

**OPEN VS. PROPRIETARY SYSTEMS IN B2B E-PROCUREMENT:
A RISK-ADJUSTED TRANSACTION COST PERSPECTIVE**

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ABSTRACT

This article presents an economic model of a monopoly retailer that enables the study of incentives for business-to-business (**B2B**) e-procurement technology investments that permit inventory coordination and improved operational control. We focus on the information technology (**IT**) adoption behavior of firms in the presence of agency costs and information uncertainty. We distinguish among three kinds of B2B e-procurement technology platforms that can be selected: traditional interorganizational systems (**IOSs**), open B2B platforms associated with electronic markets on the Internet, and hybrid solutions. We find that larger firms tend to adopt costlier, but rely upon more certain procurement technologies, such as proprietary EDI. Smaller firms tend to adopt less costly procurement technologies that entail greater supply uncertainties, such as open B2B procurement platforms.

KEYWORDS: B2B, economic analysis, electronic commerce, electronic procurement, IT infrastructure, open systems, proprietary systems, risk exposure, supply chain management, technology adoption, technology standards, uncertainty.

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“Electronic commerce is a regime transition. It is now evident that the challenges of B2B e-commerce are more daunting than first imagined. More than just deliver technology, a B2B platform must address fundamental problems of strategy, cooperation, behavior, and finance. Even the simplest service -- a standard transaction platform—requires enormously complex interactions.”

Quoted from SureFoods Web site, July 2001 (www.surefoods.com)

INTRODUCTION

The application of Internet technologies to supply chain management and e-procurement transactions has led to significant growth in an emerging segment of the U.S. economy [22]. The Gartner Group, for example, estimated that the aggregate value of worldwide business-to-business (**B2B**) transactions in 2000 reached more than \$433 billion, nearly three times the 1999 level. This is occurring in a market that analysts expect to grow very rapidly, to about \$2.2 trillion by 2003, to \$7.4 trillion by 2004, and to about \$8.5 trillion by 2005 [12, 35].

Context: The E-Transformation of Procurement

The marketplace for B2B electronic market services has not been robust [23, 39], and nobody can deny the fundamental business process changes that are occurring in global supply chain management [31]. A report released by New York-based eMarketer.com reports that “IBM has done more than \$43 billion in electronic procurement during 2000, while Boeing is now processing more than 20,000 daily transactions via its website” [7]. Indeed, many observers view the new technologies in this area a “hook up or lose out” strategic value proposition [8]. Boston Consulting Group reports that by 2004, most firms that implement these kinds of technologies will save 1% to 2% of sales revenues [18].

The procurement transaction process is at the heart of all the changes. Today, all of the parties that are typically involved in supply chain transactions believe that the importance of leveraging the capabilities of the Internet for procurement activities is critical. Among the most attractive features of B2B procurement transactions on the Internet is the fact that buyers do not need to make costly long-term commitments to dedicated and hard-wired procurement systems associated with electronic data interchange (**EDI**). (See Table 1.) Yet the available evidence points to the persistence of such proprietary systems despite the higher costs of procurement [11].

Table 1. Firm Benefits in B2B E-Procurement

SUPPLIER BENEFITS	BUYER BENEFITS
<ul style="list-style-type: none"> ❑ Small order aggregation ❑ Lower customer acquisition costs ❑ Lower transaction costs ❑ Reduced time to market 	<ul style="list-style-type: none"> ❑ Lower cost method to find and select suppliers ❑ Improved negotiation due to larger orders and transparency ❑ Lower transaction costs
<p>Source: Adapted from Transora (www.transora.com).</p>	

To explain why this may be occurring, researchers have pointed out the importance of the role of *buyer-supplier coordination* as a desirable property for downstream firms [3]. However, there has been significant debate as to the nature of the interplay among the players (e.g., [9, 41]). But even though buyer-supplier coordination is an attractive feature of proprietary EDI systems that may keep firms from switching to the open B2B supply chain and procurement platforms, these delays may be reinforced by the supply risks and uncertainties that are associated with this new generation of Internet-based systems support. An important aspect of the value that a buyer might place upon Internet-based procurement can be tied to the extent to which procurement activities occur on a regular or irregular basis, involving the same or different trade partners, for supply items whose prices are relatively stable or tend to float in a wide enough band so as to create financial risk in procurement. In addition, other concerns relate to the potential for Internet security breaches, supply discontinuities due to the bankruptcy of a smaller on-line supplier, and procedural difficulties in financial settlement.

Dai and Kauffman [11] discuss some of these trade-offs and conclude that the success of an open B2B market depends on the extent to which it can adapt to existing proprietary interorganizational systems (IOS) technologies to induce firms to switch platforms. The authors point to the relative success of B2B marketplace automation leaders, such as Ariba (www.ariba.com), Commerce One (www.commerceone.com) and i2 (www.i2.com), and their adaptability to existing EDI technologies. A recent Jupiter Research report points to the important role of private trading networks in helping firms' to transition from proprietary EDI systems to the new technologies of the Internet [30].

