Private Network EDI vs. Internet Electronic Markets: A Direct Comparison of Fulfillment Performance

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ABSTRACT

Prior literature has documented the performance benefits from the use of electronic data interchange (EDI) and the Internet. Little research, however, has provided a direct comparison between the performance of the two systems. Using purchase and fulfillment records gathered from the U.S. government’s Federal Supply Service, a direct comparison of performance is provided between a private network EDI channel and an Internet electronic market. Performance is measured using order cycle time and complete orders fulfilled. Our findings show that the Internet-based electronic market performs superior to the EDI-based channel. Order cycle times were significantly lower when using the Internet-based channel, while the percentage of complete shipments was significantly higher after controlling for product, transaction, seller, and buyer specific factors. Since EDI is still prevalent in many industries, these results point to the gains that may be realized by switching to the newer technology.

Key Words: Interorganizational Information System, Electronic Markets, Supply Chain Performance; Electronic Data Interchange; Internet

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1. Introduction

Over the past decade, there has been considerable research documenting the performance benefits from the use of electronic data interchange (EDI) (e.g., Srinivasan et al. 1994; Mukhopadhyay et al. 1995; Lee et al. 1999; Mukhopadhyay and Kekre 2002). These benefits include reduced shipment errors, higher inventory turnover, and reduced stockouts. More recent work on Internet-based electronic markets has also uncovered performance improvements in terms of lower cost of goods sold and higher inventory turnover (e.g., Zhu and Kraemer 2002). However, there is little research that provides a direct comparison between the performance of the two systems.

As organizations decide whether to maintain well-established private network EDI systems, or switch to Internet-based electronic markets, it is helpful for managers to know what benefits may be expected from switching from EDI to Internet-based electronic markets. Although the Internet is perceived to be a superior technology (e.g., lower implementation and operating costs, better search capabilities), firms in many industries have not reached a consensus on migrating from EDI to the Internet, thereby maintaining EDI-based networks (Mount 2003). As outlined by Kauffman and Mohtadi (2004), “…it is highly surprising that despite the overwhelming evidence of the advantages of e-procurement systems, proprietary systems such as electronic data interchange (EDI) continue to persist…” The decision to keep EDI systems may be due to uncertainties over potential benefits from Internet-based systems.

Although both private network EDI and electronic markets provide communication and transaction links between organizations, a growing body of literature has documented that the
two types of systems can be quite different (Bakos 1991a; Bakos 1997; Choudhury 1997; Choudhury et al. 1998; Zhu 2004; Zhu and Kraemer 2005) (Detailed descriptions of the two systems are provided in section 2.1). In this research, we develop and test a model that directly compares the fulfillment performances of an Internet electronic market, an EDI transaction system, and a traditional paper-based system, using data on approximately three million transactions by U.S. federal government purchasers through the U.S. Federal Supply Service (FSS). Fulfillment performance is measured by order cycle time and the percentage of complete orders fulfilled.

The FSS provides an excellent setting for this research for a number of reasons. First, the FSS offers both a private network EDI-based transaction system and an Internet-based electronic market, as well as a traditional paper-based system. The provision of three parallel transaction systems allows us to evaluate the performance differences among the three systems. Since all three systems are operated within the same context, this renders better control over other factors that could affect system performance, thereby minimizing potential confounding environmental effects. Second, the richness of the source data enables us to comprehensively track and estimate our models using purchase data from a diverse set of product categories for improved generalizability. Finally, the FSS data allow us to assess transaction-based performance outcomes, thus providing complementary empirical evidence to studies that have used survey methods.

Our main empirical finding is that the FSS’s Internet-based system is superior to its EDI counterpart on our two performance measures. We believe that this performance gap can be attributed in large part to the information discovery capabilities of the Internet system, lacking in EDI linkages. Since EDI channels are more prevalent than Internet-based electronic markets in
some industries, these results point to the gains that may be realized by updating communication and transaction technologies that support product search, vendor comparison, electronic information discovery, and electronic transaction processing, all available with Internet-based electronic markets.

We believe that this paper makes important theoretical and empirical contributions. From a theoretical perspective, the paper synthesizes findings from previous literature to provide a rationale for potential performance differences between Internet-based electronic markets and private network based EDI systems. On the empirical side, this paper is the first attempt to directly compare performance benefits between a private network EDI system and an electronic market. As such, our research responds to the call of Mukhopadhyay and Kekre (2002) for more research on new technologies such as the Internet.

The rest of the paper is structured as follows: Section 2 presents theoretical perspectives and reviews relevant literature related to the use of EDI and the Internet. Section 3 develops our research model and our hypotheses. Section 4 describes the procurement processes of the FSS. Section 5 details the research methodology. Section 6 presents the empirical results and robustness checks. Section 7 discusses the findings and implications. Finally, Section 8 presents our conclusions, discusses research limitations, and outlines the potential for future research.

2. Theoretical Perspective and Literature Review

2.1 EDI vs. Electronic Markets

Both EDI linkages and electronic markets are forms of interorganizational information systems (IOIS). An IOIS is defined as “an automated information system shared by two or more companies” (Cash and Konsynski 1985), and “is built around information technology that facilitates the creation, storage, transformation and transmission of information” (Johnston and
Vitale 1988; Grover 1993; Saeed et al. 2005). Typical information technologies that support IOIS are EDI and the Internet (Elgarah et al. 2005). In this section, we discuss the differences between EDI-based systems and Internet-based electronic markets and the performance implications of such differences.

EDI-based systems, often termed electronic dyads (Choudhury 1997) or information linkages (Teo et al. 2003; Bakos 1991a), are described as “the movement of business documents electronically between [or within] firms in a structured, machine-retrievable format that permits data to be transferred, without re-keying, from a business application in one location to a business application in another location” (Hansen and Hill 1989, p.405). An Internet-based electronic market, also termed “electronic commerce” (Truman 2000) or “electronic business” (Zhu and Kraemer 2005), is defined as “an interorganizational information system that allows the participating buyers and sellers in some market to exchange information about prices and product offerings” (Bakos 1997, p1676; Bakos 1991a; Choudhury et al. 1998).

