ABSTRACT
With the rapid growth of business-to-business electronic commerce and the increasing need for supply chain collaboration, systems that support supply procurement are becoming ever more important. Due to the substantial costs of hardware, software and effort needed for implementation success, firms that participate in developing e-procurement systems want to reap as much value as possible. We use the theory of incomplete contracts to understand the different ways to organize the ownership of IT assets in procurement systems across two or more firms. The purpose is to maximize the value that the participants can appropriate and give them the proper incentives to invest. Based on the theory, we investigate the primary determinants of optimal ownership for e-procurement systems, focusing on the relative importance of participants’ investments, which is a measure of the marginal value that each participant adds to any proposed ownership structure for the IT assets. We also provide a framework for analyzing e-procurement system ownership structures. We apply our approach to vendor managed inventory systems, as an illustration of the range of e-procurement systems ownership settings that we can treat with this theoretical perspective.

KEYWORDS: Economic theory, e-procurement systems, incomplete contracts, IT investments, interorganizational IS, ownership, property rights, systems implementation, supply chain management, vendor managed inventory.

ACKNOWLEDGMENTS. We thank participants of the Leverhulme Project Conference on Digital Transformations at the London Business School, the IRC Research Colloquium Series at the University of Calgary, the CIS Research Seminar at the University of Michigan, and the Information and Decision Sciences Workshop at the Carlson School of Management of the University of Minnesota for their input. We also benefited from comments that were provided to us by Hamid Mohtadi, Mayuram Krishnan, Victoria Mitchell and Ron Weber.
INTRODUCTION

In modern supply chain management, electronic procurement systems are information systems (IS) that facilitate the acquisition or exchange of materials and goods, products and services, and information between firms (Bakos, 1991; Johnston and Vitale, 1988). With the rapid advances in information technologies (IT) over the past few decades, various types of procurement systems have emerged that are recognized as interorganizational information systems (IOS) (Choudhury, 1997; Kumar and van Dissel, 1996). They include electronic data interchange (EDI) systems, which enable suppliers and buyers to exchange standardized business documents, both within and outside the Internet channel. More recently, firms have adopted more advanced procurement systems approaches, such as vendor managed inventory (VMI), collaborative planning, forecasting, and replenishment (CPFR), and e-sourcing. The last involves business-to-business (B2B) electronic marketplaces and shared IT infrastructures (Dai, Narasimhan, and Wu, 2005).

Similar to the large investments in software and systems applications that were made in the 1980s and the 1990s in the United States government and industry, we have seen a similar rise in expenditures for e-procurement systems the last ten years. These kinds of investments have fundamentally changes the potential for achieving high productivity and high quality in procurement operations (Thatcher and Pingry, 2004). Chabrow (2005) reports on a recent white paper from the Hackett Group, a business process advisory consulting firm, on the extent of investments in e-procurement systems and technologies. He notes that “[f]or each [US]$1 billion spent on procurement, ... world-class companies invest an average of [US]$1.4 million on procurement technology compared with [US]$1.1 million for typical businesses. ... [L]eading-edge companies allot 19% of operational spending to technology compared with 11% for typical
companies.” Purchasing.com, another Internet-based reporting service that tracks issues and statistics related to procurement, reports that “[a]bout 48% of every dollar that comes into a company goes out through procurement,” and “about 20% of a company's operating budget goes to high-tech suppliers” (Avery, 2000). In addition, Input Inc., a market research firm in Reston, Virginia, has indicated that state and local spending on e-procurement technology “will grow at an average annual compound rate of 17% over the next five years to reach [US]$1.1 billion by 2008, up from [US]$500 million in 2003” (Welsh, 2003). These levels of systems spending are occurring in the context of overall intermediate goods and services procurement costs of approximately of US$8.7 trillion in the United States as of 2003 (Bureau of Economic Analysis, 2004).

Interorganizational investments in e-procurement systems typically are motivated by three different kinds of potential business value impacts. First, they permit buyers and suppliers to achieve effective coordination of their procurement-related activities so as to maximize the value of their individual efforts in a dynamic environment (Seidmann and Sundararajan, 1997). Buyers need to share information on demand, discover market prices for procurement goods, make orders and determine schedules for delivery of supplies. Suppliers need to become aware of how to plan for and optimize production to meet the supply requirements of the buyers. Effective coordination also mitigates unnecessary operational risks, including lack of supplies or unnecessary and costly oversupply for the buyer (Kauffman and Mohtadi, 2004).

Second, e-procurement systems create conditions under which it is possible to achieve effective decision rights allocation across the buyer and the seller so as to maximize the business value of procurement activities (Anand and Mendelson, 1997; Brynjolfsson and Mendelson, 1993; Nault, 1998). E-sourcing and spot market purchases, CPFR, VMI and other
interorganizational means for procurement, which are available due to the new technologies of the Internet, permit business partners to make procurement decisions jointly, as though they were an *integrated firm*. The seller can take on as much responsibility in providing procurement services (e.g., price discovery, demand forecasting and replenishment scheduling) as the buyer finds that it is optimal to relinquish, based on its own level of relevant expertise.

Third, joint e-procurement system investments create the possibility for other cost savings as well, including reduction in ordering and tracking expenses, more effective demand forecasting on the basis of strong models and ample historical data, and the elimination of duplicating infrastructure (Waller et al., 1999).

The implementation of e-procurement systems requires two types of investments related to IT assets. The first kind is *system asset acquisition investment*. This includes hardware, software packages, and network and communications technologies. E-procurement system assets acquisition investments typically can be specified in a contract between the partners involved in developing the system. Such investments will be part of the contractual responsibilities of ownership. The second type is *systems implementation effort investment*. Such investment typically occurs alongside the system asset acquisitions, and includes planning, systems analysis and process redesign, systems development and installation, data conversion, documentation and testing, employee training, and maintenance to ensure continued interoperability. These investments cannot be easily specified in a contract and hence they are *noncontractible*. Without these complementary noncontractible investments, the acquisition of hardware, software and network technologies is not sufficient to produce business value in procurement.

The extent to which collaborating firms and business partners each contribute to the overall investments gives rise to significant managerial issues. Chief among them is how to optimize
investments that involve ownership of the various systems assets. This is what we refer to as the **ownership problem**. We further define an **ownership structure** for e-procurement systems as the **specific organization and distribution of ownership of IT assets among the e-procurement system participants**. We seek theory-based answers to a number of key questions involving the implementation and ownership of procurement systems. For example: On what basis should systems implementation effort investments be shared across firms in the implementation of e-procurement systems? What theoretical perspectives inform the managerial analysis of the ownership problem? Under what conditions is the value of such assets be maximized? How should that value be split by the investing business partners? What other key managerial issues arise that can be treated within the analysis framework for e-procurement system ownership? What other issues pose more difficult problems?