Emphasis: Procurement Costs and Uncertainties

In this article, we develop an economic model that shows how the nature of the trade-offs discussed above are indeed likely to lead to the co-existence, in equilibrium, of both open B2B systems and the proprietary IOS systems. The key dependency, as we will shortly show, is firm size. The emergence of co-existing networks in our examination is paralleled by the findings of Belleflamme [4], whose work

examined network technology adoption under oligopolistic competition market structures. In contrast to our results for B2B e-commerce technology platform adoption, which emerge from the trade-off between procurement costs and supply uncertainties, Belleflamme's results depend on the degree of product substitutability that is observed in the market.

Our model focuses on *uncertainty* in the B2B procurement context, for both the demand side and the supply side of procurement. In particular, we study how the choice of information technology (**IT**) may reduce procurement uncertainties and, in turn, how aggregate demand side uncertainties may influence the firm's choice of IT procurement systems. A key emphasis is on the role of unanticipated inventories associated with these uncertainties. Thus, our model is well equipped to interpret the influence of the economic slowdown, and the nearly unprecedented inventory build-up that has accompanied it, on firm choices of supply chain technologies.

There are many observers in the business press who have suggested that the DotCom "meltdown" since the end of the second quarter of 2000 has served to focus many firms' attention on operational cost reduction by reducing inventory through the adoption of more effective supply chain technologies. A recent *BusinessWeek* article reports that "with the Internet exuberance barely cold in the grave, a far more sobering period has arrived: the era of efficiency... Today's executives are no longer asking about technology that will help them launch new businesses but about gear that will cut costs and wring more efficiency out of workers" [6].

Toronto-based electronics manufacturer, Celestica (www.celestica.com), recently was identified by *BusinessWeek* as being at the top of the 100 most profitable firms in the U.S. in 2001. The firm's outstanding performance is attributed to its focus on inventory management in the supply chain context. For example, as the economy slowed in March 2001, the company faced a decline in demand for its products of \$700 million, but it was able to hold the line on excess inventory, which increased by only \$300 million. This favorable outcome was achieved at a cost of some \$60 million of investment in supply chain management systems that "wired" its plants together across 12 different countries, enabling plant managers to see what supplies and spare parts are on hand, and where they might be employed. Even more interesting is that the firm fields a "supply chain SWAT team" at its Toronto headquarter, which is charged with leveraging the central reporting capabilities of the firm's supply chain system. In this instance, the SWAT team was able to see a potential inventory glut developing in the system in real-time, and it used the firm's market power with respect to its suppliers to roll back orders based on information supplied by the system [6]. Thus, it appears that the supply chain management system implemented by the firm also plays the dual role of a financial risk management system.

But, despite the positive impression that is created by this anecdote, there are still numerous managerial issues and challenges. Chief among them is the issue of the business value that accrues to IT

investments in the supply chain area, and how the value is split among participants, so that they can optimize their participation and investments. For example, Hwang, Pegels, Rao and Sethi [19] identified *initiators* and *followers* in the EDI systems adoption context, to distinguish between firms that adopted for their own benefit and other firms that were forced to adopt to achieve compliance with a strong buyer. Economic analysis has been widely applied in Information Systems research to understand the ways that IT creates value (e.g., Barua, Kriebel and Mukhopadhyay [3], Brynjolfsson and Yang [5], and Dos Santos and Peffers [13]). It has also been applied by economists in the network context (e.g., in the works of Economides [14], Farrell and Saloner [17], Katz and Shapiro [20], and Shapiro and Varian [38]).

Yet, with the exception of the 1990s stream of research on IOS and EDI from Carnegie Mellon (e.g., Mukhopadhyay, Kekre and Kalathur [26]; Mukhopadhyay, Kekre and Pokorney [27]; Riggins, Kriebel and Mukhopadhyay [32]; and Riggins and Mukhopadhyay [33]), the University of Rochester (e.g., Seidmann and Wang [37]), and the recent work on B2B electronic market technology investment and adoption from the University of Calgary by Nault and Dexter [28] and the University of Minnesota by Dai and Kauffman [10, 11], there are still relatively few analytical and empirical economics models in this area. Moreover, few address the issue of technology adoption in B2B electronic markets and supply chain management with a perspective on current technological choices, and the role of the value of the information that becomes available to management to deal with market uncertainties. The present paper is another effort in this direction.

MODEL

Early efforts to support B2B procurement using IT emphasized management of demand uncertainty through inventory demand forecasting and reduction of inventory and transportation costs. Cycle times also were reduced through the use of sophisticated optimization algorithms (Kumar, 2001). During the last decade, increases in computing power have enabled the use of these algorithms in complex supply chain situations, and permit firms to manage uncertainties that arise in the process as never before. These capabilities are now being extended to the technological solutions for B2B e-commerce. Our focus in this article is on the economics of uncertainty in the supply chain process, so we next turn to the development of a model that incorporates this consideration and enables us to understand the dynamics of B2B technology platform adoption.

Modeling Managerial Uncertainties in Supply Chain Management

Consider a competitive retail firm (a “buyer” in the supply chain context) that is able to exert some price control on its products (i.e., a price setter), but faces critical demand uncertainties. We further assume that the retailer procures its supplies in a competitive market that is subject to supply uncertainties from the upstream supplier.