In this research, we define private network EDI systems as bilateral linkages enabled by proprietary protocols and standards (e.g., ANSI X12) and Internet-based electronic markets as transaction systems featuring multilateral relationships and enabled by the Internet open protocol and standards (i.e., TCP/IP) (Truman 2000). These definitions are consistent with those used in the previous research, such as Choudhury (1997), Choudhury et al. (1998), Zhu (2004), and Kauffman and Mohtadi (2004). The private network EDI systems do not include Internet-based EDI systems (as discussed in Johnston and Mak 2000 and Kauffman and Mohtadi 2004), which are out of the scope of this research. Electronic markets refer to electronic intermediaries that provide product offerings for buyers to purchase, and facilitate transactions between buyers and
suppliers (Bakos 1991a; Bakos 1997; Choudhury et al. 1998).¹ We limit the research scope to transaction activities conducted using these systems, recognizing EDI or the Internet may also be used for other activities, such as collaboration (e.g., information sharing, vendor-managed inventory, etc.). For the rest of the paper, unless specifically noted, EDI refers to private network EDI and electronic markets refers to Internet-based electronic markets.

While these two systems have features in common, such as the electronic communication effect (Malone et al. 1987), EDI-based systems and Internet-based electronic markets also exhibit differences from both technological and structural perspectives. From a technological perspective, the Internet is characterized by an open standard, a public network, and by broad connectivity (both front end and back end), whereas EDI is a system of proprietary standards, a private network with back end integration (Zhu and Kramer 2005; Johnston and Mak 2000). From a structural perspective, the Internet-based electronic market is characterized as a multilateral IOIS that enables a many-to-many or a one-to-many set of relationships (Johnston and Mak 2000; Choudhury et al. 1998), whereas EDI-based bilateral links establish “individual electronic links with each of a select set of trading partners” (i.e., a one-to-one type of relationship) (Choudhury 1997; Choudhury et al. 1998). Multilateral electronic markets feature the electronic brokerage effect (Malone et al. 1987) that facilitates comparisons among multiple sellers with respect to prices, product quality, product availability, or on a number of other factors (Choudhury et al. 1998). On the other hand, bilateral EDI systems feature the electronic integration effect (Malone et al. 1987) that facilitates interfirm coordination leading to improvement in the efficiency of gathering and communicating information, including information sharing, inventory control, and process monitoring (Bakos 1991a).

¹ We do not consider electronic markets involving auctions or reverse auctions (Anandalingam et al. 2005).
Previous literature has demonstrated that the technological and structural differences between EDI-based systems and Internet-based electronic markets have impacts on transaction costs. For example, Zhu and Kraemer (2005) argue that the technological differences between the Internet and EDI-based systems may lead to differences in market reach resulting in a greater degree of richness of information exchange for Internet systems. Malone et al. (1987) discuss the electronic brokerage effect whereby electronic commerce technologies can connect many different buyers and suppliers through a central database. Due to the open standards and protocols of the electronic market, the electronic brokerage effect leads to an increase in the number of alternatives (i.e., greater numbers of potential supply sources, product offerings, etc.), to an increase in the quality of the alternative eventually selected, and to a decrease in the cost of the entire product selection process. Bakos (1991 a & b, 1997) studies both electronic markets and electronic linkages such as EDI, and notes that electronic markets reduce a buyer’s search costs, thus promoting price competition and weakening the market power of sellers. Kauffman and Mohtadi (2004) distinguish proprietary platform procurement systems (i.e., EDI-based systems) from open platform procurement systems (i.e., Internet based electronic markets) and demonstrate the two systems may be used for different scenarios due to transaction cost and risk implications.

In summary, although they have many features in common, EDI-based IOIS and Internet-based IOIS (electronic markets) are different technologically and structurally. These differences provide a theoretical underpinning for an empirical, direct comparison, of performance between the two systems.

2.2. The Impact of EDI and Electronic Markets on Performance
Most of the research on how interorganizational information systems affect performance has focused on the use of EDI. In a field study of the logistics operations of Chrylser assembly centers, Srinivasan et al. (1994) find that EDI substantially facilitates the implementation of just-in-time (JIT) shipments leading to significantly lower shipment errors. A subsequent study (Mukhopadhyay et al. 1995) finds that the savings accruing to Chrysler through the use of EDI amounted to over $100 per vehicle. EDI use contributes to higher inventory turnover, lower obsolescence costs, and lower transportation costs. Lee et al. (1999) examine the use of EDI in conjunction with a continuous replenishment program at the Campbell Soup Company and a number of its retail customers. They find that EDI provides benefits in terms of lower inventory levels and reduced stockouts, not only to the EDI “champion”, but also to other firms in the supply chain. They attribute improved performance, in part, to greater “vertical information integration”. Mukhopadhyay and Kekre (2002) show that EDI-enabled B2B procurement processes bring not only strategic, but also operational benefits to suppliers and customers. The magnitude of the benefits depends on how EDI-based systems are established between suppliers and customers. For example, the supplier derives large strategic benefits when the customer initiates the system and the supplier enhances its capability.

Other research in the operations management and supply chain fields supports the benefits from the use of EDI. Ahmad and Schroeder (2001) study the impact of EDI on delivery performance and find that the extent of EDI use significantly improves delivery performance, after controlling for contextual factors. Crum et al. (1998) survey trucking companies and find both operational benefits (e.g., increased accuracy, improved communication) and strategic benefits (e.g., the ability to gain or retain competitive advantage) from using EDI. Dröge and Germain (2000) survey members of a logistics professional organization and find EDI use to be
positively associated with both inventory and financial performance, net of any impact due to the use of JIT. Finally, a survey of suppliers to Australian automotive manufacturers (Mackay and Rosier 1994) shows relationships between EDI use and improved productivity, including lower clerical staffing levels, improve data accuracy and customer service, and lower administrative costs.