There are failure costs and risks (e.g., information exploitation) associated with e-procurement system investments (Aron, Clemons, and Reddi, 2005; Clemons and Hitt, 2004; Han, Kauffman and Nault, 2004), and the benefits are uncertain and hard to divide among partners (Nault, 1997a). Also, because the e-procurement system benefits the partners of the investing firm, it may not be able to reap the full benefit. Consequently, some e-procurement system investments will not be made, a well-known issue in the economics of incentives called the **underinvestment** problem (e.g., Kaplan, 1986). An example of underinvestment in the e-procurement system domain was reported in a survey by Booz Allen Hamilton and Giga Information Group (2001), which found that most companies were unsatisfied with the B2B e-procurement exchanges they participated in due to a slowdown in investments by the market-making intermediaries.
Some researchers and practitioners have emphasized the importance of developing a proper methodology for measuring and splitting the value that is created by e-procurement and other interorganizational systems (Dai and Kauffman, 2002a). However, the business value of an e-procurement system is not readily measured, nor can the division of value be assured through an agreement beforehand, making subsequent division of the value among the participants difficult. We argue that creating the “right” ownership structure of system assets can tie a participant’s investment to the resulting benefits more closely, partially alleviating the problem of underinvestment. However, there are no broadly-accepted theoretical foundations for structuring e-procurement system ownership.

This study has the following objectives. Following Bakos and Nault (1997), who modeled Internet and e-commerce IT infrastructure investments and ownership, we apply the theory of incomplete contracts (Grossman and Hart, 1986; Hart and Moore, 1990) and develop a procedure for analyzing the optimal ownership of e-procurement system implementation effort investments. We will focus on the relative importance of participants’ investments, which has been only been given preliminary consideration in prior work (e.g., Hart and Moore, 1990), as a means to measure the marginal value that each investing participant adds to any proposed ownership structure for the IT assets. We apply our approach to VMI, as an illustration of the range of procurement systems ownership problems that we can treat with this theoretical perspective. We develop results that apply to settings involving two and three-firm e-procurement system investment partnerships, and discuss the limitations of our approaches in terms of the real world problems that arise in e-procurement system investment decision making.

IT INVESTMENTS IN VENDOR MANAGED INVENTORY SYSTEMS

VMI systems have been widely-adopted to improve procurement efficiency between
suppliers (e.g., manufacturers) and buyers (e.g., retailers). Pioneered by Wal-Mart and Procter & Gamble in 1980s, VMI systems have been adopted as an integral part of such strategic initiatives as the “Efficient Consumer Response” in the grocery industry and the “Quick Response” in the apparel industry (Seidmann and Sundararajan, 1997; Waller et al., 1999). In current electronic applications of VMI, the supplier is responsible for managing the buyer’s inventory, and makes inventory replenishment decisions for the buyer based on demand and inventory information sent by the buyer. A typical business process for inventory replenishment with VMI is depicted in Figure 1.

**Figure 1. Typical Components and Inventory Replenishment Process Under VMI**

In the chemical industry, for example, the costs for developing a VMI system can be as large as $500,000 (Challener, 2000). As described in Figure 2, VMI system assets consist of network technologies and EDI for communication and data sharing, forecasting software for market demand forecasting and placing orders based on sales and inventory data, and a point-of-sale (POS) system and retail inventory system for gathering sales and inventory data. In addition to acquiring these assets, participants must invest in implementation activities, including integrating these new systems with their existing internal systems, such as their enterprise resource planning systems. The participants must also invest in activities to achieve technological interoperability,
and standardization and synchronization for key data such as new sale items and inventory counts, etc. Finally, VMI implementation requires other systems implementation effort investments to create the necessary organizational capabilities, such as planning, aligning business processes and information systems, etc. Waller et al. (1999) argue that successful implementation of VMI depends heavily on sound business processes, interpersonal relationships, effective teamwork, and trust between the supply chain partners.

Important benefits of VMI for both the supplier and the buyer occur as increased sales from improved service levels and reduced stockouts. The buyer’s other benefits include decreases in inventory levels, and planning and ordering costs. The supplier’s costs decrease because the increased visibility of the buyer’s sales and inventory data allows better demand forecasts to plan production, better prioritization of production and logistics, and reduced inventory levels. These all result in improved resource utilization. (See Table 1.)

Table 1. Investments and Benefits Associated with VMI

<table>
<thead>
<tr>
<th>Investments</th>
<th>Supplier</th>
<th>Buyer</th>
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<tr>
<td></td>
<td>• Systems implementation</td>
<td>• Systems implementation</td>
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<td></td>
<td>• Data standardization for exchange</td>
<td>• Data standardization for sharing</td>
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<td></td>
<td>• VMI software implementation</td>
<td>• POS implementation</td>
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<td></td>
<td>• Systems integration (ERP or order processing, VMI, EDI, etc.)</td>
<td>• Systems integration (EDI, POS, and inventory management, etc.)</td>
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<tr>
<td></td>
<td>• Process reengineering</td>
<td>• Process reengineering</td>
</tr>
<tr>
<td></td>
<td>• Data standardization and synchronization</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Network technologies for communication and data sharing</td>
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</table>

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Supplier</th>
<th>Buyer</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>• Increased sales</td>
<td>• Increased sales (due to improved service levels and reduced stockouts)</td>
</tr>
<tr>
<td></td>
<td>• Improved demand forecasting and reduced demand uncertainty</td>
<td>• Reduced inventory levels</td>
</tr>
<tr>
<td></td>
<td>• Smaller buffers of production capacity and inventory</td>
<td>• Eliminating planning and ordering costs</td>
</tr>
<tr>
<td></td>
<td>• Reduced transportation costs</td>
<td>• Reduced time for order fulfillment</td>
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<td></td>
<td>• More efficient route planning</td>
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We now turn to a discussion of the theory of incomplete contracts, and the manner in which we will leverage the theory to analyze ownership and investments.
OWNERSHIP AND CONTRACTS

IS implementations continue to have time and budget overruns together with failure rates in excess of 60% (Jones, 1996; Keil and Robey, 2001). The ownership of e-procurement system assets is critical as this ownership governs implementation effort through the use of these assets in circumstances not covered by contractual agreements. Contracts can be incomplete for three reasons. First, all of the possible circumstances that may arise in the future may not be foreseen. Second, it may be too costly to negotiate and contractually describe what should occur in each circumstance. Third, it may be difficult for a court or an arbitrator to determine and enforce the contract terms. For example, an e-procurement system may not work as initially planned, one of the participants may become unable to invest as much money as it promised, there can be unexpected technological changes, or specific system implementation details or formats and protocols may be too complex to describe in a contract.