The retail electronics sector, a long-term and significant sectoral user of EDI [42], is a good case in point. For example, despite some competitive pressures from other firms, the retail electronics giant Best Buy boasts significant regional market share for electronics goods where it chooses to compete, permitting it to exert considerable control over its pricing and market segmentation strategies relative to other competitors. Yet, as most consumers know who have shopped at Best Buy's superstores for DVD players and digital televisions, the firm often has insufficient stocks of these and other popular electronic products. These stock-outs stem both from supply uncertainties as well as demand forecasting uncertainties.¹

In contexts such as we have just considered, four aspects of the retail firm stand out relative to supply chain management. These include:

- the firm's relative market power at the product demand level;
- its competitive (price taking) behavior at the product procurement level;
- its uncertainties relative to supply; and,
- its uncertainties relative to demand.

Stochastic Demand and Supply Uncertainty. Demand uncertainties arise from that fact that final sales are subject to stochastic shocks that the firm's management cannot predict, that is:

$$q_s - q_d^f = \delta q_s \Rightarrow q_d^f = (1 - \delta)q_s \quad (1)$$

with $\delta \sim f(0, \sigma_\delta^2)$ and $\delta \in [-1, 1]$. In this relation, q_d^f is the final level of sales (or final demand, d^f), q_s is the supply quantity received from a wholesale supplier s (subject to uncertainty as described below) and δ is the error in management's estimates of final demand due to random shocks. To keep the analysis realistic, this error is assumed to be *relative* and, thus, we model it proportional to the magnitude of the supply (hence δq_s is included in the right hand side.) The random variable δ is symmetrically distributed with a distribution f that has mean 0 and variance σ_δ^2 . A convenient way to ensure this lower bound on δ is to assume that δ has a truncated symmetric distribution (such as the truncated normal distribution) in the interval $[-1, 1]$.

Uncertainty in the source of supply can be modeled in an analogous fashion, but it is relative to a control variable q_o that represents the quantity to be ordered from the supplier. Thus, we write:

$$q_s - q_o = q_o u \Rightarrow q_s = (1 + u)q_o \quad (2)$$

with $u \sim g(0, \sigma_u^2)$ and $u \in [-1, 1]$. In this relation, the distribution g can also be any symmetric truncated distribution. The source of fluctuations in the supply channel is likely to be independent of any random

¹ Since most of Best Buy's products are procured on a national basis, Best Buy faces much greater competition in procurement against the other regional leaders than it does in its product market. For example, Best Buy leads in central states while Circuit City leads in the western states.

fluctuations in demand so that $cov(\delta, u) = 0$. Then, the variable q_o is the control variable that management wishes to optimize (similar to what we described in the Celestica example).

Calculating Retailer Profits. The retailer's expected profits $E(\pi_r)$ may now be calculated by integrating its objective function over the two uncertainty dimensions:

$$E(\pi_r) = \int_{-1}^1 g(u) du \int_{-1}^1 \pi_r(q_s, q_d^f) f(\delta) d\delta \quad (3)$$

In order to calculate the expected profits in Eq. 3, we first evaluate the conditional expectation, $E(\pi_r(q_s))$, which holds q_s constant but integrates over q_d^f , based on:

$$\begin{aligned} E(\pi_r(q_s)) &= P(q_s)q_s \Big|_{q_s < q_d^f} \cdot \text{prob}(q_s < q_d^f) \\ &\quad + P(q_d)q_s \Big|_{q_s > q_d^f} \cdot \text{prob}(q_s < q_d^f) \\ &\quad - c[q_s \cdot \text{prob}(q_s < q_d^f) + q_s \cdot \text{prob}(q_s > q_d^f)] \\ &\quad - s(q_s - q_d^f) \text{prob}(q_s > q_d^f) \end{aligned} \quad (4)$$

$P(\cdot)$ is the inverse demand function, c is the unit cost of obtaining the product from the distributor (both as a unit product cost and/or the transaction processing cost), and s is unit inventory cost. The asymmetric nature of the losses show up in two ways. *First*, they occur in the form of revenue, which is determined by whichever of the two quantities, q_s and q_d^f , is smaller. *Second*, they also occur as inventory costs which arise in the event of over-supply relative to final sales.

We use s to denote the inventory cost, with the idea in mind that storage costs are cumulative over time. Both in the food retail sector, where products are perishable and in the non-food retail sector (e.g., electronics, clothing, etc.) where obsolescence matters, time is critical, and inventory costs may reach the point where they might equal or even exceed the product's price. The parameter s is capable of representing time implicitly, if each product line is associated with a different value of s . A manager of a retail firm often tracks inventory turnover for its products. Thus, different values of s can be attributed to each product as a composite of storage costs, storage time and risk of obsolescence. We will interpret s in this fashion.

We can express the probabilities in Eq. 4 in terms of δ and its density function $f(\delta)$ from Eq. 1. We note that $0 \leq \delta \leq 1$ when $q_s \geq q_d^f$ and $0 \geq \delta \geq 1$ when $q_s \leq q_d^f$. The conditional expected profit in Eq. 4 is:

$$\begin{aligned} E(\pi_r(q_s)) &= \int_{-1}^0 P(q_s)q_s f(\delta) d\delta + \\ &\quad \int_0^1 P[(q_s(1-\delta))] \cdot q_s(1-\delta) f(\delta) d\delta - \\ &\quad cq_s - s \int_0^1 \delta q_s f(\delta) d\delta \end{aligned} \quad (5)$$