More recent studies have examined the impact of electronic markets on performance. Zhu and Kraemer (2002) find that firms that use Internet technologies are more likely to be agile and capable of competing in dynamic markets than are firms without these capabilities. Zhu (2004) finds that electronic commerce capabilities and information technology infrastructure both are positively related to firm performance in terms of sales per employee, inventory turnover, and cost reduction. Choudhury et al. (1998) study the aircraft parts industry and find inventory levels are unaffected by the use of electronic markets, although there are some improvements in identifying parts and reducing aircraft downtime.

In summary, a number of studies show linkages between the use of electronic transaction systems, including EDI and Internet-based electronic markets, and improved performance. However, none of these studies provide a direct comparison between the performance impacts of Internet-based electronic markets and EDI-based transaction systems. Based on the different characteristics of the two systems, as outlined above, performance could vary substantially.

### 2.3. Measures of Fulfillment Performance

There have been a number of methods used to measure the performance of EDI or Internet-based electronic markets. These measures include reduction in cost (e.g., Mukhopadhyay et al. 1995; Zhu and Kraemer 2002), reduction in inventory (e.g., Choudhury et al. 1998; Zhu and Kraemer 2002), reduction in data entry errors (e.g., Dearing 1990),
improvement in supplier-buyer relationships (Dearing 1990; Subramani 2004), responsiveness to customer needs (e.g., Ahmad and Schroeder 2001), and improvement in delivery quality (e.g., Srinivansan et al. 1994; Ahmad and Schroeder 2001).

For this paper, we assess performance based on the fulfillment levels of the EDI and Internet-based IOIS. Fulfillment performance is an essential metric given the shift from product-centric, firm-specific management models to customer-centric, supply chain management (Kalakota and Robinson 2003). Improved fulfillment performance enhances customer satisfaction, hopefully leading to improved financial performance. In particular, we evaluate an organization’s fulfillment performance using two variables: order cycle time and complete orders fulfilled. In addition, we calculate the percentage of units short-shipped, a dimension of complete orders fulfilled, and use this measure to augment our analysis. (Detailed definitions of these variables are provided in Section 4.2).

The use of Internet-based electronic markets and EDI-based systems may result in significantly different performance levels due to their technological and structural differences as discussed in Section 2.1. In the next section, we develop a research model that links the differences in these two systems to fulfillment performance, and hypothesize the impacts of the two systems on performance.

3. Hypotheses Development

The process of purchasing a product can include several stages, from problem recognition, to information search, to the evaluation of alternatives, to the actual purchase transaction, and finally, to post-purchase fulfillment (Engel and Kollat 1978; Kolter 2002). In general, the pre-purchase period involves a process of information discovery leading to the purchase decision. This is a period when the buyer searches for product alternatives, compares
the offerings, and negotiates for the desired products from among suppliers. Once a purchase decision has been made and communicated to the supplier, the actual transaction processing takes place and the order is fulfilled. Transaction processing is when the transaction is executed by the exchange of appropriate documents, and remittances are made from buyer to supplier.

Finally, the post-purchase period includes, potentially, a number of activities encompassing production, order picking, and transportation. The fulfillment performance, in terms of both complete orders filled and order cycle time, is generally measured after this last stage in the purchase process and can depend on the performance of the supplier at all three stages of the ordering process. For example cycle time can be reduced and/or the number of complete orders shipped can be increased if the supplier does the following: provides real time and accurate inventory information to potential buyers (pre-purchase period); expedites purchase orders and confirmation through electronic means (transaction period); and uses expedited transportation carriers (post-transaction period).

We use the concepts of information discovery (Barua et al. 2004) and transaction processing (Mukhopadhyay and Kekre 2002) to distinguish between three potential transaction channels. Information discovery and transaction processing can be conducted through either electronic means or traditional means (paper-based). Traditional transaction channels, such as telephone, fax, personal sales calls, etc., are characterized as having both traditional, paper-based (i.e., non-electronic) information discovery and transaction processing characteristics. Although these channels do make use of technologies (e.g., fax machines), the technologies do not allow for direct integration between the buyer’s and seller’s information systems, nor do they allow for rapid electronic search capabilities. Electronic markets, on the other hand, allow for both electronic search capabilities and electronic transaction processing (Baura et al. 2004; Zhu and
Kraemer 2005; Bakos 1991a; Bakos 1997; Choudhury et al. 1998). Finally, private network EDI systems typically allow for electronic transaction processing through their document exchange properties (such as purchase orders, shipping notices, invoices, fund transfers, etc.), but have only limited electronic information discovery capabilities. For example, with an EDI system, a buyer may be able to query a supplier as to inventory status, but there may be limited capabilities to query and compare the status of multiple vendors. Table 1 summarizes the characteristics of the three communication and transaction channels in terms of information discovery and transaction processing.

<<Insert Table 1 about here>>

Empirical research has shown that the use of technology with information discovery capabilities and electronic transaction processing can lead to better supply chain outcomes for the buyer in terms of lower prices, higher levels of availability, and lower cycle times (Barua and Lee 1997, Riggins and Mukhopadhyay 1994, Wang and Seidmann 1995). The use of the technology allows buyers to search more quickly, conveniently, and widely for various purchase options. If purchasers can obtain real-time data on inventory availability, they can purchase from sellers that have inventory in stock, thus avoiding short-shipments and delivery delays. In addition, the use of technology for transaction processing can reduce order cycle times, in that this technology removes much of the potential for human delays in document processing.