Grossman and Hart (1986) and Hart and Moore (1990) argue that every contract is incomplete, and when circumstances not covered by the contract are encountered, the participants must divide the joint value through bargaining. A participant’s bargaining power depends on the assets it owns. Ownership is the right to decide about the disposition of the assets (Hart, 1995). Hart and Moore (1990) assume that this bargaining leads to the Shapley value which specifies that each participant receives its expected marginal contribution: the participant’s incremental contribution to each potential set of itself and other participants multiplied by the probability of each such set (Shapley, 1953). For a buyer-supplier relationship, the Shapley value is the same as the two-person Nash bargaining solution (Hart, 1995), where the buyer and supplier share equally in the value created between them beyond the sum of the value each would have created alone.
In e-procurement systems there are positive investment externalities across participants whereby the marginal returns to one participant’s investments in system implementation effort are increased if other participants have higher investments. In an integrated firm the marginal value one participant gets from another participant’s investment is accounted for in determining the integrated firm’s level of investment. However, individual participants’ incentives to invest in non-integrated, multiple participant relationships are based on the value they can capture. As we discussed earlier, because participants cannot directly capture the value from their investments that accrue to other participants, this can cause participants to underinvest. The relationships between the ownership of e-procurement system assets, investments, and business value are shown in Figure 2.

**Figure 2. The Relationships among Investment, Ownership, and Value**

![Diagram showing relationships between ownership of system assets, systems implementation effort investments, value distribution, and value created from e-procurement system.]

**Note:** Ownership of e-procurement system assets determines the value created from the system by affecting participants’ levels of systems implementation effort investments (solid lines). This impact of ownership on investments and value creation occurs because IT asset ownership affects participants’ bargaining power, which, in turn, determines value distribution (dotted lines).

IT Asset ownership affects participants’ bargaining power to capture value after investments in system implementation effort have been made which, in turn, affects their level of investment in implementation effort. These levels of implementation effort investment determine the value that is created. Therefore, IT asset ownership determines the value the e-procurement systems can create by affecting the levels of systems implementation effort investments made by
individual participants.

There have been a number of studies on how IT-based interorganizational activities should be governed (e.g., Malone et al., 1987; Gurbaxani and Whang, 1991), on network externalities and adoption (e.g., Riggins et al., 1994; Wang and Seidmann, 1995), and on measuring business value (e.g., Mukhopadhyay et al., 1995; Srinivasan et al., 1994). In addition, several studies showed how IOSs can embed divisions of profits to motivate participants to make higher levels of investment (e.g., Nault and Dexter, 1994; Nault, 1997b; Bakos, 1997; Nault and Tyagi 2001). However, there are few studies on how bargaining over systems-created value after investments in systems implementation effort are made can impact the participants’ levels of investment beforehand.

Clemons and Kleindorfer (1992) modeled the sharing of value from participants’ investments as Nash bargaining in a setting with a single supplier and multiple identical buyers. They showed that the more specific the investments and the higher the switching costs of a participant, the lower its profit due to its lower relative bargaining power, and, therefore, the lower its level of investment. However, the authors assumed that investments under different circumstances are verifiable, and more importantly, that the ownership structure for e-procurement system assets is predetermined: the supplier is the owner who earns profits in the form of transfer payments from the buyers.

More recently, in B2B e-markets with different ownership structures, Yoo et al. (2001) showed that buyer-owned or supplier-owned marketplaces can provide services at a lower price, attract more buyers and suppliers, and generate larger total profit as compared to intermediary-owned marketplaces. Although the level of analysis is different, their work is related to ours in that ownership affects participants’ bargaining power and profit.
OPTIMAL ASSET OWNERSHIP STRUCTURE IN E-PROCUREMENT SYSTEMS

To determine optimal ownership structures in the context of e-procurement systems, we need to assess four determinants, each of which can reduce the set of ownership structures to consider. The determinants are (a) complementarities between assets, (b) essentiality of an asset to a participant, (c) indispensability of a participant to an asset, and (d) relative importance of participants’ investments. The first two are asset-related, and the latter two are participant-related. With the increasing standardization of IT affecting the degree to which the other determinants narrow the set of potential ownership structures, relative importance is increasingly significant in distinguishing which ownership structure is optimal. We now define and discuss each in greater detail.

**Complementarities between IT Assets**: Hart and Moore (1990) define strictly complementary assets as those assets that are unproductive unless used together. The value that a set of participants investing in systems implementation effort can create with all but one of a set of complementary systems assets is the same value they can create with none of them. Thus, complementary IT assets should be owned by a single participant or be under common ownership. Both permit ownership rights for the set of complementary assets to be held together. In e-procurement systems, market demand forecasting software is strictly complementary to sales and inventory data. For example, the former cannot create value unless it is used with the latter.

**Essentiality of an IT Asset to a Participant**: Bakos and Nault (1997) define an asset as essential to a participant if, without access to the asset, the participant cannot create any value from its additional investments. Essentiality is a marginal condition: without the essential asset there are no marginal returns from a participant’s investment. Bakos and Nault (1997) show that if one or more assets are essential to all participants, then all the assets—not only those that are
essential—should be owned together. In e-procurement systems, sales and inventory data are essential to both the buyer and supplier because without access to this data neither of their investments yields returns.

**Indispensability of a Participant to an IT Asset:** Hart and Moore (1990) define a participant as *indispensable* to an IT asset if the other participants cannot create value from the asset without the indispensable participant. Indispensability is also a marginal condition: without the indispensable participant there are no additional marginal returns based on the asset from other participants’ investment. Thus, the participant is necessary to create value from that asset. Hart and Moore (1990) show that if a participant is indispensable to an asset, then the participant should own the asset.

Brynjolfsson (1994) argues that if a participant has specific knowledge necessary for the productivity of a physical asset, then the participant is indispensable to the physical asset, and it is optimal to give ownership of the physical asset to the participant. The indispensability of a participant stems from the strict complementarities between the participant’s specific knowledge (an information asset tied to a participant) and the physical asset. In e-procurement systems, if only the supplier has specific knowledge necessary to implement the market demand forecasting software, then the supplier is the only participant whose investment can yield value from that asset and the supplier is indispensable to the forecasting software.

Bakos and Nault (1997) show that if a participant is indispensable to an IT asset that is essential to all participants, then the indispensable participant should own all the IT assets. Early e-procurement systems typically had proprietary architectures developed by the initiators who were indispensable to their system, and the initiators usually owned all of the system assets. However, with the advances in communications technologies, more companies have adopted
standard technologies for e-procurement that have made the system initiator increasingly dispensable.