This can be simplified because q_s is a *given* at this stage. This means that the term $P(q_s)q_s$ is independent of δ in the first integral. Moreover, since $f(\delta)$ is symmetric in δ , and the integral covers half the range of δ , the first integral can be evaluated as $(1/2)P(q_s)q_s$. We define the final term, the *demand error integral*,

as $\Omega_\delta \equiv \int_0^1 \delta f(\delta) d\delta$, so that the conditional expectation of profits is given by:

$$E(\pi_r(q_s)) = (1/2)P(q_s)q_s + \int_0^1 P[(q_s(1-\delta))] \cdot q_s(1-\delta) f(\delta) d\delta - cq_s - sq_s \Omega_\delta \quad (6)$$

Unanticipated Over-Supply in Inventory. In this expression, Ω_δ represents the *mean value* of δ , conditional on $\delta > 0$. Recall that we defined δ as the extent to which actual demand falls short of supply. Thus, Ω_δ represents the extent to which there will be, *on average*, an unanticipated oversupply or inventory build-up. Since $\delta \in (0,1)$, it follows that $\Omega_\delta < 1$. Although Ω_δ is an analytically distinct feature of $f(\delta)$, it is likely that Ω_δ will be positively related to the variance σ_δ^2 so that a more widespread distribution involves a larger value of Ω_δ . However, Ω_δ contains a signal value for the extent of oversupply while σ_δ^2 is pure white noise.

At this point, expected profits are still conditional on supply. The unconditional value of expected profits in Eq. 3 are related to this conditional expectation by integrating over the supply variance u :

$$E(\pi_r) = \int_{-1}^1 E(\pi_r(q_s)) g(u) du \quad (7)$$

We can then use Eq. 6, which provides an explicit form of $E(\pi_r(q_s))$. But since q_s is treated stochastically now, Eq. 2 is used to express q_s in terms of the non-stochastic q_o , the retailer's quantity of goods to be ordered up the supply chain. The resulting expression will involve the stochastic parameters δ and u , as arguments of the inverse demand function of $P[q_o(1+u)]$ and $P[q_o(1+u)(1-\delta)]$. As a result, further analysis must involve a Taylor series approximation of the inverse demand function, around the non-stochastic order size q_o to linearize the demand function. This expansion is carried out up to the second term, and then the results can be integrated over the appropriate density functions, and simplified. Following this process, the retail firm's expected profits become:

$$E(\pi_r) \cong (1-\Omega_\delta)P(q_o)q_o - (c + s\Omega_\delta)q_o + q_o^2 P'(q_o) A(\sigma_u^2, \sigma_\sigma^2, \Omega_\delta) \quad (8a)$$

where the final term

$$A(\sigma_u^2, \sigma_\sigma^2, \Omega_\delta) \cong (1-\Omega_\delta)\sigma_u^2 + \frac{1}{2}\sigma_\sigma^2(\sigma_\sigma^2 + \sigma_u^2) - \Omega_\delta \quad (8b)$$

Notice in Eq. 8a and 8b that while the supply and demand uncertainties, σ_δ^2 and σ_v^2 , affect expected profits adversely, the role of the unanticipated over-supply parameter, Ω_δ is mixed. It affects expected profits adversely via the revenues and inventory costs (the first two terms). But it also affects expected profits positively via the slope of inverse demand $P'(q_o)$, which is negative. This observation is tied to the market power of the retail firm. In fact for a competitive firm where demand is horizontal and $P'(q_o) = 0$, unanticipated oversupply, Ω_δ , reduces expected profits unambiguously. By contrast, firms with some market power are in a position to *reduce* the price level to respond to excess inventory build-up when supply exceeds sales (i.e., $q_s > q_d^f$, or $\delta > 0$), moderating the adverse effect of overestimating the demand. At the same time, however, the adverse effect of uncertainty, σ_δ^2 and σ_v^2 , exists *only* when firms enjoy some market power, but disappears otherwise. This leads us to assert Proposition 1:

Proposition 1. *Retail firms with greater market power are better able to absorb the adverse effect of oversupply shocks, by reducing prices, than those with little or no market power. They also are more adversely affected by supply and demand uncertainties than are competitive firms.*

2.2. Optimization in the Presence of Linear Demand

As before, a retail firm will select order level q_o in its supply chain to maximize expected profits. We examine the case of a linear demand (so that $P'' = 0$), where the Taylor series approximation from Eq. 8a and 8b is precise and the analysis is tractable. Specifically, we let $P(q_o) = a - bq_o$. The first order condition for optimization yields:

$$\frac{dE(\pi_r)}{dq_o} = 0 \Rightarrow q_o^* = \frac{1}{2b} \cdot \frac{(a-c) - (a+s)\Omega_\delta}{(1+\sigma_u^2)(1+\frac{1}{2}\sigma_\delta^2 - 2\Omega_\delta)} \quad (9a)$$

$$\pi_r^{e*} = \frac{1}{4b} \cdot \frac{[(a-c) - (a+s)\Omega_\delta]^2}{(1+\sigma_u^2)(1+\frac{1}{2}\sigma_\delta^2 - 2\Omega_\delta)} \quad (9b)$$

The denominators of Eq. 9a and 9b are positive due to the concavity condition we impose for ensure optimality. As a result, a positive value of output and profit level implies that the numerator must be positive, $a(1-\Omega_\delta) > c + s\Omega_\delta > 0$. This means the strength of the demand per unit a , adjusted for unanticipated oversupply, must exceed the sum of costs. The supply and demand uncertainties, σ_δ^2 and σ_u^2 , adversely affect optimum output and profits. However, the parameter Ω_δ continues to play a dual role in its effect on profits and output; via the numerator it reduces both, and via the denominator it increases both. The latter effect arises from the negative slope of the inverse demand function, and shows that larger firms with market power can absorb effects of unanticipated inventory build-up by reducing prices.

