INFORMATION SYSTEMS RESEARCH
Vol. 17, No. 2, June 2006, pp. 180–193
ISSN 1047-7047 | EISSN 1526-5536 | 06 | 1702 | 0180

INFORMS
DOI 10.1287/isre.1060.0083
© 2006 INFORMS

Information Technology, Contract Completeness and Buyer-Supplier Relationships

Rajiv D. Banker
Fox School of Business, Temple University, 210C Speakman Hall, Philadelphia, PA 19122, banker@temple.edu

Joakim Kalvenes*
Edwin L. Cox School of Business, Southern Methodist University, 6210 Bishop Boulevard, Dallas, TX 75275, kalvenes@smu.edu

Raymond A. Patterson
School of Business, University of Alberta, 3-21 E Business Building, Edmonton, Alberta, Canada T6G 2R6, ray.patterson@ualberta.ca

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 idea, 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. We find that a substantial increase in contract completeness due to reduced cost of information technology could increase the cost per supplier even though the cost of coordination and the cost per term monitored decrease. Such an increase in the cost per supplier leads to a reduction in the number of suppliers the buyer chooses to do business with. Similarly, we find that if coordination cost is reduced when more information technology is deployed so that the number of suppliers in the buyer's pool increases substantially, the buyer might choose to make the supplier contracts less complete and instead rely on a more market-oriented approach to finding a supplier with good fit.

Key words: contract theory; transaction cost; interorganizational systems; business-to-business relationships

History: Sanjeev Dewan, Senior Editor; Il-Horn Hann, Associate Editor. This paper was received on November 7, 2002, and was with the authors $15\frac{1}{2}$ months for 4 revisions.

* corresponding author

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 transaction cost (i.e., the costs of search, coordination and monitoring).

In this paper, we posit that improvements in ITT not only reduce coordination cost (which tends to increase the optimal number of suppliers), they also increase the ability to monitor supplier compliance in an economical fashion. Increased monitoring of supplier activities enable a conversion of these factors from non-contractible to contractible, making supplier contracts more complete. But with more suppliers and more contract terms, monitoring costs may increase more than the benefits from more tightly specified supplier contracts. In our analysis, we focus on buyer-supplier relationships between a single buyer and multiple homogenous, pre-qualified suppliers in the presence of changes in ITT that affect contract completeness. 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 cost of monitoring increases with the number of suppliers and contract terms.

1.1. Previous Research

Malone et al. (1987) analyzed the effect of information technology on outsourcing decisions, focusing on transaction costs incurred in the dealings between a buyer and his suppliers. They found that the increased use of ITT decreases buyer search 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. Using similar analysis of transaction cost, Bakos (1991) found that the increased use of ITT leads to reduced cost of coordination of buyer-supplier activities, which would tend to increase the number of suppliers the buyer chooses to do business with. While these transaction cost-based result have 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 Helper (1991), Cusumano and Takeishi (1991). The analysis in this paper builds upon the transaction cost literature and augments it by considering how increased use of ITT impacts simultaneously the breadth of enforceable terms included in contracts and the optimal number of suppliers.

In the literature studying inter-organizational systems and investments in these systems, the focus has been on asset ownership and the distribution of benefits arising from these joint investments. Building upon work by Grossman and Hart (1986), Hart and Moore (1990, 1999) and Milgrom and Roberts (1992) on incomplete contracts and asset ownership, Bakos and Brynjolfsson (1993a,b) and Clemons et al. (1993) reconciled this theoretical prediction with observed reduction in the number of suppliers in industries such as automobiles. They relied on the assumption that suppliers, while investing in interorganizational systems, 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 the work by Clemons and Kleindorfer (1992), the distribution of benefits is based on *ex post* bargaining. Since the benefits of the investments are unkonwn *ex ante*, opportunistic behavior on part of the participants results in under-investment in inter-organizational systems. The higher the relationship-specificity of the investment and the higher the switching cost of the participants, the lower the investment in the system. More recent developments in the inter-organizational systems literature incorporate the ideas of incomplete contracting. Bakos and Nault (1997) extended the framework of Hart and Moore (1990) to study implications of ownership for network asset investments. Based on calaculations of Shapley values in *ex post* bargaining, they derived conditions to determine the best ownership structure for essential network assets.

Han et al. (2003) combined the ideas of Clemons and Kleindorfer (1992) and Bakos and Nault (1997) to study the effects of inter-organizational system investments within the framework of incomplete contracting over the system investments. Anticipating their *ex post* bargaining power, participants will adjust their investments based on the expected surplus they receive. The model provides insights into how ownership of the different components of an inter-organizational system should be divided between the participants.

In another stream of research, the consequences of inter-organizational system adoption were investigated. Wang and Seidmann (1995) modeled Electronic Data Interchange (EDI) adoption among suppliers and showed that one supplier's adoption may cause negative externalities on other suppliers, leading to increased cost differentials in the supplier pool and increased concentration in the upstream market. This, in turn, may explain why some buyers use fewer suppliers in spite of the transaction cost reductions associated with EDI adoption. Seidmann and Sundararajan (1997) focused on the consequences of information sharing following the adoption of inter-organizational systems. They found that information sharing might change the relative bargaining power of the participants, thus rendering some participants worse off in spite of the collective increase in value to the participants as a group. In the context of procurement, the implementation of inter-organizational systems might result in the buyer appropriating rents from his suppliers due to increased competition among the suppliers.

Modeling EDI as a single technology with negative externalities among suppliers, Barua and Lee (1997) derived manufacturer penalty and subsidy policies aimed at providing efficient and effective incentives for suppliers to invest in EDI at a certain time. As technology converges toward a uniform standard (be it open or proprietary), the importance of investment incentives are reduced, as the investment can be used by the suppliers in multiple supply chain relationships. Thus, one may argue that as ITT continues to develop, and, potentially, the investment by suppliers in ITT increases, the relationship-specific part of the investment may actually be reduced.

Whereas the work in this paper is also studying buyer-supplier contracts, it differs from previous work in this area in that it does not consider contracting over investments in inter-organizational systems nor

the subsequent *ex post* bargaining over gains from these investments. Instead, the buyer-supplier contracts considered in this paper deal with the terms and conditions under which the suppliers provide the buyer with products. As such, it builds upon the principal-agent literature that deals with supplier monitoring cost. In this context, Milgrom and Roberts (1992) point out that as the cost of monitoring suppliers decreases, the buyer will increase the weight of the performance-based part of the supplier compensation scheme. This paper expands upon these ideas by also considering which aspects of the suppliers' activities to include in a contract and, subsequently, which aspects to monitor.