Since both EDI and the Internet-based electronic markets have electronic-based transaction processing, they should both reduce order cycle time compared to paper-based systems. Both systems, too, may contribute to greater percentages of complete orders fulfilled. The Internet with its advanced information discovery systems should allow buyers to search for suppliers with available inventory. EDI, with more rudimentary electronic information
discovery characteristics (e.g., inventory queries) should also result in better order fulfillment compared to paper-based systems. Therefore, our first two hypotheses are as follows:

**H1:** *The use of EDI transaction systems or Internet-based electronic markets will result in shorter order cycle times, compared to the use of traditional, paper-based transaction systems.*

**H2:** *The use of EDI transaction systems or Internet-based electronic markets will result in a higher percentage of complete orders fulfilled, compared to the use of traditional, paper-based transaction systems.*

As discussed above, private network EDI and Internet systems are technically and structurally different. The implication of these differences is that electronic markets feature the capability for simultaneous search so that a buyer can compare real-time product offerings from multiple potential vendors at the same time (on a single webpage, for example). EDI-based transaction systems, on the other hand, do not offer such capability. If a buyer needs to search for products or vendors, the buyer has to place a number of request-for-quotes (RFQs)\(^2\) to a set of potential vendors and compare their responses. In contrast to the simultaneous search capabilities of the Internet, this process may be viewed as a sequential search procedure. The simultaneous search capabilities offered by electronic markets can greatly reduce buyer search costs (Smith and Brynjolfsson 2001; Smith 2002). As Malone et al. (1987) state, “*[t]he standards and protocols of the electronic markets allow a buyer to screen out obviously inappropriate suppliers, and to compare the offerings of many different potential supplier quickly, conveniently, and inexpensively.*”

\(^2\) An EDI standard transaction set (840) containing information needed by a vendor to perform a request for price and availability quote for a product or service.
As a result, electronic markets typically allow greater search capabilities than those provided in private network EDI systems, a notion also noted in previous literature (Barua et al. 2004; Choudhury et al. 1998; Zhu and Kraemer 2002; Zhu 2004). Greater search capabilities allow purchasers to more readily locate appropriate products and suppliers, thus reducing order cycle times and improving product availability. For example, a buyer is able to choose a product in stock (as opposed to a product that must be back ordered), that can be delivered within 3-5 days (as opposed to a competing vendor that offers 5-7 day delivery, for example). Therefore, we expect that electronic markets to outperform EDI-based systems. Our next two hypotheses are as follows:

**H3:** The performance results, with respect to order cycle times, should be superior for Internet-based electronic markets as compared to EDI-based transaction systems.

**H4:** The performance results, with respect to complete orders fulfilled, should be superior for Internet-based electronic markets as compared to EDI-based transaction systems.

In summary, we propose that both EDI-based systems and Internet-based electronic markets should reduce order cycle times and improve performance with respect to orders fulfilled and short-shipments compared to traditional transaction systems. However, the improvements should be greater for electronic markets, due to better information discovery technology. A direct comparison between the performance of an EDI system and an electronic market will be made, using data gathered from the Federal Supply Service.

3. The Federal Supply Service Procurement Process

The U.S. federal government is one of the largest (if not the largest) procurer of goods in the world. A core component of the U.S. federal government’s supply chain is the Federal Supply Service of the General Services Administration, which acts as an intermediary in the
chain. The FSS is designed to bring purchasers from a large number of government agencies together with a variety of product providers. Both buyers and sellers are certified by the United States government. Buyers are identified as authorized to purchase for a specific agency. Vendors must meet a rigorous set of standards to qualify for inclusion in the General Services Administration’s Supply Business or on the Federal Supply Schedules, and thus be certified as vendors for products that can be purchased by FSS users.

The FSS provides government buyers with access to over four million products and services. The FSS system includes three identifiable channels for placing orders: paper forms; government developed electronic data interchange systems using the ANSI X12 standard; and the Internet-based GSA Advantage! system. All terms and conditions that apply to paper-based orders apply, as well, to both of the electronic channel formats. All government users (certified buyers) have all three channels available to them and all vendors (certified sellers) are required to support all three channels. A key difference across the channels is the product and vendor information available to buyers. As shown in Table 2, the traditional paper forms offer the least amount of information, the EDI systems additional information, including inventory availability for individual vendors; and GSA Advantage! the greatest quantity and most timely information, including real-time information on multiple vendors.

<<Insert Table 2 about here>>

The availability of a search engine on GSA Advantage! facilitates simultaneous product and vendor searches and comparisons. No comparable capability is available through the private network EDI system (although a certified user may search sequentially, as discussed earlier). Therefore, while both the EDI and the Internet-based electronic markets provide electronic transaction processing, the Internet-based channel provides greater technology-based information.
discovery characteristics. The question this paper addresses is whether these advanced capabilities result in performance benefits to users.

4. Research Methodology

4.1 Data

Data were collected from the FSS. The data are the FSS’s transaction and fulfillment records of goods shipped during fiscal year 2000. The source data consist of 3.7 million records, each record corresponding to one purchase order and fulfillment. Given the size of the database and the diversity of products in the dataset, we only include those product categories with over 100,000 transactions a year in our main analysis. This criterion yields four product categories as defined by the FSS. They are: hand tools and hardware (category 1); office supplies and devices (category 2), brushes, paints, sealers, and adhesives (category 3), and containers, packaging and packing supplies (category 4). Across these product categories, there were 2,960,776 transactions in sum, accounting for 80% of total records. Of these records, 4,451 were eliminated because of likely entry errors or missing data. Specifically, 460 records were eliminated because the shipping date was earlier than the order date; 3,424 records were eliminated because of incomplete product identifiers, and 567 records were eliminated because of non-positive transaction prices. Finally, 2,956,325 records remained.

Table 3 presents descriptive statistics on transaction frequency by transaction channel and by product category. For example, the table shows that for office supplies and devices, 686,187 or 42.93% of the transactions were made using the Internet-based GSA Advantage! channel, 806,639 or 50.47% of the transactions were conducted using the EDI-based channel, and 105,408 or 6.60% of the transactions were made through the traditional, paper-based channel. All product categories have a substantial number of transactions with each channel, with the
highest percentage of transactions occurring through the EDI-based channel. Furthermore, the four product categories are quite distinct in their use of transaction channels (e.g., heaviest use of the *GSA Advantage!* Internet channel for office supplies and devices, with lighter use for hand tools and hardware). Therefore, including multiple categories in our analysis is likely to increase the generalizability and the robustness of our results.