Relative Importance of Participants’ Investments: We define the relative importance of participants’ systems implementation effort investments as a measure of the marginal value that each participant adds to any proposed ownership structure for the IT assets by making additional investment in system implementation effort. This definition emphasizes that the participant with the greatest relative importance is the participant whose incremental investment can create the most value for the set of participants. Therefore, like essentiality and indispensability, relative importance is a marginal value concept. In an e-procurement system, if the supplier’s investment creates greater value than the buyer’s investment, then the supplier’s investment is relatively more important than the buyer’s. We argue that the most critical source of relative importance is the difference in the participants’ specific knowledge in how to generate value—an information asset that is not transferable (Jensen and Meckling, 1992). Relative importance is related to but not the same as indispensability. The latter is a relationship between a participant and an IT asset. The former is a relationship between participants in the context of the set to which they belong (although one participant may be relatively more important than others across many different sets of participants). When one participant has greater specific knowledge of how to generate value, that participant should own the assets because the more knowledgeable participant has greater incentives to invest when it owns the assets.

A possible source of relative importance is the relative size of the participant. Larger participants tend to benefit from economies of scale by using the same or similar system assets in their relationships with a number of business partners. A related source is a participant’s ability to create network externalities: the greater the number of business partners, the more value it can
create from its investment. Furthermore, the effectiveness of management can affect participants’ returns on investment. In addition to these internal sources, there can be external factors that affect which participant’s investments can create more value. For example, regulations can restrict some participants’ investment activities, and it may be more profitable to give asset ownership to the participant with less restricted IT investment opportunities. Table 2 summarizes the determinants of the optimal ownership structure for e-procurement system assets.

Table 2. Determinants of Optimal Ownership for E-Procurement System Assets

<table>
<thead>
<tr>
<th>DETERMINANTS</th>
<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>Complementarities</td>
<td>Two IT assets are strictly complementary if either one of the assets cannot create value without the other.</td>
</tr>
<tr>
<td>Essentiality</td>
<td>An IT asset is essential to a participant if the participant’s investments cannot create any value without the asset.</td>
</tr>
<tr>
<td>Indispensability</td>
<td>A participant is indispensable to an IT asset if the without the participant in the set the set’s investments cannot create any value without the asset.</td>
</tr>
<tr>
<td>Relative Importance of Investment</td>
<td>The relative magnitude of the value to the set of participants created by participants’ investment.</td>
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ANALYZING VMI ASSET OWNERSHIP STRUCTURES

We next apply the determinants to find the optimal ownership structure for IT assets in our VMI example. We first analyze optimal ownership structures with two participants, a buyer and a supplier. Then, we extend the model for a third party.

Analyzing IT Asset Ownership for VMI for a Buyer and Supplier

Steps for analyzing appropriate ownership structures for VMI IT assets are given in Figure 3. In the first step we identify the participants and the IT assets. Then we apply the IT asset-related determinants to identify whether groups of IT assets are complementary and if any assets are essential. This permits us to identify the feasible sets of assets, and enumerate the possible ownership structures for them. Then we apply the participant-related determinants, dispensability and relative importance of investment, which allow us to evaluate the different
ownership structures.

**Figure 3. Steps for Analyzing IT Asset Ownership Structures for VMI Systems**

1. **Identify the participants and the IT assets**
2. **Identify the feasible sets of IT assets that create positive marginal benefit**
3. **Enumerate possible ownership structures based on the feasible sets of IT assets**
4. **Evaluate ownership structures of IT assets and determine the optimal structure**

- **Apply asset-related determinants:**
  - complementarities and essentiality
- **Apply participant-related determinants:**
  - indispensability and relative importance

**The Participants and the IT Assets:** There are two participants, a supplier and a buyer.

The VMI system has three IT assets: the communication and data sharing network \((N)\), sales and inventory data \((D)\), and market demand forecasting software \((F)\).

**Analyzing Complementarities:** As we indicated in our definition of complementary assets, we consider the market demand forecasting software \((F)\) to be strictly complementary to the sales and inventory data \((D)\). Without the sales and inventory data, the forecasting software cannot accurately forecast future sales and inventory levels, and thus, the participants cannot obtain business value from production efficiencies, and reduced inventory and stockouts. The strict complementarity of the market demand forecasting software with the sales and inventory data suggests that both should be owned together.

The market demand forecasting software is not strictly complementary to the network \((N)\); the network can provide value from stock reordering and invoicing. Nor is sales and inventory data strictly complementary to the market demand forecasting software. However, the network is strictly complementary to the market demand forecasting software. Given the volume of sales
and inventory data created continuously, it is impractical to think about transporting the data to the forecasting software without the network. Finally, neither the sales and inventory data nor the network are strict complements to each other. Each can generate value without the other.

**Analyzing Essentiality:** Because without the electronic medium of data exchange, neither participant can create value from its system implementation effort investments for the VMI system, the communication and data sharing network \((N)\) is essential to both participants. Thus, essentiality is a marginal condition. Although VMI may generate value without the network, the network is essential for both participants to generate a positive return to their additional investment.

Similarly, the sales and inventory data \((D)\) also are essential to both supplier and buyer. Without the sales and inventory data from the buyer, the participants’ systems implementation effort investments do not yield any return. Although it is arguable that without the sales and inventory data VMI would not have any value, this does not make the sales and inventory data essential. The lack of marginal return on either the buyer’s or seller’s investment without sales and inventory data makes this asset essential. The market demand forecasting software \((F)\) is not essential as the participants with the other two assets could generate return from their systems implementation effort investments. For example, these investments could lead to more efficient invoicing and reordering even in absence of market demand forecasts.

**Feasible Sets of Assets:** With these three IT assets, there are seven possible sets: three individual IT assets, three sets of two IT assets, and the full set of three IT assets. Because the communication and data sharing network \((N)\) and the sales and inventory data \((D)\) are essential to both participants, any participant who does not own both assets cannot get a positive marginal return from investment. So all the assets—not only those that are essential—should be owned
together (Bakos and Nault, 1997), and we need only consider ownership over \{N, D, F\}.

Even without any essential IT assets, the complementarities alone suggest that all the assets should be owned together. Because the market demand forecasting software \(F\) is strictly complementary to the sales and inventory data \(D\), and the network \(N\) is strictly complementary to the forecasting software \(F\), any ownership structure that confers ownership of the data \(D\) on one of the participants should give ownership of the forecasting software \(F\) to the same participant. The same is true for the network \(N\) and the forecasting software \(F\).