1.2. Organization

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 in Section 3 by considering the effects of supplier investments in ITT on the buyer's optimal choices of the level of ITT, the number of suppliers to contract with, and the degree of contract completeness. Section 5 concludes the paper with a summary of our principal results and some suggestions for an empirical investigation that might confirm or contradict the model proposed in this paper.

2. Basic Model

Following the assumptions in Clemons et al. (1993), consider a buyer that is using several 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. 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. In other words, the scenario we model is one in which a buyer maintains a set of pre-qualified suppliers. Over the duration of a supplier contract, the buyer

undertakes a multitude of projects, each of which requires goods and services from a number of suppliers.

Given the cost of ITT, the decision problem for the buyer involves the selection of the appropriate number of suppliers to pre-qualify 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, the cost of coordinating the suppliers' activities, and the cost of the chosen level of ITT. In this 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. We assume that the buyer takes the cost of ITT as given. Finally, for analytical tractability, we assume that all functions are twice continuously differentiable with respect to all variables.

The value of the buyer's output, net of the cost of its production, depends on how many suppliers (n) the buyer is doing business with and on how many terms (x) 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 good fit. Similarly, increasing the number of contract terms reduces the risk of variation in the suppliers' delivered product. Finding suppliers with a better fit implies positive first-order derivatives of the benefit function, B, with respect to x and n.

Selecting the number of terms (x) to include in the contract and, in particular, selecting the specific terms to include, may be a difficult problem in and of itself. Also, there is the risk of over-specifying a contract so

that a supplier is constrained to behave in a manner that is not efficient. For instance, if both on-time delivery performance and flexibility in product mix are part of the contract, enforcing both of these terms rigorously may result in the supplier increasing inventory levels, which in turn may lead to higher production costs over time.[1] We assume that the buyer is sufficiently rational to evaluate which contract terms will result in higher benefit to the buyer, and to evaluate the degree to which their inclusion will benefit the buyer.

Contract monitoring includes all activities that enforce the terms in the supplier contracts. The cost of monitoring the supplier contracts increases with the number of suppliers and the number of contract terms, and decreases with 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.

Consistent with Bakos and Brynjolfsson (1993b), we use the term coordination cost so as to include all cost necessary to facilitate transactions between the buyer and the suppliers, including search cost. We assume that coordination cost increases with the number of suppliers and decreases with the level of ITT. Hence, the coordination cost function is

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

[1] This particular point was made by one of the anonymous referees.

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.,

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

The cost of monitoring and coordination depend on the available amount of ITT, t. The buyer decides how much ITT to deploy given the prevailing cost a of ITT. We assume that the technology cost function is increasing in both the amount of ITT acquired and the cost level a. Thus, the technology cost function is

$$K = K(t; a) \tag{9}$$

which is assumed to satisfy the conditions

$$K_t > 0 \text{ and } K_a > 0. \tag{10}$$

The marginal cost is increasing both with respect to the amount of ITT and the cost of ITT, i.e.,

$$K_{tt} > 0 \text{ and } K_{ta} > 0. \tag{11}$$

The assumption that $K_{ta} > 0$ is consistent with any cost function of the form $K(t; a) = ak(t)$ where $k(t)$ is an increasing function of t. The assumption that $K_{tt} > 0$ is consistent with a scenario in which there are diseconomies of scale when complementary ITT investments are taken into account. If the assumption about K_{tt} is relaxed, it cannot be guaranteed that the technology cost function is convex.

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, coordination, and technology costs.

The buyer's decision problem can then be formulated as

$$\max_{n,x,t} \quad B(n, x) - M(n, x, t) - C(n, t) - K(t; a). \tag{12}$$

For convenience, let $U(n, x, t; a) = B(n, x) - M(n, x, t) - C(n, t) - K(t; a)$. For analytical tractability, we assume that the buyer's decision problem has an interior solution.[2] The first-order necessary conditions for a maximum are

$$U_n = B_n - M_n - C_n = 0, \tag{13}$$

$$U_x = B_x - M_x = 0, \tag{14}$$

and

$$U_t = -M_t - C_t - K_t = 0 \tag{15}$$

The second-order sufficient conditions for a maximum are derived from the Hessian matrix

$$H_U = \begin{bmatrix} U_{nn} & U_{nx} & U_{nt} \\ U_{nx} & U_{xx} & U_{xt} \\ U_{nt} & U_{xt} & U_{tt} \end{bmatrix}. \tag{16}$$

At a local optimum, the principal minor determinants of H_U satisfy the conditions

$$\det H_{U1} = U_{nn} < 0, \tag{17}$$

$$\det H_{U2} = U_{nn}U_{xx} - U_{nx}^2 > 0 \text{ and} \tag{18}$$

$$\det H_{U3} = U_{nn}U_{xx}U_{tt} - U_{nn}U_{xt}^2 - U_{nx}^2U_{tt} + U_{nx}U_{nt}U_{xt} + U_{nx}U_{nt}U_{xt} - U_{xx}U_{nt}^2 < 0. \tag{19}$$

Please note that, the conditions on the principal minor determinants also include $U_{xx} < 0$ and $U_{tt} < 0$, etc.

3. Analysis

An analysis of our model provides insights into the change in relationship between buyers and suppliers when the level of ITT changes as the cost of technology decreases. We begin by examining how the amount of technology employed by the buyer changes as the cost of ITT decreases. Once we have established that lower cost of ITT always leads to an increase in the level of ITT deployed by the buyer, we proceed to analyze how the use of ITT is re-allocated between the monitoring and coordination activities through changes in the number of suppliers and the degree of contract completeness chosen by the buyer as a result of changes in the level of ITT deployed.

[2] If the buyer's decision problem is concave, then the interior solution is unique and all results derived apply globally. In the opposite case, there might be multiple local optima and the derived results are guranteed only for small changes in the parameter value.