<<Insert Table 3 about here>>

**4.2 Dependent and Independent Variables**

As discussed in Section 2.3, our analysis includes two main performance measures as dependent variables – order cycle time and complete orders fulfilled. Short-shipment percentage is an additional performance measure complementary to complete orders fulfilled. The key independent variables are a dummy variable indicating whether a transaction is conducted through the EDI channel and a second dummy variable indicating whether a transaction is conducted through the Internet channel. The base case is the paper-based channel.

Order Cycle Time (CYCLE), the first dependent variable, measures how efficiently a supply chain moves products to customers. For comparable products, a fast moving supply chain usually implies greater efficiency; for example, lower order processing times and lower inventories-in-transit. We measure a supply chain’s order cycle time as the elapsed time between when a customer order is placed and when it is shipped\(^3\).

Complete Orders Fulfilled (COMPLETE), the second dependent variable, indicates whether a transaction is completely fulfilled. Complete fulfillment is described as being “*about delivering the right products in the right quantity at the right time to the right location*” (Kay 2001). We assign a value of “3” to correspond to a complete (requested quantity delivered),

\(^3\) This is different from a common definition of order cycle time as the elapsed time between when an order is made and when the order is received by the customer. We use the alternative definition due to data limitations.
correct (no substitute products shipped), and on-time (no units backordered) order. A “2” is assigned to an order with any two of the three requirements fulfilled, a “1” to an order with only one of three requirements fulfilled, and a “0” to orders with none of the requirements. For simplicity, we call this variable COMPLETE, although, as indicated above, the variable encompasses the correct and on-time shipment of products, as well as the complete (requested quantity) shipment. Figure 1 visually presents how the variable is defined. If an order is fulfilled without any part of the order backordered, it is given a “1” in the “right time” dimension; if an order is fulfilled with the requested quantity, it is given a “1” in the “right quantity” dimension; and if an order is fulfilled with the product requested (as opposed to a substitute product), it is given a “1” in the “right product” dimension. When the order fulfillment status is at point (1, 1, 1), the order is fulfilled in a complete, correct, and on-time manner and the variable is coded 3. When the order fulfillment status is at point (1, 0, 1), (1, 1, 0), or (0, 1, 1), the order is partially fulfilled and the variable is coded 2. An order fulfillment status at any of the points (0, 0, 1), (0, 1, 0), or (1, 0, 0), implies a partially fulfilled order with a variable coding of 1. Finally, when the order fulfillment status is at the point (0, 0, 0), the order is coded 0.

Short Shipment Percentage (SHORT), a dependent variable used to complement COMPLETE, is a continuous variable that measures the “right quantity” dimension of order fulfillment with greater granularity. It is calculated as the percentage of units in a customer’s order that are out of stock, and thereby short-shipped. Results from estimating SHORT are used to complement and supplement the regression results from estimating COMPLETE.

We use two dummy variables to measure our key independent variables representing the FSS’s EDI and Internet transaction channels. (The base case is the paper-based transaction channel.) As outlined above, government purchasers can procure products through three
different channels – a traditional, paper-based channel, an EDI channel, and an electronic market channel, GSA Advantage!. If the purchase was conducted through EDI, then the EDI channel dummy (EDI) is coded 1 and the Internet channel is coded 0. If the purchase was conducted through GSA Advantage!, then the Internet channel (INTERNET) is coded 1 and the EDI channel is coded 0. If the purchase was conducted through the traditional, paper-based channel, then both of the dummy variables are coded 0.

4.3 Control Variables

In constructing an econometric model to compare the performances of the three transaction channels, a key issue is controlling for other factors that could influence fulfillment performance. These factors relate to the seller, the buyer, and the transaction itself, including the product that is transacted. First, with respect to the seller, fulfillment performance can be affected by a seller’s distribution capability. Since, the FSS operates five warehouses, it may be that the various warehouses provide different levels of service. From our data, it is possible to identify the warehouse from which a fulfillment order is shipped. Thus, we include a series of dummy variables to control for the fixed warehouse effect. The base case, is no warehouse use; that is drop shipments from the FSS’s supplier directly to the FSS’s customer.

Second, with respect to the transaction, we include a variable measuring transaction quantity; that is, the number of units being transacted. Controlling for transaction quantity is important since there may, for example, be a greater chance for short-shipments if large volumes of a product are purchased. As well, large purchases may take longer to process, so that order cycle time could be higher for large purchases than for smaller purchase quantities. In addition, we include a series of dummy variables for the months in which the transaction occurred to control for demand seasonality.
Third, we have variables to control for the product being purchased. In particular, product price and item transaction frequency are included to control for the potential differences in inventory management practices for high and low-value items and for frequently and infrequently purchased products. For example, firms may minimize inventory levels for high value products to hold down inventory holding costs. As a result, high value products may have lower fulfillment rates and longer cycle times than low value products, *ceteris paribus*. As well, the FSS may stock proportionally higher inventory levels for frequently transacted items, resulting in better fulfillment performance. If the FSS does not adopt this policy, frequently transacted items may be associated with lower fulfillment performance. Furthermore, since our data include multiple product categories, a series of dummy variables to control for potential differences between product categories is included. For example, office supplies may be given a lower fulfillment priority than hand tools.

Finally, we control for potential heterogeneity among buyers by including a variable measuring a buyer’s annual transaction volume. Larger total purchase volume may indicate a buyer with, potentially, greater financial resources. In addition, this variable controls for the potential learning effect among buyers. Buyers who make more transactions with the FSS may be better able to utilize the functionality provided by electronic channels.