IT ADOPTION DECISIONMAKING IN THE B2B E-PROCUREMENT CONTEXT

We earlier observed that different procurement strategies and the related technologies that firms must adopt do not offer the same levels of cost savings and risk avoidance. We next consider the roles of *platform type* (open vs. proprietary) and *firm size* (large vs. small).

Proprietary Vs. Open Platform Adoption

To probe this assertion further in the context of our model, we next extend our model by considering two forms of supply chain management technologies, ϕ_1 and ϕ_2 . Each is characterized by different levels of procurement costs and supply risks. They are as follows:

- **Proprietary platform technologies:** Technology ϕ_1 exposes the adopter to relatively high procurement transaction costs c , but the procurement risks given by σ_u^2 are low because many relatively reliable long-standing suppliers will be on the network.
- **Open platform technologies:** Technology ϕ_2 causes the adopter to face relatively low procurement transaction costs, c , but there are high procurement risks, as depicted by the cost variance σ_u^2 because relatively fewer suppliers will have been able to achieve open platform connectivity (at least in the short-run, when primary value flow considerations are made by the adopter).

Our characterization of proprietary version open systems is meant to emphasize special contrasts. The variable ϕ_1 is intended to represent proprietary procurement systems, such as traditional and Web-based EDI; and collaborative planning, forecasting and replenishment (CPFR) systems; and supplier-managed inventory (SMI) and co-managed inventory (CMI) systems.² The variable ϕ_2 is intended to represent the first generation of open B2B technology platforms that are associated with Internet-based supply chain management systems (e.g., Ariba, i2 and CommerceOne, prior to their moves to incorporate other firms' proprietary software capabilities to build their suites of supply chain software capabilities).

Recall that we pointed to the possibility of uncertainties due to security problems, supply discontinuities and financial settlement risks when open platforms are selected, in spite of their broader span of market participants and possibly lower supply prices. The trade-off between the technologies can be represented in a comparative cost-variance framework for a given level of expected profits. We can understand this trade-off through the iso-profit surfaces, $\bar{\pi}^e_r$, and totally differentiating Eq. 9a with

² We note that industry practices are slightly more complex than our model depicts. There are many instances of *product sharing alliances* and *platform convergence strategies* that bring together proprietary and open platform capabilities for supply chain management. Examples include Ariba's, Novopoint's (www.novopoint.com) and Transora's (www.transora.com) recent adoption of Synchra Systems Inc.'s (www.synchra.com) proprietary supply chain CPFR software suite. See Ariba [1]; Novopoint [29]; and Transora [45]. Overall, this suggests the possibility of identifying *mixed strategy technology adoption approaches*. Recognizing the inherent limitations relative to real world decisionmaking, we limit ourselves to modeling *pure-play technology adoption strategies*.

respect to c and σ_u^2 , yielding:

$$\frac{d\sigma_u^2}{dc} \Big|_{\bar{\pi}_r^e} = -\frac{1}{2b} \cdot \frac{1}{\bar{\pi}_r^e} \cdot \frac{[(a-c) - (a+s)\Omega_\delta]^2}{1 + \frac{1}{2}\sigma_\delta^2 - 2\Omega_\delta} \quad (10a)$$

When optimum sales in Eq. 9a and optimum profits in Eq. 9b are positive, the slope in Eq. 10a will be negative:

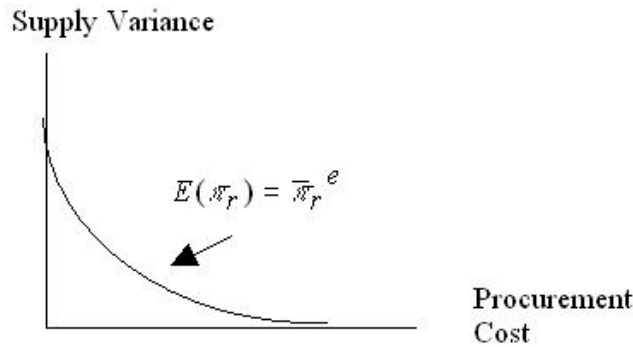
$$\frac{d\sigma_u^2}{dc} \Big|_{\bar{\pi}_r^e} < 0 \quad (10b)$$

This negative slope describes a trade-off between a firm's choice of technologies that entail lower procurement costs but a higher supply variance versus those that entail a lower procurement cost, but higher supply variance. Through marginal analysis of the second derivative of the iso-profit surface, we can find the sign of curvature of the trade-off curve. This is found by differentiating Eq. 10a with respect to c to obtain:

$$\frac{d^2(\sigma_u^2)}{dc^2} = \frac{1}{2b} \cdot \frac{1}{\bar{\pi}_r^e} \cdot \frac{1}{1 + \frac{1}{2}\sigma_\delta^2 - 2\Omega_\delta} > 0 \quad (11)$$

From the signs we observe in Eq 10b and 11, we can see that the firm will face a trade-off curve that is convex to the origin, as in Fig. 1.