PROPOSITION 1. *The amount of ITT deployed by the buyer increases as the cost of ITT decreases.*

PROOF. Applying the envelope theorem to the first-order conditions (13)–(15) for parameter a yields

$$\frac{d}{da}U_n = U_{nn}\frac{dn^*}{da} + U_{nx}\frac{dx^*}{da} + U_{nt}\frac{dt^*}{da} + U_{na} = 0 \tag{20}$$

$$\frac{d}{da}U_x = U_{nx}\frac{dn^*}{da} + U_{xx}\frac{dx^*}{da} + U_{xt}\frac{dt^*}{da} + U_{xa} = 0 \tag{21}$$

$$\frac{d}{da}U_t = U_{nt}\frac{dn^*}{da} + U_{xt}\frac{dx^*}{da} + U_{tt}\frac{dt^*}{da} + U_{ta} = 0. \tag{22}$$

We observe that $U_{na} = 0$ and $U_{xa} = 0$. Solving (20)–(21) for dn^*/da and dx^*/da yields

$$\frac{dn^*}{da} = -\frac{U_{nx}}{U_{nn}}\frac{dx^*}{da} - \frac{U_{nt}}{U_{nn}}\frac{dt^*}{da} \tag{23}$$

$$\frac{dx^*}{da} = -\frac{U_{nx}}{U_{xx}}\frac{dn^*}{da} - \frac{U_{xt}}{U_{xx}}\frac{dt^*}{da}. \tag{24}$$

Substituting (24) into (23) yields

$$\frac{dn^*}{da} = \frac{U_{nx}U_{xt} - U_{nt}U_{xx}}{U_{nn}U_{xx} - U_{nx}^2}\frac{dt^*}{da}. \tag{25}$$

Substituting (25) into (24) yields

$$\frac{dx^*}{da} = \frac{U_{nx}U_{nt} - U_{nn}U_{xt}}{U_{nn}U_{xx} - U_{nx}^2}\frac{dt^*}{da}. \tag{26}$$

Substituting (25) and (26) into (22) and solving for dt^*/da yields

$$\frac{dt^*}{da} = -\frac{U_{ta}(U_{nn}U_{xx} - U_{nx}^2)}{U_{nn}U_{xx}U_{tt} - U_{tt}U_{nx}^2 + U_{nx}U_{nt}U_{xt} - U_{xx}U_{nt}^2 + U_{nx}U_{nt}U_{xt} - U_{nn}U_{xt}^2}. \tag{27}$$

Recognizing the denominator as $\det H_{U3}$ and the second factor in the numerator as $\det H_{U2}$ in (27), we can conclude that $dt^*/da < 0$. That is, if the purchase price level a decreases, the optimal investment in technology, t^* increases. □

Proposition 1 states that an exogenous decrease in a is equivalent to an exogenous increase in t^*. This result is intuitively appealing. As the factor price of ITT goes down, the buyer will choose to deploy more of it. The result is also consistent with the empirical observations in Brynjolfsson and Hitt (1996) and Dewan and Min (1997).

Given that a reduction in the cost of ITT will lead to increased use of this factor, we next analyze how a change in the level of ITT affects the number of suppliers selected by the buyer. In the discussion that

follows, the sign of $U_{nx} = B_{nx} - M_{nx}$ will be of interest. 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).[3] Thus, M_{nx} is likely to be positive and the sign of U_{nx} is likely to be negative.

PROPOSITION 2. *The optimal number of suppliers decreases with the level of ITT if and only if*

$$U_{nx} < \frac{U_{xx}U_{nt}}{U_{xt}} < 0. \tag{28}$$

PROOF. By the chain rule,

$$\frac{dn^*}{da} = \frac{dn^*}{dt}\frac{dt^*}{da}. \tag{29}$$

dn^*/da is given by equation (25) so that

$$\frac{dn^*}{dt} = \frac{U_{nx}U_{xt} - U_{nt}U_{xx}}{U_{nn}U_{xx} - U_{nx}^2}. \tag{30}$$

By equation (18), $U_{nn}U_{xx} - U_{nx}^2 > 0$. Consequently, $dn^*/dt < 0$ if and only if $U_{nx}U_{xt} - U_{nt}U_{xx} < 0$. By the second-order conditions, $U_{xx} < 0$ while by assumption, $U_{nt} > 0$ and $U_{xt} > 0$. Therefore, $dn^*/dt < 0$ if and only if

$$U_{nx} < \frac{U_{xx}U_{nt}}{U_{xt}} < 0.$$

□

One would normally expect that an increase in the amount of ITT deployed would result in an increase in the number of suppliers the buyer chooses to do business with given that contract monitoring cost and coordination cost both are reduced when more ITT is used. If U_{nx} is not sufficiently negative (or is positive),

[3] 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.

then the number of suppliers does, indeed, increase with the level of ITT. Since $M_{nx} < 0$ when relative performance evaluation of suppliers is important, U_{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 (28) holds, then $|U_{nx}|/|U_{xx}| < |U_{nt}|/|U_{xt}|$. 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 adding a contract term when there is an increase in the level of ITT.

The change in the optimal number of suppliers when the amount of ITT increases can be explained intuitively in the following way. Consider the marginal net revenue and cost functions with respect to n in Figure 1, where $x^*(n,t)$ is found by solving for x in the first-order necessary conditions (13) and (14) for a given t. In somewhat loose terms, if the optimal number of suppliers is to *decrease* with an increase in t, as suggested by Proposition 2, then the marginal cost $M_n(n, x^*(n,t); t) + C_n(n; t)$ must increase more than the increase in the marginal net revenue $B_n(n, x^*(n,t))$. That is,

$$B_{nx}\frac{dx^*}{dt} < M_{nx}\frac{dx^*}{dt} + M_{nt} + C_{nt}. \tag{31}$$

Re-arranging the terms, this is equivalent to

$$U_{nx}\frac{dx^*}{dt} - M_{nt} - C_{nt} < 0. \tag{32}$$

Recall equation (20). By Proposition 1, $dt^*/da > 0$, while $U_{na} = 0$ by assumption. The equation can then be re-written as

$$\frac{d}{dt}U_n = U_{nn}\frac{dn^*}{dt} + U_{nx}\frac{dx^*}{dt} + U_{nt} = 0. \tag{33}$$