### 4.4 Econometric Model

Our estimation is conducted at the transaction level (i.e., each transaction is an observation). We estimate the following:

\[
CYCLE = \beta_0 + \beta_1 EDI + \beta_2 INTERNET + \beta_3 PRICE + \beta_4 QUANTITY + \beta_5 BVOL + \beta_6 \\
FREQ + \sum_{i} \gamma_i WAREHOUSE_i + \sum_{i} \delta_i MONTH_i + \sum_{i} \lambda_i CATEGORY_i + \varepsilon. \tag{1}
\]
\[
\text{COMPLETE} = \beta_0 + \beta_1 \text{EDI} + \beta_2 \text{INTERNET} + \beta_3 \text{PRICE} + \beta_4 \text{QUANTITY} + \beta_5 \text{BVOL} + \\
\beta_6 \text{FREQ} + \sum_{i=1}^{W} \gamma_i \text{WAREHOUSE}_i + \sum_{i=1}^{m} \delta_i \text{MONTH}_i + \sum_{i=1}^{n} \lambda_i \text{CATEGORY}_i + \zeta
\]

\[
\text{SHORT} = \beta_0 + \beta_1 \text{EDI} + \beta_2 \text{INTERNET} + \beta_3 \text{PRICE} + \beta_4 \text{QUANTITY} + \beta_5 \text{BVOL} + \beta_6 \\
\text{FREQ} + \sum_{i=1}^{W} \gamma_i \text{WAREHOUSE}_i + \sum_{i=1}^{m} \delta_i \text{MONTH}_i + \sum_{i=1}^{n} \lambda_i \text{CATEGORY}_i + \eta
\]

where:

- CYCLE, COMPLETE, and SHORT are defined as in section 4.2.
- WAREHOUSE\textsubscript{i} represents one of a series of dummy variables, coded 1 if the goods are shipped from WAREHOUSE\textsubscript{i}. If goods are shipped directly from the supplier (and not through an FSS warehouse), then all of the warehouse dummy variables are coded 0.
- MONTH\textsubscript{i} consists of 11 dummy variables, each denoting a month in which the transaction was initiated. December is omitted as the base case for comparison purposes.
- CATEGORY\textsubscript{i} is a series of dummy variables for all (but one) product categories.
- QUANTITY is transaction quantity, measured as the total units in a transaction.
- PRICE is the product price.
- BVOL is the buyer’s total annual purchase volume with the FSS during the year the data were collected, measured in dollars.
- FREQ is an item’s transaction frequency measured as the number of times the item was transacted during the year.
- \(\beta, \gamma, \) and \(\delta\) are parameters to be estimated and \(\varepsilon, \zeta\) and \(\eta\) are disturbance terms.

Table 4 presents the descriptive statistics and the correlation matrix for the variables. To check for potential multicollinearity, we estimated ordinary least squares (OLS) variants of our
models and computed variance inflation factor (VIF) scores for all independent variables. The VIF scores for all independent variables are between 1.00 and 4.72, lower than the commonly accepted level of 10 (Kennedy 2003), indicating that multicollinearity may not be a concern.

4.5 Model Estimation

The dependent variable, complete orders fulfilled, is an ordered multinomial-choice variable; that is, with 3 being the best outcome and 0 the worst. A regular multinomial logit model fails to account for the ordinal nature of the variable, while an ordinary least squares (OLS) regression is more appropriate for a cardinal dependent variable (Greene 1997). Ordered logit models, on the other hand, have been widely used to estimate ordinal responses with ordered values.

The second dependent variable, order cycle time, is the counted number of days between the placement of an order and the shipment of that order. As a count measure, it follows a Poisson distribution (Greene 1997). According to Greene (1997, p. 931), a preponderance of zero values for the dependent variable (in our case, orders that are received and shipped on the same day) and the clearly discrete nature of count data, suggest that a Poisson regression is a better estimation approach than a linear model. However, the dependent variable may be “over-dispersed” since a Poisson distribution assumes equal mean and variance. In the case of over-dispersion (i.e., variance greater than mean), a negative binomial distribution is considered, since a negative binomial regression relaxes the assumption of equal mean and variance. A test of deviance statistics following the Poisson regression yielded a highly significant (p<0.000) Chi-
squared statistic of $3.32e+7$, suggesting over-dispersion. A negative binomial regression is therefore used.\(^4\)

The third dependent variable, short-shipment percentage, is always non-negative; that is, can only be either zero or a positive number. When an order is completely filled, short-shipment percentage equals zero; otherwise it may be any positive number up to 100. Moreover, the percentage of data points that equal zero for short shipments is much larger than what one would expect under normal distributions. In total 2,670,264 observations are zeros, accounting for 90.3\% of the total cases (i.e., 90.3\% of the shipments were completely filled). Therefore, it can be determined that short-shipment percentage has a censored distribution; that is, it is left-censored at the value zero. The existence of a censored dependent variable results in a non-normal error distribution, thus violating one of the ordinary least squares’ assumptions. Hence, OLS results may be biased. Therefore, a Tobit model is considered. Tobit, a censored regression model, is designed to estimate regressions with censored dependent variables by compensating for the non-normal distribution of the dependent variable (Greene 1997).

A final estimation concern is that there are repeated transactions for the same buyers over time implying that these transactions may not be independent. Thus, we estimate our models with Huber-White robust standard errors that correct for model estimations with repeated observations within a cluster (Wooldridge 2002)\(^5\).

5. Empirical Findings

5.1 Estimation Results

The equations for order cycle time, complete orders fulfilled, and short shipment quantity are estimated individually. In order to show the robustness of our results, we estimate three

\(^4\) Estimations using Poisson regressions were also performed and the results are consistent with those presented.
variants of the model. Model 1 is a base model that includes the independent variables, EDI and INTERNET, and control variables for time (i.e., month dummies) and shipping location (i.e., warehouse dummies). Model 2 adds two additional control variables, PRICE and QUANTITY, to account for product and transaction specific effects. Model 3 is the full model that adds the control variables BVOL, FREQ, and the product category dummies, to further control for buyer and product related factors.