**Analysis of VMI Asset Ownership Structures:** We use a simplified version of the incomplete contracting model developed by Hart (1995) for two-person bargaining. The buyer, which we denote with \(b\), makes investment \(i_b\) in systems implementation effort, and the supplier, which we denote with \(s\), makes investment \(i_s\) in systems implementation effort where these investments range from zero to some fixed upper limit. Together in the e-procurement system, the buyer and the supplier can create *joint value* \(V(i_b, i_s)\) within the relationship from their VMI system, which depends on the levels of their system implementation effort investments. We denote the *standalone value* generated by the buyer’s and supplier’s investments outside the relationship conditional on the assets each owns as \(r_b(i_b|A_b)\) and \(r_s(i_s|A_s)\). \(A_b\) and \(A_s\) represent the sets of IT assets that the buyer and the supplier own. \(V(\bullet), r_b(\bullet)\) and \(r_s(\bullet)\) all are increasing at a decreasing rate in investments \(i_b\) and \(i_s\). We refer to \(r_b(\bullet)\), and \(r_s(\bullet)\), the values outside the relationship, as the *disagreement payoffs*. They represent the value participants receive when agreement cannot be reached in bargaining.

Following Hart (1995), we make the following assumptions:

- **Assumption 1 (Systems Implementation Effort Investment Synergy).** The value of the investments in e-procurement system implementation effort is always greater within the relationship than outside the relationship: \(V(i_b, i_s) > r_b(i_b|A_b) + r_s(i_s|A_s)\) \(\forall i_b, i_s, A_b, A_s\).
• Assumption 2 (Participants’ Marginal Relationship Specificity). Participants’ marginal return from investments in implementation effort within their current relationship is always greater than their marginal return from investments in implementation effort outside the relationship:

$$\frac{\partial V_i|_{i_j,s}}{\partial i_j} > \frac{\partial r_j|_{i_j,A_j}}{\partial i_j}, j \in \{b,s\}, \forall i_i$$

• Assumption 3 (IT Asset Ownership Impact). IT asset ownership cannot decrease participants’ marginal return from investment in implementation effort outside the relationship:

$$\frac{\partial r_j|_{i_j,A_j}}{\partial i_j} \geq \frac{\partial r_j|_{i_j,A'_j}}{\partial i_j}, j \in \{b,s\}, A_j \supset A'_j, \forall i_i$$

Assumptions 1 and 2 mean that the e-procurement systems implementation effort investments are relationship-specific. Assumption 3 implies that IT asset ownership increases not only the marginal return of investments in implementation effort within the relationship, but also may increase marginal return outside the relationship.

Because a complete contract for value sharing cannot be written, the supplier and buyer divide the value through bargaining. Consistent with Hart (1995) and Clemons and Kleindorfer (1992), we use the Nash bargaining solution to represent the outcome of the bargaining process. The Nash solution divides the incremental profit evenly so each receives disagreement payoff plus half of the incremental profit less the cost of investment:

**Buyer’s Payoff:**

$$r_b(i_b | A_b) + \frac{1}{2}[V(b_i,i_s) - r_b(i_b | A_b) - r_s(i_s | A_s)] - i_b$$

**Supplier’s Payoff:**

$$r_s(i_s | A_s) + \frac{1}{2}[V(b_i,i_s) - r_s(i_s | A_s) - r_b(i_b | A_b)] - i_s$$

Next, we consider the two logical ownership structures for VMI assets in the presence of one buyer and one supplier: supplier ownership and buyer ownership. We do not analyze joint ownership because the payoffs to joint ownership are lower than these two alternatives. In supplier ownership, the supplier owns the network (N), the data (D) and the forecasting software
(F), and the buyer also owns (D).\(^1\) In buyer ownership, the buyer owns N, D, and F.

Table 3 shows each participant’s marginal return from investment under these two ownership structures. A participant’s marginal return represents its investment incentives, and the ownership structure that entails the greatest marginal return for both participants is optimal.

These marginal returns are calculated by taking the first derivatives of the buyer’s and supplier’s payoffs (given above) with respect to their respective system implementation effort investments \((i_b\) and \(i_s\)) under each ownership structure. For comparison, we include the integrated firm case where both participants jointly maximize their total profit.

<table>
<thead>
<tr>
<th>Table 3. Comparison of VMI Asset Ownership Structures</th>
<th>MARGINAL RETURN ON INVESTMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ASSIGNMENT STRUCTURE</strong></td>
<td>Supplier</td>
</tr>
</tbody>
</table>
| Supplier Ownership                                    | \[
\frac{1}{2} \frac{\partial V(b, i_s)}{\partial i_s} + \frac{1}{2} \frac{\partial r_s(i_s | NDF)}{\partial i_s} \] |
| Buyer Ownership                                       | \[
\frac{1}{2} \frac{\partial V(b, i_s)}{\partial i_s} + \frac{1}{2} \frac{\partial r_b(i_s | NDF)}{\partial i_s} \] |
| Integrated Firm                                        | \[
\frac{\partial V(b, i_s)}{\partial i_s} \] |

Note: A participant’s marginal return represents its investment incentives. The ownership structure that entails the greatest marginal return for both participants is optimal.

Referring to Table 3, and given our Marginal Relationship Specificity Assumption, the supplier and buyer underinvest in each of the ownership structures compared with an integrated firm. This is because each participant cannot capture the full marginal return from its investment in systems implementation effort:

\[
\frac{1}{2} \frac{\partial V(b, i_s)}{\partial i_s} + \frac{1}{2} \frac{\partial r_s(i_s | NDF)}{\partial i_s} = \frac{\partial V(b, i_s)}{\partial i_s}, j \in \{b, s\}, \forall i_b,i_s.
\]

\(^1\) In practice, it is typical that only the buyer owns the sales and inventory data that describe its demand, inventory management and procurement activities. The supplier, however, can duplicate the buyer’s data through the procurement system and add value to it within the scope of the relationship, by combining it with other kinds of data or performing other analyses to yield new information. In this case, the supplier has the right to use the data, but the buyer retains ownership of the data. However, because accessing data that are shared through the procurement system has the same effect on the supplier’s marginal returns as owning the original data, as long as the relationship with the buyer is sustained, we do not make a distinction between usage rights and ownership of data as Van Alstyne et al. (1995) did. Thus, in supplier ownership, both the supplier and the buyer own the data.
The terms on the left hand side correspond to the marginal returns to investment under buyer or supplier ownership. The right hand side is the marginal return to systems implementation effort investment in the integrated firm. Each participant’s investment is greater when it owns the VMI assets. Following Table 3, the supplier’s investment in implementation effort is greater in supplier ownership, as the buyer’s investment in implementation effort is greater in buyer ownership:

$$\frac{1}{2} \frac{\partial V(b_i, i_i)}{\partial i_i} + \frac{1}{2} \frac{\partial V(b_i, i_i | NDF)}{\partial i_i} \geq \frac{1}{2} \frac{\partial V(b_i, i_i)}{\partial i_i} + \frac{1}{2} \frac{\partial V(b_i, i_i | \emptyset)}{\partial i_i}.$$