Comparing this expression to equation (31) and recalling that $U_{nn} < 0$ by the second-order conditions, this is equivalent to $dn^*/dt < 0$. In Figure 1, this is represented by the intersection of the curve $M_n(n, x^*(n,t''), t'') + C_n(n,t'')$ and the curve $B_n(n, x^*(n,t'))$. On the other hand, for the buyer to choose a *larger* number of suppliers as the amount of ITT increases, the marginal net revenue must increase more than the marginal

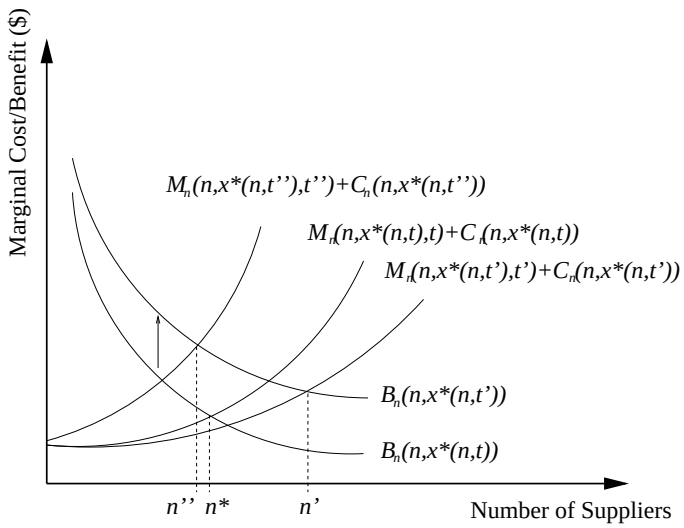

Figure 1 **Change in the number of suppliers due to use of more ITT.**

cost. Please recall that we consider the marginal functions here with respect to the number of suppliers. In Figure 1, this is represented by the intersection of the curves $M_n(n, x^*(n, t'), t') + C_n(n, t')$ and $B_n(n, x^*(n, t'))$.

A necessary condition for $dn^*/dt < 0$ is thus that

$$M_{nx}\frac{dx^*}{dt} + M_{nt} + C_{nt} > 0, \tag{34}$$

i.e., the increase in marginal cost due to an increase in the number of terms included in the contract is larger than the reduction in marginal cost due to ITT improvements. When $dx^*/dt > 0$, this implies that $M_{nx} > 0$ (i.e., economies of scale, if any, in the buyer's monitoring of its suppliers is dominated by an increase in supplier coordination costs). Figure 1 suggests that the increase in the number of contract terms must be quite large for the supplier pool to decrease as the level of ITT increases (the case represented by Proposition 2). In fact, the increase in contract size x must be so large that the total transaction cost per supplier increases even though both the coordination cost per supplier and the monitoring cost per contract term per supplier decrease. Thus, the change in the level of contract completeness will tend to moderate an increase in the supplier pool as the cost of monitoring and coordination decreases when more ITT is deployed, rather than to reduce the supplier pool size. A parametric example illustrating a supplier pool decrease as the cost of ITT goes down is provided in the Appendix.

In practice, a reduction in the number of suppliers when the level of ITT increases is likely to be associated with the deployment of a radically new technology in the buyer-supplier relationship that enables the economical monitoring of a large number of new contract terms. This might be the case if the cost of process monitoring drops below a threshold level so that the buyer chooses to install a system for monitoring a vast array of supplier activities. As a consequence, the contract size increases dramatically, resulting in an increased cost per supplier used.

PROPOSITION 3. *The optimal number of contract terms included in a contract decreases with the level of ITT if and only if*

$$U_{nx} < \frac{U_{nn}U_{xt}}{U_{nt}} < 0. \tag{35}$$

PROOF. By the chain rule,

$$\frac{dx^*}{da} = \frac{dx^*}{dt}\frac{dt^*}{da}. \tag{36}$$

dx^*/da is given by equation (26) so that

$$\frac{dx^*}{dt} = \frac{U_{nx}U_{nt} - U_{nn}U_{xt}}{U_{nn}U_{xx} - U_{nx}^2}. \tag{37}$$

By equation (18), $U_{nn}U_{xx} - U_{nx}^2 > 0$. Consequently, $dx^*/dt < 0$ if and only if $U_{nx}U_{nt} - U_{nn}U_{xt} < 0$. By the second-order conditions, $U_{nn} < 0$ while by assumption, $U_{nt} > 0$ and $U_{xt} > 0$. Therefore, $dx^*/dt < 0$ if and only if

$$U_{nx} < \frac{U_{nn}U_{xt}}{U_{nt}} < 0.$$

□

Since $U_{nx} = B_{nx} - M_{nx}$, if the marginal cost of monitoring is decreasing in the number of contract terms (i.e., $M_{nx} < 0$), or if the marginal cost of monitoring increases at a low rate in the number of contract terms, then the number of contract terms would tend to increase with the level of ITT. Thus, if U_{nx} is not sufficiently negative (or is positive), then the number of suppliers increases with the level of ITT. On the other hand, if U_{nx} is large and negative, so that the marginal cost of monitoring is increasing rapidly in the number of contract terms (so that M_{nx} is large and positive), the buyer would trade off an increase in the number of

contract terms against an increase in the number of suppliers so as to take advantage of the factor that yields the largest net contribution. Then, an increase in the amount of ITT *reduces* the number of terms included in the supplier contracts. If the condition in (35) holds, then $|U_{nx}|/|U_{nn}| < |U_{xt}|/|U_{nt}|$. That is, the ratio of the magnitude of change in the marginal value of adding a contract term to the magnitude in 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 a contract term to the magnitude of change in the marginal value of adding a supplier when there is an increase in the level of ITT. In this case, the increase in the number of suppliers makes the monitoring cost higher per term included in the contracts. This might happen if coordination cost is initially high so that the buyer chooses to use a relatively small number of suppliers with tightly specified contracts so as to make up for the otherwise poor expected fit resulting from the limited supplier pool. As the buyer increases the supplier pool as more ITT is deployed, the probability that the buyer can find a supplier with good fit increases even though the contract is less detailed.

Please note that, it is possible for U_{nx} to take on a value so that the buyer would choose to add both suppliers and contract terms when the level of ITT increases. Intuitively, with enhanced ITT, the buyer is better off if he increases the number of suppliers (n) or the number of contract terms (x), or both. However, if $U_{nx} < 0$ 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 U_{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. As the following corollary shows, it is never optimal for the buyer to reduce both the number of suppliers and the number of contract terms when the level of ITT increases.