Figure 1. Technology Adoption Iso-Profit Curve



This leads us to assert a second proposition:

Proposition 2: *Firms' iso-profit curve associated with B2B technology platform adoption in the parameter space of supply procurement risks versus costs is convex.*

Differential Adoption in Large and Small Firms

One of the key threads in the literature on IT value is the importance of firm size related to investment strategy and the magnitude of the returns that are achieved. Is firm propensity to adopt open versus proprietary B2B technology platforms also likely to depend on firm size?

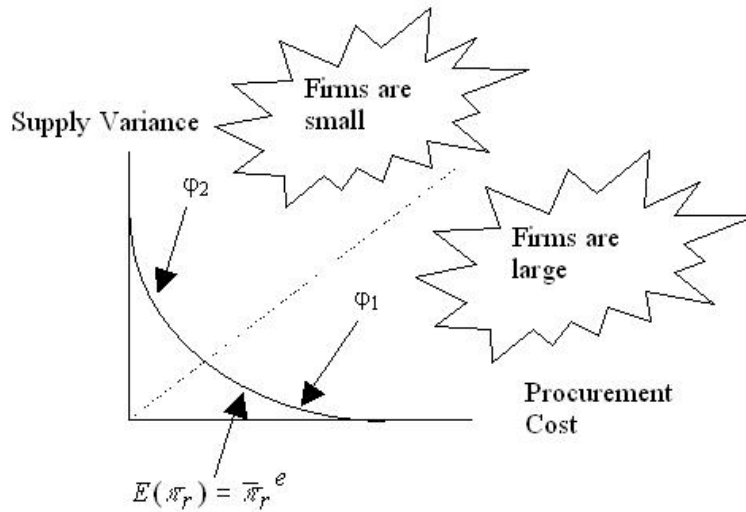
To answer this question we must relate firm order size to firm profits from Eq. 9a and 9b. This

yields:

$$q_o^* = \frac{2\pi_r^{e*}}{(a-c)-(a+s)\Omega\delta} \quad (12)$$

Next, suppose that profits are held at their maximum level. Sales will still vary depending on the quantity in the denominator and especially, unit procurement cost, c . Among all firms that earn *same* profits (specified by π_r^{e*} in Eq. 12), and lie on the iso-profit contour shown in Fig. 1, firms with *higher* unit procurement costs will be the *larger* ones (based on q_o^* in Eq. 12), lying on the lower part of iso-profit contour. By the same token, firms with the *lower* procurement costs will be the *smaller* ones, and will lie on the upper part of iso-profit contour. (See Fig. 2.)

Figure 2. B2B Platform Adoption and Firm Size



From this result, the following proposition emerges:

Proposition 3: *Firms self-select into different groups. Smaller firms adopt technologies that entail lower costs but higher supply variance (i.e., open B2B technologies). Larger firms adopt technologies that entail higher procurement costs but lower supply variance (e.g., more traditional IOSs and the new proprietary solutions).*

This finding generally matches what we believe has been happening in industry. The larger more established firms emphasize the maintenance of smooth supply lines by reliance on proprietary IOS technologies such as EDI. They keenly appreciate the extraordinary costs associated with “scrapping everything” and fully committing themselves to vendors who have yet to demonstrate they are truly able to achieve critical mass in the market. Over time, these firms’ suppliers have also begun to recognize the diminution of bargaining power that is associated with “tied procurement systems.” (Strassmann [43] cites the case of General Electric’s pullback from its commitment to B2B e-commerce IT investments.)

Moreover, they recognize that any significant mistake could become a “billion dollar blunder,” and require several years time for a full recovery. Along these lines, a recent *Computerworld* article comments:

“Many reasons can be traced to the limitations of the early technology. Early e-marketplaces had the most advanced technology at the time, but their applications were too costly, too complex and took too long to roll out compared with the expectations set by their B2C predecessors. This meant that potential buyers and sellers didn't participate in sufficient numbers for the model to reach critical mass and become profitable.” (Samec [36])

So from the point of view of a large firm, all of the risks with respect to systems success that a small firm might face would be amplified. Large software applications take longer to build, are more prone to implementation delays, and are more costly to implement effectively. They also are more susceptible to outright project failure than smaller applications are. In addition, larger organizations operate with an exponentially complex network of buyers and suppliers. Take the example of the national United States retailer, Sears, Roebuck and Co, which has more than 6,000 suppliers. In the past four years, the firm identified a need to bring these suppliers into compliance with its own internal standards for e-commerce-capable procurement systems connectivity, to ensure control of its strategy costs.

After contacting the EC/EDI service branches of [] consulting firms, Sears decided to pursue a relationship with a smaller, dedicated e-commerce services company. “The big players weren't eager to jump into an unproven business model, and their lack of enthusiasm made us wary,” said a Sears spokesperson. “It made more sense to work with a smaller firm dedicated to e-commerce, with no ancillary businesses. We wanted someone whose fortunes were tied to the quality of customer service, someone willing to stake their reputation on the quality of work they do to bring our suppliers up to speed ...” (SPS Commerce [40])

SPS Commerce reports that its proprietary approach has been to cover “all of the bases” for Sears, including Internet, fax, paper and application-to-application documentary exchange for B2B transactions. This is clear evidence that larger firms may be more willing to bear the cost of reducing risk by bearing high transaction costs.