Analyzing Indispensability: To determine which of the two ownership structures for the VMI assets is optimal, we need to consider indispensability and relative importance of investments in systems implementation effort. First, suppose the supplier is indispensable to the forecasting software ($F$). For example, the supplier may have a proprietary forecasting algorithm. Then, without the supplier the buyer cannot create any marginal benefit from investment outside the relationship: $dr_b(i_b | NDF) / d_l = 0$. As a result, the participants’ marginal return is at least as high under supplier ownership as under buyer ownership, and the former is the optimal ownership structure. Similarly, if the buyer is indispensable to the data ($D$), then buyer ownership is optimal. Without the buyer, the supplier cannot create any marginal benefit from investment in implementation effort outside the relationship.

Analyzing Relative Importance: With recent innovations such as open source software and standardized information and communication technologies, neither participant may be indispensable. When this is the case, indispensability is not sufficient to choose between supplier and buyer ownership. This is because the marginal returns to systems implementation
effort investment outside the relationship \( \frac{dr_i}{di} \) and \( \frac{dr_b}{di} \) are higher for the IT asset owner. To establish the optimal ownership structure, we have to determine the participants’ relative importance.

To determine this we have to find which participant’s investment in implementation effort creates greater marginal return for the relationship it participates in. For VMI this equates to finding which participant’s marginal return to investment has a greater impact on the overall value that the supplier and buyer jointly create.

Our definition of relative importance does not allow us in general to determine which ownership structure is best based on increased investments by all participants because the rank-ordering of participants’ marginal returns may be different at different investment levels and with different sets of assets. However, for a given situation it informs us about which participant’s incremental investment in implementation effort is most important for increasing the joint value. If the buyer’s incremental investment is more important than the supplier’s, it is more critical to increase the buyer’s incentives for non-contractible investment than it is to increase those of the supplier. As a result, allocating IT asset ownership to the buyer increases the joint value because, based on the buyer’s marginal return (i.e., the right column in Table 3), buyer ownership outperforms supplier ownership. In contrast, if it is more critical to increase the supplier’s incentives for systems implementation effort investment, then allocating asset ownership to the supplier increases supplier investment and the joint value.

As we discussed, the relative importance of participants’ investments in implementation effort stems from the specific knowledge that each participant possesses. Suppose that the supplier in our VMI example has superior knowledge and skills about how to forecast demand (e.g., because it has a better forecasting algorithm than the buyer), and that it is critical to
integrate the forecasting system with the supplier’s order management system to ensure that the replenishment orders are placed in a timely manner. Then, relative to the buyer’s incremental investment, the supplier’s incremental investment is more important in creating joint value, and VMI value is increased most if the supplier owns all the IT assets. However, if consumer demand changes quickly because of changing tastes, then the supplier may not be able to accurately forecast demand based on historical data. In this case, the buyer’s specific knowledge of consumers’ changing tastes (which is hard to transfer) becomes crucial in forecasting future demand. Therefore, the buyer’s incremental investment in implementation effort is more important, and VMI value is increased the most if the buyer owns all the assets.

Because of the positive investment externalities (the marginal returns to one participant’s investments are increased if other participants have higher investments), it is possible that the allocation of asset ownership to the participant with the most important system implementation effort investments can increase the investments of all the participants. However, without specific functional forms for the joint and standalone value functions in our model \( V(\bullet), r_b(\bullet), \) and \( r_s(\bullet) \), we cannot compare these levels of investment resulting from different ownership structures.

**Extending the Analysis of VMI by Incorporating a Third Party**

The role of third parties in business relationships has become more important due to increases in outsourcing. An example of such a third party is SPS Commerce (www.spscommerce.com), a consulting and IT service company, that provides supply chain enablement services, including communication and data sharing network outsourcing, for suppliers and buyers. We next analyze a three-firm model and, using our framework, summarize how optimal ownership changes. (For additional details of the mathematical analysis of the case, see the Appendix.)
**Participants and Assets:** In addition to the buyer and supplier, we add a third party. The assets are the same: the communication and data sharing network \((N)\), sales and inventory data \((D)\), and market demand forecasting software \((F)\).

**Analyzing Complementarities:** The market demand forecasting software \((F)\) is strictly complementary to the sales and inventory data \((D)\), and the network \((N)\) is complementary to the forecasting software \((F)\) as in the buyer-supplier analysis.

**Analyzing Essentiality:** \(N\) and \(D\) continue to be essential to the buyer and supplier, and they are also essential to the third party.

**Feasible Sets of Assets:** Due to the complementarities of \(F\) to \(D\) and \(N\) to \(F\), and essentiality of \(N\) and \(D\), the only feasible set of assets is \(\{N, D, F\}\) as in the buyer-supplier analysis.

**Analysis of VMI Asset Ownership Structures:** With a third party, we use the Shapley value as the bargaining solution concept because for n-person games, the Shapley value is considered a “fairer” division than the Nash bargaining solution. As we mentioned earlier, a participant’s Shapley value is each participant’s incremental contribution to each potential set of itself and other participants multiplied by the probability of each such set.

**Analyzing Indispensability:** If the third party has the sole expertise for managing the network \((N)\) and so the third party is indispensable to \(N\), then it is optimal to give the ownership of all the IT assets to the third party (i.e., the network and forecasting software will be owned by the third party, and the data will be owned by both the third party and the buyer). This is because without the third party, the network has no effect on the supplier’s and the buyer’s marginal return on systems implementation effort investment because \(N\) is essential to both parties. In other words, both the supplier and the buyer need \(N\) to create value, but, at the same time, that cannot happen without the third party.
Analyzing Relative Importance: If no participants are indispensable to any IT asset (again, which is plausible with increasingly open systems and technology standards), we need to evaluate whose incremental investment in implementation effort is the most important in creating value. If the third party’s incremental investment is the most critical in terms of creating value for the e-procurement system, then third party ownership of all the assets (i.e., having the network and forecasting software owned by the third party, and the data owned by the third party and the buyer) remains the optimal ownership structure for the VMI assets. This is because the third party’s incremental investment in implementation effort generates the greatest marginal return to the VMI relationship. Similarly, if the buyer’s (supplier’s) incremental investment generates the greatest marginal return to the relationship, then either buyer ownership of all the assets (supplier ownership) becomes optimal. This ownership structure gives the buyer (the supplier) the maximum investment incentives.