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

sc Proof. Suppose that both $dn^*/dt < 0$ and $dx^*/dt < 0$. Then, by equation (35)

$$U_{nx} < \frac{U_{nn}U_{xt}}{U_{nt}} < 0. \tag{38}$$

Therefore,

$$\frac{U_{nt}}{U_{xt}} > \frac{U_{nn}}{U_{nx}}. \tag{39}$$

Substituting this relationship into equation (28) yields

$$U_{nx} < \frac{U_{nn}U_{xx}}{U_{nx}}. \tag{40}$$

Consequently,

$$U_{nn}U_{xx} - U_{nx}^2 < 0, \tag{41}$$

violating the second-order condition in (18) for an interior optimum. □

The corollary is supported by the simple observation that if the buyer increase neither n nor x, then there is no reason to increase the amount of ITT deployed since ITT has no alternative use in our model.

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 determine only the number of suppliers to do business with. Since $C(n,t)$ and $M(n,t)$ share the same characteristics with respect to n and t, these two functions can be represented by $C(n,t)$ alone when x is treated as a constant. This results in the formulation

$$\max_{n,t} \quad B(n) - C(n,t) - K(t;a). \tag{42}$$

For convenience, let $V(n,t;a) = B(n) - C(n,t) - K(t;a)$. The first-order necessary conditions for the maximum are

$$V_n = 0, \tag{43}$$

$$V_t = 0. \tag{44}$$

The second-order necessary and sufficient conditions are

$$V_{nn} < 0, \tag{45}$$

$$V_{tt} < 0, \tag{46}$$

$$V_{nn}V_{tt} - V_{nt}^2 > 0. \tag{47}$$

COROLLARY 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. Applying the envelope theorem and taking the total derivative of equation (43) with respect to a yields

$$\frac{d}{da}V_n = V_{nn}\frac{dn^*}{da} + V_{nt}\frac{dt^*}{da} + V_{na} = 0. \tag{48}$$

Similarly, for equation (44),

$$\frac{d}{da}V_t = V_{nt}\frac{dn^*}{da} + V_{tt}\frac{dt^*}{da} + V_{ta} = 0. \tag{49}$$

Solving these two equations for dt^*/da yields

$$\frac{dt^*}{da} = -\frac{V_{nn}V_{ta}}{V_{nn}V_{tt} - V_{nt}^2}. \tag{50}$$

Since $V_{nn} < 0$, $V_{ta} < 0$, and $V_{nn}V_{tt} - V_{nt}^2 > 0$, it follows that $dt^*/da < 0$. Recall that $dn^*/da = (dn^*/dt)(dt^*/da)$. Solving equations (48) and (49) for dx^*/da yields

$$\frac{dn^*}{da} = \frac{V_{nt}V_{ta}}{V_{nn}V_{tt} - V_{nt}^2}. \tag{51}$$

Consequently, as $V_{nt} > 0$, $dn^*/da < 0$ and $dn^*/dt > 0$. □

This result is consistent with previous findings in Malone et al. (1987) and Bakos (1991), who implicitly assume that the activities in a buyer-supplier relationship (such as which supplier activities are contracted and monitored) remain fixed while their cost goes down.

4. Supplier Investment in Technology

Suppose that the suppliers can choose their investment level in ITT. Further assume that the suppliers' investment in ITT has an impact on the buyer's cost and benefit functions. Similarly, the buyer's investment in ITT impacts the suppliers' cost of contracting and coordination. Let supplier i's benefit function be defined as $D_i(n, x)$, while the cost of monitoring and coordination is given by $L_i(s_i; x, t)$ and the cost of technology is given by $P_i(s_i; a)$. We assume that $\partial L_i/\partial s_i < 0$, $\partial L_i/\partial x > 0$, $\partial L_i/\partial t < 0$, $\partial P_i/\partial s_i > 0$, and $\partial P_i/\partial a > 0$, while $\partial^2 P_i/\partial s_i \partial a > 0$. Supplier i's decision problem is given by

$$\max_{s_i} \quad D_i(n,x) - L_i(x,s_i;t) - P_i(s_i;a), \tag{52}$$

$$\text{s.t.} \quad D_i(n,x) - L_i(s_i;x,t) - P_i(s_i;a) \geq 0 \tag{53}$$

where s_i is supplier i's investment in ITT. For analytical tractability, we assume that all functions are twice continuously differentiable, problem (52) has an interior solution and the suppliers have identical, but stochastic cost functions so that their investments in technology are identical. We shall therefore suppress the subscript i in the suppliers' decision problem. The buyer will compensate the suppliers for their transaction and technology costs so that the buyer's decision problem is

$$\max_{n,x,t} B(n,x) - M(n,x,t;s) - C(n,t;s) - K(t;a) - nD(n,x;s,a) \tag{54}$$

We assume that the buyer decides on his technology investment, t, and that the suppliers takes this, as well as n and x as given when making their investment decisions, s. The buyer is a Stackelberg leader and the suppliers are followers. The buyer anticipates the suppliers' investment s when deciding n, x, and t. The suppliers' reaction function $s^*(n,x,t,a)$ can be found by solving the suppliers' decision problem (52) with respect to s. Consistent with the principal-agent literature, we assume that the buyer has perfect information about the suppliers' cost and benefit function, and the suppliers are compensated so that $D(n,x) = L(s^*;x,t) + P(s^*;a)$. The buyer can then solve the equivalent problem of maximizing social welfare (Holmstrom and Milgrom 1991), i.e.,

$$\max_{n,x,t,s} Q(n,x,t,s;a), \tag{55}$$

where $Q(n,x,t,s;a) = B(n,x) - M(n,x,t,s) - C(n,t,s) - K(t;a) - nL(x,t,s) - nP(s;a)$.