Table 5 presents the results for all three models. The coefficients are consistent across the models, demonstrating the robustness of our results. As a consequence, only the results from the full model (Model 3) are discussed. The coefficient for INTERNET (β = -0.409) is negative and significant (p<0.001) in the order cycle time equation while the coefficient for EDI is negative but insignificant. Thus, Hypothesis 1 is supported only for electronic markets indicating that the use of electronic markets reduces the time between when an order is placed and when it is shipped, as compared to the traditional (paper-based) ordering system. The coefficient for INTERNET (β = 0.278) is positive and significant (p<0.001) in the complete orders fulfilled equation, while the coefficient for EDI is positive but insignificant. Thus, Hypothesis 2, as well, is supported only for electronic markets indicating that the use of the Internet increases complete orders fulfilled, as compared to the traditional ordering system. Finally, the coefficient for INTERNET is negative and significant in the short shipment percentage equation, whereas for EDI, the coefficient is negative but insignificant, implying that the use of electronic markets (but not EDI) reduces the percentage of short-shipments, as compared to using the traditional transaction channel. As a complementary measure to complete orders fulfilled, this last result provides further evidence for Hypothesis 2.

5 We also estimated the models using regular standard errors. The results are consistent, although more significant, than those presented from our main estimations using the Huber-White robust standard errors.
Hypotheses 3 and 4 provide direct comparisons between the performance of the EDI system and electronic markets. In order to test these hypotheses, we performed Wald-tests (Greene 1997) comparing the magnitudes of the EDI and INTERNET coefficients in each of the six regressions. The results are in Table 6. For Hypothesis 3 to be supported, the coefficients for INTERNET in the regressions on Order Cycle Time must be significantly “more negative” than their EDI counterparts, implying that the order cycle times using the electronic market are significantly lower than the cycle times using the EDI-based transaction channel. As shown in the first row of Table 6, Hypothesis 3 is strongly supported. In order for Hypothesis 4 to be supported, the coefficients for INTERNET must be significantly greater than the coefficients for EDI in the Complete Orders Fulfilled equations. As indicated in the second row of Table 6, this is true at the .001 significance level. To provide further support for Hypothesis 4, as shown in the third row of Table 6, the coefficients for INTERNET in the regressions on Short-Shipments are significantly “more negative” than their EDI counterparts, implying that a lower percentage of items was short-shipped when using the electronic market.

Table 7 presents log likelihood ratio tests for each of the three regressions. The tests compare the fit of the complete models to models without the EDI and INTERNET variables (i.e., restricted models). The purpose of the tests is to determine whether the inclusion of these two variables improves the prediction of the three dependent variables. In all tests, the log likelihood ratio is significant at the p-value of .001, indicating that the fit of the complete models is significantly better than the fit of the restricted models.
5.2 Validation and Robustness Checks

In order to validate our estimations, we performed several different robustness checks. First, we calculated hit rates for the ordered logit models used to estimate complete orders filled. The hit rates indicate that the ordered logit models correctly predict complete orders fulfilled 89.53% of the time. Second, since our data include four product categories, we ran our models using sub-samples for each product category separately and obtained consistent results for our key variables (EDI and INTERNET). Third, we reran our models using 50%, 10% and 1% randomly drawn samples. The results from the random draws are consistent with those reported, indicating that our results are not sensitive to the volume of data points. Furthermore, we estimated our model using only the sub-sample of transactions involving buyers who purchased exclusively through a single channel throughout the year (either electronic market, EDI or traditional). This sample selection excludes buyers who may use one channel for a particular type of products (e.g., commodities) and a second channel for other types of products (e.g., strategic purchases). The reduced sample included 64,403 out of 67,709 buyers, and approximately 74.31% of the transactions in our dataset. We find that the results (Table 8) are consistent with those reported above, although with this estimation, both the EDI channel and the Internet channel outperformed the paper-based channel, with the Internet-based channel achieving the highest performance results. Finally, we estimated our models using data on the smaller FSS product categories not included in our original estimations. These categories have annual numbers of transactions between 1,000 and 10,000. The results (Table 9) are consistent

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6 The results are omitted for brevity but available upon request.
7 These product categories include (1) service equipment; (2) agricultural machinery and equipment; (3) material handling equipment; (4) rope, cable, chain and fittings; (5) cooling equipment; (6) pumps and compressors; (7) plumbing, heat and sanitation equipment; (8) pipe, tubing, hose and fittings; (9) prefabricated structures and scaffolding; (10) construction and building materials; (11) commercial telecommunication equipment; (12) electrical and electronic equipment component; (13) photographic equipment; and (14) books, maps and other publications.
with those reported, indicating that our findings can be generalized to a broad range of product categories.

<<Insert Tables 8 and 9 about here>>

6. Discussion

A number of research studies have shown performance benefits from using EDI-based systems (e.g., Srinivasan et al. 1994; Mukhopadhyay et al. 1995; Lee et al. 1999). More recently, researchers have differentiated between EDI and electronic markets (Choudhury et al. 1998) and stated that it is not clear that EDI results can be extended to electronic markets (Zhu and Kraemer 2002). Despite the rich literature on the performance evaluation of the use of EDI-based systems, and the growing body of literature on the performance of Internet-based electronic markets, little or no research has been done to compare and contrast the two systems in terms of performance. Our research provides an empirical addition to the existing literature on performance improvements from electronic-based transactions. The paper also makes the first attempt using a direct comparison to show how Internet-based electronic markets can outperform EDI-based transaction systems in terms of order fulfillment.