DISCUSSION

We now broaden our discussion to consider a number of other managerial and theoretical issues that arise when we consider the strengths and weaknesses of our perspective on ownership. These include: the degree of managerial sensitivity to issues of e-procurement system ownership; the impacts of increasing standardization of e-procurement system-related technologies; and specific IT investments and the ownership of e-procurement system assets.

Managerial Sensitivity to E-Procurement System Ownership

We believe managers may not be sensitive enough to IT asset ownership issues when making e-procurement implementation decisions. Because of the uncertain payoffs, many participants may wish to own fewer IT assets to mitigate the risky costs associated with implementation failure, and let their business partners own more IT assets. Ironically, without the appropriate
incentive that comes from IT asset ownership, these managers tend to underinvest in implementation activities such as planning, systems analysis and process redesign, systems development and installation, data conversion, documentation and testing, employee training and maintenance. This, in turn, makes it more likely that their implementations fail.

**Standardization of IT and Relative Importance of Investment in Implementation Effort**

The increasing standardization of IT has made complementarities, essentiality and indispensability less significant while making relative importance of participants’ e-procurement system implementation effort investment an increasingly critical determinant of optimal ownership structures. We consider each of these in turn.

**Complementarities:** We mentioned that there are strict complementarities between two or more IT assets if they cannot create value unless they are used together. Development of open standards and the emergence of technology adapters (Dai and Kauffman, 2002b) are two factors that have led to a decrease in complementarities between IT assets by making it easier for e-procurement systems investment participants to connect their own IT assets with otherwise incompatible technologies. For example, St. Paul, Minnesota-based SPS Commerce provides an “any-to-any transformation engine” that ensures interoperability between any supplier and any buyer using different formats for document exchange (e.g., EDI, XML and flat files) (SPS Commerce, 2005).

**Essentiality:** An IT asset is essential to a participant in an e-procurement system if the participant cannot create any value from investment without access to the asset. With increasing standardization of IT and fiercer competition among hardware vendors and software solution providers, today there are a number of competing IT products that are available to e-procurement system participants. This availability of alternative substitutable IT assets has made a single IT
asset less essential to the participants. For example, today various types of demand forecasting software solutions for VMI are available in the marketplace (e.g., Vendor Managed Inventory.com, 2005). These include: Demand Solutions Inc.’s (www.demandsol.com) “Rough Cut” software to match production capacity to market demand and “True Collaboration” software to optimize store level replenishment for clothing and apparel; River One’s (www.riverone.com) “Interactive 6.0” inter-enterprise supply chain information control software for the electronics industry; and, Jada Management Systems’ (www.jadaman.com) “NetVMI” buyer-to-supplier demand sharing software.

**Indispensability:** In early examples of e-procurement systems, such as EDI, the system provider had specific know-how and technical expertise for software development and system management, making its sole ownership optimal. However, with the increasing standardization of technologies and sophistication on the part of B2B e-market and e-procurement system participants, the expertise necessary to implement and operate an effective procurement infrastructure has become more broadly available (Bakos and Nault, 1997). As a result, today, a single participant is rarely the owner of an entire e-procurement system due to its decreasing indispensability.

Because of the diminishing ability of the other determinants to distinguish among ownership structures, the relative importance of participants’ e-procurement systems implementation effort investments is becoming increasingly significant in determining optimal ownership structure. But how does this trend affect optimal ownership in e-procurement systems? In our VMI example, there was only one feasible set of assets that creates positive marginal return due to essentiality of the network and the data, and the complementarities between the data and the demand forecasting software. In the absence of essential and complementary IT assets, there are
a greater number of feasible sets of IT assets because they no longer need to be under common
ownership to create value. And, without indispensable participants, a single participant no
longer needs to own a particular IT asset. Instead, which participant should own the IT asset is
determined by which participant’s investment is more important in creating value. Therefore, we
expect that advances in IT will make ownership structures more flexible, making it optimal for
each participant to own assets that are most productive under its ownership due to better specific
knowledge. In addition, because relative importance of participants’ investment with respect to
an e-procurement system-related IT asset is impacted by a number of firm and industry-specific
factors (e.g., firm size, and the vagaries of market demand), we expect significant variations in e-
procurement system ownership across industries.

Specific Investments and Ownership of E-Procurement Systems Assets

In our analysis, we assumed that, for a given set of IT assets, participants’ joint value in the
VMI relationship and their standalone values outside the VMI relationship were increasing in
specific investments in systems implementation effort. This implies that the specific investments
increase the value of the IT assets in the relationship and also increase the value of the IT assets
in alternative uses. However, the specificity of investments sometimes may constrain the value
of IT assets outside the current relationship. Specific investments in implementation effort in the
face of proprietary technologies and technological standards, fast technological changes, and
modifications made to IT assets all will have an influence on the optimal ownership structure for
the IT assets.

Proprietary Technologies: If the technologies used in an e-procurement system are
proprietary and cannot be easily redeployed in other business relationships, then participants are
less motivated to own the IT assets. This is because they are locked into the proprietary
technologies. They will incur unattractive switching costs if the relationship breaks down and then they will have to transact with other companies that use different technologies to support e-procurement. Then who should own the IT assets in this case? The participant who is best able to reuse the assets in other business relationships should own the system because the restrictive aspects of specific investments will be smaller.

A traditional proprietary EDI system is a case in point. Dominant buyers were the initiators of such systems and they typically owned the systems too (Riggins et al., 1994). A large dominant buyer can reuse the IT assets in multiple business relationships with its suppliers. Sometimes, due to its superior bargaining position, it even can force its suppliers to use its system. The value of the IT assets in alternative uses under buyer ownership will decrease less than under supplier ownership, and even may increase with more specific investments. An example which fits this general characterization is Wal-Mart, and its proprietary EDI-based procurement system, “Retail Link” (Brown, 2000).

Fast Technological Change: The rapid evolution of technology makes it likely that the current technologies which the participants adopt for their e-procurement systems will become obsolete in the near future. They will have to upgrade to new technologies with improved functionality. Otherwise, firms will be locked into older technologies that might become incompatible with other newer technologies. In this situation, the participants in an e-procurement system will not want to make specific investments in systems implementation effort because they may not be able to reap their value if they have to adopt new technologies to support future business relationships.