PROPOSITION 4. *If the cost of ITT decreases, then the optimal investment in ITT increases for the buyer, the suppliers, or both.*

PROOF. Suppose that (n_0, x_0, t_0, s_0) is the buyer's optimal solution for ITT cost level a_0 and suppose that (n_1, x_1, t_1, s_1) is the optimal solution for $a_1 < a_0$. Assume that both $t_1 < t_0$ and $s_1 < s_0$. Then, by definition of optimality, $Q(n_1, x_1, t_1, s_1; a_1) > Q(n_0, x_0, t_0, s_0; a_1)$. By assumption, $K_a > 0$ and $P_a > 0$, while the

first-order partial derivative with respect to a of the other terms in Q is zero. Then, $Q(n_0, x_0, t_0, s_0; a_1) > Q(n_0, x_0, t_0, s_0; a_0)$, contradicting the supposition that (n_0, x_0, t_0, s_0) is an optimal solution for a_0. □

Proposition 4 confirms the intuition that if the suppliers cannot act strategically so as to avoid a shift in rent distribution between the buyer and the suppliers, some additional ITT will be acquired jointly by the buyer and his suppliers if the cost of ITT goes down. The proposition also confirms that social welfare increases as the cost of ITT is reduced, resulting in benefits for the buyer and his suppliers. In this model, we have assumed that the buyer is a Stackelberg leader in a principal-agent arrangement so that the buyer accumulates all the benefits of the ITT cost reduction while his suppliers continue to receive their indifference compensation. Other allocations of the increase in social welfare are possible.

Given that the amount of ITT deployed will increase as cost goes down, we are interested in how this additional ITT will affect the number of suppliers selected by the buyer and the degree of completeness used in the supplier contracts. There are three cases to consider. In the first case, both the buyer's and the suppliers' deployment of ITT increases. In the other two cases, either the buyer or the suppliers increase ITT deployment, while the other side reduces ITT use.

PROPOSITION 5. *If the cost of ITT decreases and both $dt^*/da < 0$ and $ds^*/da < 0$, then the optimal number of suppliers or the optimal contract size, or both, increase.*

PROOF. The first-order conditions for the buyer's decision problem are

$$Q_n = 0, \qquad Q_x = 0, \qquad Q_t = 0, \qquad \text{and} \qquad Q_s = 0. \tag{56}$$

Applying the envelope theorem to Q_n, Q_x, Q_t, and Q_s, respectively, we get

$$\frac{dn^*}{da} = -\frac{Q_{nx}}{Q_{nn}}\frac{dx^*}{da} - \frac{Q_{nt}}{Q_{nn}}\frac{dt^*}{da} - \frac{Q_{ns}}{Q_{nn}}\frac{ds^*}{da} - \frac{Q_{na}}{Q_{nn}} \tag{57}$$

$$\frac{dx^*}{da} = -\frac{Q_{nx}}{Q_{xx}}\frac{dn^*}{da} - \frac{Q_{xt}}{Q_{xx}}\frac{dt^*}{da} - \frac{Q_{xs}}{Q_{xx}}\frac{ds^*}{da} \tag{58}$$

$$\frac{dt^*}{da} = -\frac{Q_{nt}}{Q_{tt}}\frac{dn^*}{da} - \frac{Q_{xt}}{Q_{tt}}\frac{dx^*}{da} - \frac{Q_{ts}}{Q_{tt}}\frac{ds^*}{da} - \frac{Q_{ta}}{Q_{tt}} \tag{59}$$

$$\frac{ds^*}{da} = -\frac{Q_{ns}}{Q_{ss}}\frac{dn^*}{da} - \frac{Q_{xs}}{Q_{ss}}\frac{dx^*}{da} - \frac{Q_{ts}}{Q_{ss}}\frac{dt^*}{da} - \frac{Q_{sa}}{Q_{ss}} \tag{60}$$

Suppose that $dn^*/da > 0$ and $dx^*/da > 0$, and substitute (59) and (60) into (57) to obtain

$$\left(Q_{nn}Q_{xx} - Q_{nx}^2\right)\frac{dn^*}{da} = (Q_{nx}Q_{xt} - Q_{nt}Q_{xx})\frac{dt^*}{da} + (Q_{nx}Q_{xs} - Q_{ns}Q_{xx})\frac{ds^*}{da} - Q_{xx}Q_{na}. \tag{61}$$

$dn^*/da > 0$ only if $Q_{nx} < 0$. But, if $Q_{nx} < 0$ and $dn^*/da > 0$, then by (58), $dx^*/da < 0$. □

Proposition 5 extends the basic result from the previous section to the case when both the buyer and his suppliers choose to increase their investments in ITT given a reduction in the cost of ITT.

If only the buyer or the suppliers (but not both) increase ITT use, the result is ambiguous. Applying the envelope theorem to the buyer's first-order conditions (56) and solving for dt^*/da and ds^*/da, it can be shown (after some algebra) that

$$\frac{dt^*}{da} = -\frac{\det H_{Q3c}}{\det H_{Q3a}}\frac{ds^*}{da} + \frac{Q_{nt}Q_{xx} - Q_{nx}Q_{xt}}{\det H_{Q3a}}Q_{na} - \frac{\det H_{Q2a}}{\det H_{Q3a}}Q_{ta} \tag{62}$$

$$\frac{ds^*}{da} = -\frac{\det H_{Q3c}}{\det H_{Q3b}}\frac{dt^*}{da} + \frac{Q_{ns}Q_{xx} - Q_{nx}Q_{xs}}{\det H_{Q3b}}Q_{na} - \frac{\det H_{Q2a}}{\det H_{Q3b}}Q_{sa} \tag{63}$$

where

$$H_{Q3a} = \begin{bmatrix} Q_{nn} & Q_{nx} & Q_{nt} \\ Q_{nx} & Q_{xx} & Q_{xt} \\ Q_{nt} & Q_{xt} & Q_{tt} \end{bmatrix} \quad H_{Q3b} = \begin{bmatrix} Q_{nn} & Q_{nx} & Q_{ns} \\ Q_{nx} & Q_{xx} & Q_{xs} \\ Q_{ns} & Q_{xs} & Q_{ss} \end{bmatrix} \quad H_{Q3c} = \begin{bmatrix} Q_{nn} & Q_{nx} & Q_{nt} \\ Q_{nx} & Q_{xx} & Q_{xt} \\ Q_{ns} & Q_{xs} & Q_{ts} \end{bmatrix} \tag{64}$$

and

$$H_{Q2a} = \begin{bmatrix} Q_{nn} & Q_{nx} \\ Q_{nx} & Q_{xx} \end{bmatrix} \tag{65}$$

$\det H_{Q2a} > 0$, $\det H_{Q3a} < 0$, and $\det H_{Q3b} < 0$ by the second-order necessary conditions for a local optimum, while $\det H_{Q3c}$ is indeterminant. While the signs of dt^*/da and ds^*/da cannot be determined without knowing the functional form of Q, the sign of $\det H_{Q3c}$ plays an important role in determining whether t and s are net complements to or net substitutes for one another.

