonstrate that the arguments put forward by Clemons et al. (1993) and Bakos and Brynjolfsson (1993a, 1993b) hold under more general conditions.

Finally, the paper provides some interesting avenues for empirical research. Our model shows that the number of suppliers may increase or decrease as modern ITT is introduced in buyer-supplier relationships, depending on the behavior of the different cost components that govern the relationships. These cost components may differ between industries and between firms within an industry, and may change over time with the development of new ITT. Also, we consider monitoring cost and relationship-specific cost as two alternative explanations for a possible reduction in the number of suppliers used by a buyer. It will be valuable to establish empirically which one has merit and, if both factors are relevant, which one is more important.

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