In contrast, smaller firms are willing to sacrifice supply process risks for lower procurement costs they obtain by adopting open B2B e-commerce platforms. There have fewer “bases” to cover, and little impetus to “recreate the wheel” with new supply chain technology solutions, but incentives to control procurement costs. Vail Resorts, Inc. (www.vailresorts.com), operator of Grand Teton Lodge, and Vail, Beaver Creek and Breckenridge ski resorts, is a case in point. As a small enterprise and B2B e-marketplace customer of CommerceOne, Vail Resorts would be unable to get the attention of a

proprietary B2B system provider, which, for profitability, would mostly focus on larger customers.

Towards B2B E-Commerce: Analyzing Adoption When a Firm Switches Technology Platforms

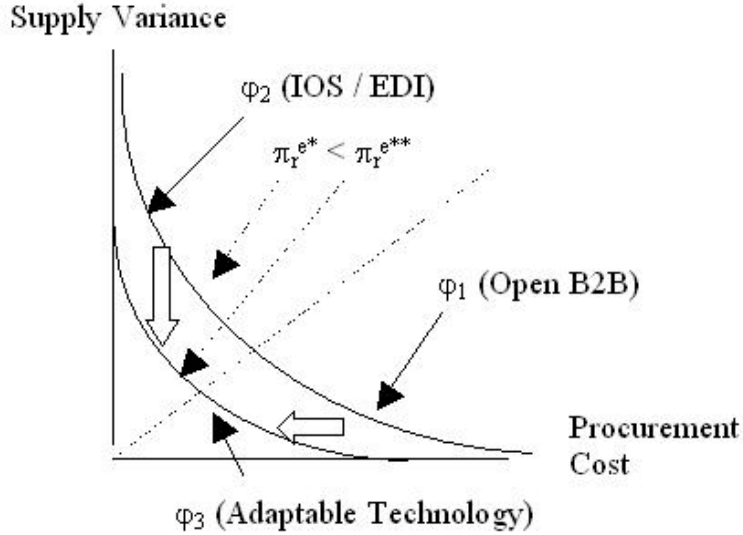
One of the most well known results in microeconomics characterizes adoption inertia that ensues when a new technology is superior but presents an adopter with risks due to the variance of adoption and implementation cost, in the presence of an older, more well-established technology that has a larger *installed base*. The last few years, we have seen a similar situation develop with respect to technology platforms that support procurement. EDI is tried and true, and knowledge of how to make it work is widespread. Moreover, EDI is known to produce measurable business value due to improvements in operational aspects of procurement (e.g., [21, 25, 26]).

But will new B2B platforms be perceived as having potential to create *enough* value so traditional users of EDI technologies in supply chains make the switch? To provide insights, we model a third kind of B2B platform. A *hybrid adaptable B2B technology platform* is defined as a more adaptable technology platform, φ_3 , which gives the adopter to low procurement transaction costs c , through the connectivity it offers to the Internet, but the procurement risks given by σ_u^2 are also low, similar to the proprietary solutions we discussed.

Hybrid B2B technology solutions assure supply continuity by virtue of their adaptability in the marketplace and their ability to cater to the larger firms' traditional customer bases. Examples of such adaptable and flexible approaches may be found among some of the highly successful e-commerce technology market leaders, such as Ariba and Commerce One, as well as firms that provide logistics technologies such as UPS and Manugistics (www.manugistics.com).

To consider the impacts of introducing this new kind of technology in the marketplace, see Fig. 3. The figure shows that both large and small firms will have an incentive to move to this technology, as this implies a higher iso-profit line, i.e., an IT investment frontier that corresponds to a higher profit level for the hybrid B2B technology solution adopter. Thus, we expect that firms are likely to cluster around the new, more adaptable form of technology, as depicted in the figure.

Figure 3. Adaptability Impact of Hybrid B2B Platform



This result can be summarized as follows:

Proposition 4: *The emergence of a more adaptable technology that reduces both procurement costs and supply uncertainty will attract both large and small firms, and will dominate both the pure IOS and the open B2B technology platforms.*

Effects of Inventory Accumulation and Economic Downturn on B2B Technology Adoption

The recent economic downturn and the collapse of the DotCom sector that has accompanied it have triggered a massive unanticipated inventory accumulation across a number of industrial sectors. Many firms were unprepared for this change, and thus they experienced an increase in the value of the parameter Ω_δ , unexpected over-supply, in our model. What is the likely effect of this downturn on firms' B2B technology platform adoption decisions? Does this pattern imply different adoption propensities among the large vs. small firms?

Consider the effect of Ω_δ on firm size and profitability for two firms of different sizes. Suppose that both firms face demands with same slope, b , but $a_l > a_s$, with a_l and a_s representing the vertical intercept of inverse demand for large (subscripted l) and small (subscripted s) firm market shares, respectively.