If dt^*/da and ds^*/da have opposite signs, it is mathematically possible to obtain $dn^*/da > 0$ and $dx^*/da > 0$. Referring to (55), this is rather implausible since the gross benefit $B(n, x)$ goes down. This must be counter-acted by a larger decrease in total cost. If $dt^*/da > 0$, the buyer's investment in ITT is shifted to a reduced number of suppliers whose cost (due to increased supplier ITT investments) is larger than before the reduction in a. A possible scenario would be a supplier's investment in an ERP system

incompatible with the buyer's system so that the buyer chooses to let the supplier do all information processing and accepting worse expected fit in return for a substantial reduction in $K(t; a)$. If $ds^*/da > 0$, then each supplier's total cost goes down. However, the reduction in supplier ITT investments significantly increases buyer monitoring cost, $M(n, x, t, s)$, so that a contraction in both n and x becomes attractive.

5. Conclusion

We expect the new millennium 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 in addition to search and coordination cost is introducted to capture the complexity in buyer-supplier relationships. If the marginal monitoring cost decreases as modern ITT is introduced, a buyer might 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 might 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 provides some interesting avenues for empirical research. Our model shows that the number of suppliers might 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 might differ between industries, between firms within an industry, and might 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.

From an empirical point of view, the model developed in this paper presents some distinct challenges. Most importantly, several of the model parameters are not observable. The amount of ITT deployed by a buyer for the purpose of contract monitoring or for the purpose of coordination of activities with suppliers is difficult to separate from ITT investments for other uses by the buyer. Similarly, it is not possible to obtain the cost per contract for monitoring. However, it is possible to observe both the number of suppliers used by a buyer and the size and complexity of the supplier contracts. Thus, an empirical investigation should focus on these two variables and how they relate to model predictions.

Our model takes as given the cost of ITT and predicts how the equilibrium in contract size, supplier pool, and level of deployed ITT changes as there are perturbations in the cost of ITT. ITT investments take time to implement. Therefore, it would be appropriate to study the change in equilibria over a time horizon of a few years.

Let $\Delta x/\Delta t$ be the change in contract completeness and let $\Delta n/\Delta t$ be the change in the number of suppliers as the amount of ITT changes. As argued previously, neither of these can be determined since t cannot be observed. However, the ratio of these two differentials,

$$\frac{\Delta x/\Delta t}{\Delta n/\Delta t} = \frac{\Delta x}{\Delta n}$$

can be observed. $\Delta x/\Delta n > 0$ implies a positive correlation between the change in contract size and the change in number of suppliers. The existence of $\Delta x/\Delta n < 0$ would provide support for the theory that increased contract monitoring cost might lead to a reduction in the number of suppliers.

Assuming that there are similarities in cost structure between companies within the same industry and that there are differences in cost structure between industries, the magnitude of the relationship between Δx and Δn can be studied for a number of industries. Differences between industries (such as positive or negative correlation between Δx and Δn) may be attributed to the cost structure in different industries.

As inter-organizational systems are standardized (for instance, through the transition from traditional EDI to web-based EDI), we expect that relationship-specific investments are reduced over time. A reduction in

relationship-specific investments reduces the potential for ex post supplier renegotiaion of the contract. A longitudinal study of $\Delta x/\Delta n$ might reveal a reduction over time in the number of companies that reduce their supplier pools as more ITT is introduced. However, if reductions in the number of suppliers do not disappear, this would provide support for contract monitoring cost as an explanatory factor for supplier pool reduction over *ex-post* bargaining.

Acknowledgments

Comments and suggestions from seminar participants at Carnegie Mellon University, Southern Methodist University, the University of Texas at Dallas, Northwestern University, and the 1998 Workshop on Information Systems and Economics are gratefully acknowledged. Special thanks to Eli Snir for many helpful discussions.

Appendix. Parametric Example

In this appendix, we provide a parametric example to illustrate the effect of technology cost reductions on the number of suppliers and the number of contract terms. Define the following benefit and cost functions:

$$
\begin{aligned}
B(n,x) &= A_1\left((c_1x+c_2n)^{\rho}+(c_3x+c_4n)^{\rho/2}\right)^{1/\rho},\\
M(n,x,t) &= A_2e^{-\gamma_2 t}n^{\alpha_2}x^{\beta_2},\\
C(n,t) &= A_3e^{-\gamma_3 t}n^{\alpha_3},\\
K(t;a) &= at^2.
\end{aligned}
$$

The buyer's benefit is a constant elasticity of substitution (CES) function, the monitoring cost and coordination cost functions are Cobb-Douglas, while the technology cost is a simple quadratic function. It is straightforward to show that the benefit function is concave and the cost functions are convex for positive parameter values, so that the buyer's objective function is concave and all the assumptions about the first-order and second-order conditions in Section 2 are satisfied.

Define the following parameter values:

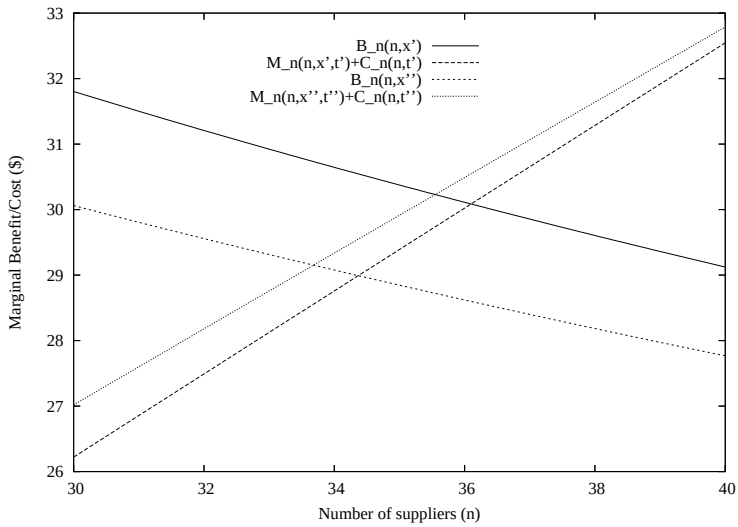

Figure 2 **Change in the number of suppliers due to use of more ITT.**

$$A_1 = 1,000, \quad c_1 = 0.1, \quad c_2 = 1.5, \quad c_3 = 0.1, \quad c_4 = 0.21, \quad \rho = -10,$$
$$A_2 = 0.5, \quad \alpha_2 = 1.1, \quad \beta_2 = 2.5, \quad \gamma_2 = 1.5,$$
$$A_3 = 0.5, \quad \alpha_3 = 2, \quad \gamma_3 = 0.5.$$