An example of this is occurring now with barcoding and radio frequency identification (RFID) technology. Barcoding systems have been frequently used in supply chain management
operations for more than two decades now, but there is increasing pressure for business partners to adopt RFID, to set up for future costs saving as RFID technology standards emerge. However, the standards have been slow to materialize, for example, around the selected frequencies (e.g., high frequency 13.56 MHz RFID systems, in lieu of ultra-high frequency 865 to 928 MHz systems or microwave frequency 2.45 GHz systems) that control the read-range and communication bandwidth in the operation of RFID tags (Curtin, Kauffman and Riggins, 2005), and around the standards for cost-effective, small and lightweight RFID tag readers that can be distributed throughout supply chain operations (Reva Systems 2005).

**Modifications Leading to IT Asset Specificity:** When IT assets are modified on behalf of a particular business partner, they become dedicated and their specificity increases (Williamson, 1985). Similarly, when an e-procurement system needs to be modified to meet the specific requirements of a business partner, the value of the related IT assets for the owner will be constrained in alternative uses. So, when there is a need for significant modifications of the e-procurement system, we expect that the owner’s incentives for specific investment will be mitigated.

An example of a recent and newsworthy instance of modifications leading to IT asset specificity has come with Wal-Mart’s June 2003 mandate its largest 100 suppliers to pilot using RFID tags on shipped items at the pallet level by January 2005 (Roberti, 2003). Haley (2003) reports predictions that Wal-Mart may be able to save more than US$8 billion annually using RFID by reducing the labor costs and item stockouts, and reducing item theft. However, these benefits will only materialize with supplier compliance around RFID systems and operational procedures that are specific to Wal-Mart’s decisions. A number of other retailers announced plans during 2004 for mandated supplier adoption of RFID technologies, with firm-specific
technology compliance requirements as well. They include Target, Best Buy, Albertson’s, Tesco, Metro AG, Carrefour and Ahold, and the United States Department of Defense (Bachelordor and Sullivan, 2004; Vollmer, 2004). So our expectation is that the mandated e-procurement systems modifications and upgrades will put a heavy burden on these firms’ business partners.

CONCLUSIONS

This study operationalizes the theory of incomplete contracts in a real world e-procurement context that involves multiple participants and multiple IT assets for the purpose of determining the optimal ownership structure of the IT assets in e-procurement systems. We analyzed a buyer-supplier case and extended the analysis by adding a third party that plays a crucial role in the relationship between the buyer and supplier. We used the theory to provide answers to issues that require new managerial insights about how to maximize the value that participants can appropriate from their investments in e-procurement systems implementation.

Our research offers a new perspective and normative guidance on how managers should think about IT asset ownership to create and capture greater value from their IT investments. A related contribution of our work is the manner in which we have conceptualized the analysis process for determining the optimal ownership structure of e-procurement system assets. Even those who work with the theory of incomplete contracts probably have not parsed the stepwise separation of the asset-related and the participant-related determinants as we have. We believe that providing a process to create the optimal ownership structure for a set of IT assets is an effective starting point that leads to rich and meaningful guidance for senior managers.

We also defined the relative importance of participants’ investments to make it workable in an applied setting, and identified some possible factors affecting which participant’s investment
is more important. We showed that relative importance plays a key role in determining which participant should own the e-procurement system assets. We further argued that the most critical source of relative importance is the difference in participants’ non-transferable specific knowledge. Because the investment participants become more dispensable as the technologies used for e-procurement support become more open and standardized, the optimal structure of IT asset ownership is increasingly determined by the participants’ relative importance in jointly creating value from the IT assets. We argue that the more knowledgeable participant should own the e-procurement system assets in question because that participant’s investment is more productive in creating value.

The results that we obtained from analyzing the addition of a third party to our buyer-supplier example help to explain the recent surge in VMI outsourcing. In the past, the technologies used in VMI were proprietary and were developed by a particular participant, usually a buyer, who also owned the system. However, with the increasing standardization of the technologies, the participants have become more dispensable, and increasingly, firms are outsourcing their VMI capabilities to third parties, who often become the owners of the VMI system assets. A case in point is Enterprise Data Management. The firm provides an ASP-based VMI outsourcing service called Datalliance (www.datalliance.net). Due to better technical knowledge and expertise in managing VMI systems built up from experience with multiple implementations, the third party’s investments in VMI system assets have become more important than those of the buyer or supplier.
REFERENCES


APPENDIX: ANALYSIS OF OWNERSHIP STRUCTURES IN THREE-FIRM CASE

The general Hart and Moore model consists of a set $S$ of $I$ risk neutral participants and a set $A$ of assets. In our three-firm case with a third party, which we denote with $t$, $S = \{b, s, t\}$ and $A = \{N, D, F\}$. The value generated by a set of participants $S$ controlling asset $A$ is $v(S, A)$.

Also, \( \frac{\partial v(S, A)}{\partial i_j} = v'(S, A), j \in \{s, b, t\} \) is participant $j$’s marginal return on investment. We analyze three ownership structures: supplier ownership, buyer ownership, and third party ownership.

Here, we use the Shapley value as the solution concept. As we mentioned earlier, a participant’s Shapley value is each participant’s incremental contribution to each potential set of itself and other participants multiplied by the probability of each such set. For a bargaining situation among $I$ participants, participant $i$’s Shapley value is:

\[
\sum_{S \in \mathcal{P}} \frac{(s-1)!(I-s)!}{I!} (v(S) - v(S \setminus \{i\})).
\]

The results of analyzing the participants’ marginal returns of the three different ownership structures are shown in Table A1.

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>EXPECTED MARGINAL RETURNS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier Ownership</td>
<td>Supplier ($s$) $\frac{1}{3}v'(s, d) + \frac{1}{3}v'(s, d) + \frac{1}{3}v'(s, d)$</td>
</tr>
<tr>
<td>Buyer Ownership</td>
<td>Buyer ($b$) $\frac{1}{6}v'(b, d) + \frac{1}{3}v'(b, d) + \frac{1}{2}v'(b, d)$</td>
</tr>
<tr>
<td>Third Party</td>
<td>Third Party ($t$) $\frac{1}{6}v'(t, d) + \frac{1}{3}v'(t, d) + \frac{1}{2}v'(t, d)$</td>
</tr>
<tr>
<td>Integrated Firm</td>
<td>$\frac{1}{6}v'(s, d) + \frac{1}{3}v'(s, d) + \frac{1}{2}v'(s, d)$</td>
</tr>
</tbody>
</table>

Note: A participant’s marginal return represents its incentives for systems implementation effort investment. The ownership structure that entails the greatest marginal return for all the participants is optimal. We included the integrated firm case for comparison purpose.