First, from Eq. 9b we can observe the ratio of the profits of the two firms:

$$\frac{\pi_r^e * (a_l)}{\pi_r^e * (a_s)} = \left[\frac{(a_l - c) - (a_l + s)\Omega_\delta}{(a_s - c) - (a_s + s)\Omega_\delta} \right]^2 \quad (13)$$

It is now possible to see what happens to the profits of the two types of firms in the face of an unexpected over-forecast of demand, leading to a rise in Ω_δ . To see this we differentiate the profit ratio, Eq. 13. This yields the following informative result:

$$\text{sign}\left[\frac{\partial \pi_r^e(a_l)}{\partial \Omega_\delta} - \frac{\partial \pi_r^e(a_s)}{\partial \Omega_\delta}\right] = \text{sign}(a_l - a_s)(c + s) > 0 \quad (14)$$

Eq. 14 tells us that an unanticipated inventory build-up creates a gap between small and large firms in terms of relative profits, favoring the larger ones. This leads us to:

Proposition 5: *An unanticipated inventory buildup favors large firms over smaller firms. The greater are the unit production and unit inventory costs each experiences, the larger will be the profit gap between the two.*

Combining this result with what we learn about B2B technology platform choices of firms in Fig. 2, it is evident that firms forced to contract after the economic slowdown will be more likely to adopt procurement technologies with lower costs -- even at the risk of higher supply variance. They move up along the iso-profit line in Fig. 2. In contrast, firms that experience either *no* contraction or further expansion are more likely to adopt technologies with higher costs but lower supply variance. They move down along the iso-profit line in Fig. 2.

CONCLUSIONS

In this article, we modeled the trade-offs in the choices that firms must make when they consider the adoption of open B2B platforms (such as open electronic B2B market exchanges) *versus* proprietary IOS systems. The two types of systems generally match what we have seen in industry during the last seven or eight years, with the move from EDI and other post-EDI proprietary solutions to limited adoption of B2B exchanges. Our model characterizes the latter solution as involving a trade-off between less costly but also more uncertain sources of supply, compared to more secure but costlier sources of supply. The recent collapse of the DotCom sector in the digital economy, especially the spate of news about the many failures in the B2B services marketplace, points to the greater risks that are involved in the continuity of supply when a firm chooses to procure via the open B2B platforms [24]. When firms take into account these procurement risks and uncertainties, we expect to see a pattern of behavior among firms: Larger firms are more likely to trade the supply uncertainty with higher procurement costs and settle for proprietary IOS systems. Smaller firms will emphasize lower cost but less certain supply sources and opt for the open B2B platforms. Thus, despite the attractiveness of the open B2B platforms, both B2B and IOS systems are likely to co-exist, consistent with evidence developed elsewhere [11]. Our explanation for this co-existence relates to firm size, as firms' demand for both types of systems is based on size.

We are also able to characterize the circumstances in which an open B2B technology platform for procurement may dominate existing EDI technology. Our insight, similar [11], is that by selecting “adaptable” systems that can integrate with the retail firms’ traditional EDI-based technology

infrastructure, while at the same time also offer the attractiveness of some of the open platform characteristics. Thus, we predict a *convergence* of both large and small firms to superior procurement technology that mixes open and proprietary elements. With this in mind, we offered a number of illustrative examples of these developments in the marketplace to support our modeling findings (such as those offered now by Ariba and CommerceOne, in conjunction with their strategic alliances with other vendors).

In addition to supply uncertainty, we have included demand uncertainty in our framework. This allows us to address the technology adoption behavior in the aftermath of the historical decline of the DotComs; supply disruptions also result in lower overall demand. With the slowdown in demand, we also have seen inventory build-ups that are similar to the unanticipated inventory build up that we model. One consequence of the economic slowdown that we also predict is that the distinction between the procurement technology adoption patterns of the larger and smaller firms will actually *intensify*.

The irony of our main result is that increased supply chain management cost sensitivity of the smaller firms is a consequence of their higher prior exposure to over-supply risks. But such firms are among those that are forced to take even greater risks in order to their lower procurement costs. We see these risks borne out in practice with the spate of business press news about the difficulties that firms have to make their procurement technology investments and their adoption of B2B electronic market solutions pay off [15, 16].

One limitation of our model is its emphasis on the *pure-play* technology adoption choices of open and proprietary systems. In future work, we intend to emphasize issues of timing and vendor selection tactics when mixed open/proprietary e-procurement solutions are selection. A second limitation is that we do not consider vendor subsidies and the role of changing market psychology with respect to the upside benefits of B2B e-commerce procurement solutions. Vendor-side subsidies permit buyers and suppliers to consider adopting *sponsored technologies*, which develop network externalities and user side benefits at a different rate and for different reasons than what a technology purist might argue is a “first-best” technological solution in a given setting. Thus, we view modeling sponsorship and subsidies as some next steps with this research, as Riggins, Kriebel and Mukhopadhyay [34] recognized was important in the context of EDI. Finally, even though our model considers the downturn in economic growth that affected the DotComs, we do not treat market expectations about specific vendors (some of whom, like Ariba, figure among the DotComs whose equity prices have been hard hit). Clearly, vendor reputation matters in this context, especially among new market entrants, where adopter expectations about future success are key.

In conclusion, and quoting the Surefoods' Web site (www.surefoods.com), we remind the reader:

What is required is a realistic and sustainable structure for e-business platforms that: (1) drives

adoption toward critical mass; (2) reduces risk for all [] players; (3) leverages the self-interest of the individual firms; and (4) remains truly pro-competitive in structure, not just through artificial safeguards” (SureFoods, 2001).

Clearly, there is still much to be learned before we can provide definitive normative guidance for senior managers about how to get these aspects of their B2B e-procurement technology decisions “right.”

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