Suppose that $a' = 300$. The equilibrium choice of the number of suppliers, n' is 36, as indicated by the intersection of the functions $B_n(n, x')$ and $M_n(n, x', t') + C_n(n, t')$ in Figure 2. As the cost of ITT decreases to $a" = 263$, the two functions shift up to $B_n(n, x")$ and $M_n(n, x", t") + C_n(n, t")$, respectively, with the intersection of the two curves defining the new equilibrium $n" = 34$.

Table 1 summarizes the optimal choices of supplier size pool (n^*), contract size (x^*), and technology (t^*) for the parametric example. As the cost of technology (a) decreases, the amount of technology deployed increases. The availability of more technology changes the relative benefit of suppliers and contract terms so that the number of suppliers decreses while the number of contract terms increases. The reason for this shift is that as more contract terms are specified, the monitoring cost increases substantially so that the monitoring cost per supplier used increases although the monitoring cost per term has gone down. The increase in monitoring cost per supplier is larger than the reduction in coordination cost per supplier so that the net cost per supplier has increased (from 18.16 to 18.66). Consistent with transaction cost economics, the buyer will choose to do business with fewer suppliers.

Technology Cost a	ITT Level t^*	Suppliers Selected n^*	Contract Terms x^*	Monitoring Cost per Supplier $M(n^*, x^*, t^*)/n^*$	Coordination Cost per Supplier $C(n^*, t^*)/n^*$	Total Cost per Supplier $(M+C)/n^*$
300	0.99	36	46	7.25	10.92	18.16
263	1.21	34	58	9.38	9.28	18.66

Table 1 Summary of optimal choices of suppliers, contract terms, and technology for parametric example.

References

Bakos, J. Y. 1991. Information links and electronic marketplaces: The role of interorganizational information systems in vertical markets. *J. Management Inform. Systems* **8**(2), 31–52.

Bakos, J. Y., E. Brynjolfsson. 1993a. From suppliers to partners: information technology and incomplete contracts in buyer–supplier relationships. *J. Organ. Comput.* **3**(3), 301–328.

Bakos, J. Y., E. Brynjolfsson. 1993b. Information technology, incentives, and the optimal number of suppliers. *J. Management Inform. Systems* **10**(2), 37–53.

Bakos, J. Y., B. R. Nault. 1997. Ownership and investment in electronic networks. *Inform. Systems Res.* **8**(4) 321–341.

Barua, A., B. Lee. 1997. An economic analysis of the introduction of an electronic data interchange system. *Inform. Systems Res.* **8**(4) 398–422.

Brynjolfsson, E., Hitt, L. 1996. Paradox lost? Firm-level evidence on the returns to information system spending. *Management Sci.* **42**(4) 541–558.

Brynjolfsson, E., T. W. Malone, V. Gurbaxani, A. Kambil. 1994. Does information technology lead to smaller firms? *Management Sci.* **40**(12) 1628–1644.

Clemons, E. K., P. R. Kleindorfer. 1992. An economic analysis of interorganizational information technolgy. *Decision Support Systems* **8**(5) 431–446.

Clemons, E. K., S. P. Reddi, M. C. Row. 1993. The impact of information technology on the organization of economic activity: The “move to the middle” hypothesis. *J. Management Inform. Systems* **10**(2) 9–35.

Cusumano, M. A., A. Takeishi. 1991. Supplier relations and management: A survey of Japanese, Japanese-transplant

and U.S. auto plants. *Strategic Management J.* **12** 563–588.

Dewan, S., C.-K. Min. 1997. The substitution of information technology for other factors of production: A firm level analysis. *Management Sci.* **43**(12) 1660–1675.

Grossman, S. J., O. D. Hart. 1986. The costs and benefits of ownership: A theory of vertical and lateral integration. *J. Political Econom.* **39** 691–719.

Han, K., R. J. Kauffman, B. R. Nault. 2003. Who should own it? Ownership and incomplete contracts in interorganizational systems. Mimeo, Carlsson School of Management, University of Minnesota, Minneapolis, MN.

Hart, O., J. Moore. 1990. Property rights and the nature of the firm. *J. Political Econom.* **98** 1119–1158.

Hart, O., J. Moore. 1999. Foundations of incomplete contracts. *Rev. Econom. Stud.* **66**(1) 115–138.

Helper, S. 1991. How much has really changed between U.S. automakers and their suppliers? *Sloan Management Rev.* **32**(4) 15–28.

Holmstrom, B, P. Milgrom. 1991. Multi-task principal-agent analyses: Incentive contracts, asset ownership, and job design. *J. Law, Econom. and Organ.* **7** 24–52.

Malone, T. W., J. Yates, R. I. Benjamin. 1987. Electronic markets and electronic hierarchies: Effects of information technology on market structure and corporate strategies. *Comm. ACM* **30**(6) 484–497.

Milgrom, P., J. Roberts. 1992. The economics of modern manufacturing: Technology, strategy, and organization. *Amer. Econom. Rev.* **80**(3) 511–528.

Seidmann, A., A. Sundararajan. 1997. Building and sustaining interorganizational information sharing relationships: The competitive impact of interfacing supply chain operations with marketing strategy. J. DeGross, K. Kumar, eds. *Proc. 18th Internat. Conf. Inform. Systems*. Atlanta, GA, 205–222.

Wang, E. T. G., A. Seidmann. 1995. Electronic data interchange: Competitive externalities and strategic implementation policies. *Management Sci.* **41**(3) 401–418.