In this paper, we show that federal government purchasers who use the Internet-based GSA Advantage! can expect lower order cycle times, a greater percentage of complete orders, and a smaller percentage of items short-shipped after controlling for transaction characteristics, buyer characteristics, item characteristics, and other environmental factors. That is, Internet-based systems outperform both EDI-based and traditional transaction systems with lower order cycle times, higher order fulfillment, and a smaller percentage of items short-shipped. To illustrate these results, we use regression estimates from Table 5 (Model 3) to compute the
potential effects of transaction channel choice on the dependent variables. The potential effects are computed as the changes to the dependent variable when the EDI or Internet variables change from 0 to 1, while maintaining the rest of the independent variables at their means. Table 10 presents the potential effects for our sample. We can see from the table, that relative to the use of the traditional transaction channel, EDI has only a minor impact on cycle time and complete shipments. On the other hand, the use of the Internet-based GSA Advantage! has a substantial impact. GSA Advantage! reduces cycle time by from 4.8 days to 3.0 days or by 37.5% on average. In addition, GSA Advantage! increases the order fulfillment rate by 2 percentage points from 91.7% to 93.7%. Finally, GSA Advantage! reduces short-shipments by 1.87 percentage points from 4.78% of total shipments under a paper-based channel to 2.91% of total shipments. This represents a 39.02% reduction in the short-shipment percentage. These results show that the performance improvements resulting from the use of electronic markets, relative to EDI-based and traditional channels, are not only statistically significant, but economically significant.

<<Insert Table 10 about here>>

Performance differences among transaction channels may be attributed to the ways that transactions are facilitated. Both Internet and EDI-based transaction systems facilitate the electronic exchange of documents (e.g., purchase orders, acknowledgement of purchase orders, etc.). Electronic document exchanges may reduce cycle time and increase order fulfillment rates due to increased order accuracy. However, the most important advantage of the Internet-based system over both of its alternatives may be its superior information discovery characteristics. The ability to use information discovery tools to locate suppliers with available inventory and to compare offerings among suppliers may lead to both increased order fulfillment and reduced
cycle time. As a result, we find Internet-based transaction systems are associated with better fulfillment levels, compared to both EDI-based and traditional transaction systems.

Our result that the EDI system did not outperform the paper-based system is surprising, given the EDI system’s superior transaction capabilities. However, it should be noted that when we estimated transactions conducted by purchasers who only used one transaction system throughout the year (see Table 8), the EDI system did outperform the paper-based channel.

Our findings provide complementary empirical evidence and alternative perspectives to the concept of online informational capability (OIC) (Barua et al. 2004), which is a key factor in determining performance or net-enhanced business value (e.g., Zhu and Kraemer 2002; Barua et al. 2004). We shed light on an important decision faced by businesses; that is, the choice between EDI and Internet-based transaction systems. Although many firms have switched from private network EDI systems to electronic markets, the use of EDI is still prevalent in some industries. For example, a survey of logistics managers in the food industry found that private network EDI technology was used to place four times as many orders with suppliers than was web-based technology (although neither technology was used as much as traditional transaction channels) (Dresner et al. 2001). Our own statistics show that EDI-based channels are still heavily used by government purchasers. For example, for the hand tools category, the EDI-based channel was used for 90.19% of FSS purchases, while the Internet-based channel for only 7.30% of purchases. Clearly, there may be significant performance gains if a higher proportion of FSS purchasers, and, perhaps, greater numbers of purchasers in general, converted from EDI-based systems to electronic markets. On the other hand, suppliers (especially those with inferior performance) may be reluctant to move toward the use of electronic markets since their use heightens competition among suppliers through reductions in search costs (Bakos 1991a; Bakos
1997), reductions in information asymmetry between buyers and suppliers (Bakos 1997), and
decreases in supplier bargaining power (Clemons et al. 1993; Malone et al. 1987).

Although our results strongly support increased performance through the use of
electronic markets, caution should be employed in generalizing the results. The FSS supply
chain is regulated more closely than most supply chains in the private sector. For example,
government purchasers are only allowed to procure through either the FSS or through suppliers
that are pre-approved by the FSS, whereas in the private sector, purchasers may be free to
procure from a greater number of sources. The FSS supply chain is also one of the largest in the
world in terms of transaction volumes. The specific conditions of the FSS supply chain may not
be applicable to smaller organizations. However, we believe the FSS supply chain may be
comparable to internal supply chains of large retail firms; for example, supermarket chains,
where retail outlets are supplied from central distribution centers and/or directly from vendors.

7. Conclusions

This paper examines how the use of different types of communication and transaction
channels can affect organizational performance, most notably order cycle time and complete
orders fulfilled. Using data gathered from the FSS supply chain, three types of channels are
examined – a traditional, paper-based channel, a private network EDI channel, and an Internet-
based channel. Our paper extends previous research on EDI performance (e.g., Srinivasan et al.
1994; Mukhopadhyay et al. 1995; Lee et al. 1999) to the electronic market context. Our results
support recent research that demonstrates that the use of electronic markets may lead to
improved performance over private network IOIS (Zhu and Kraemer, 2002; Zhu, 2004). Despite
literature that notes substantial differences between the two channel technologies (Choudhury et
al. 1998), there is no research, of which we are aware, that provides a direct performance
comparison between EDI and Internet transaction systems. Our findings suggest that channel choice does matter, and that the information discovery capabilities of the Internet-based IOIS may contribute to its superior performance. Since EDI channels still dominate some industries (e.g., Dresner et al. 2001), these results point to the gains that may be realized by updating communication and transaction technologies to support product search and vendor comparisons.

A limitation of this paper is the use of a single organization, the Federal Supply Service, to test our results. This limitation reduces the generalizability of the results. However, on the plus side, sampling from a single organization allows us to strictly control for the influence of parallel technologies and purchasing procedures, such as just-in-time purchasing programs, that may influence organizational performance (e.g., Srinivasan et al. 1994). A further limitation is that the types of products examined in this research are indirect products, including those often associated with maintenance, repair, and operations (MRO) categories. These materials are often purchased on a spot market basis without long term commitments. Further research may determine if our results can be extended to direct input materials that are purchased under long term contracts.

References


Wesley, Reading, MA.


Figure 1: Dimensions of Complete Order Fulfillment
Table 1: Information Discovery and Transaction Processing in Three Transaction Channels

<table>
<thead>
<tr>
<th>Channel Characteristics</th>
<th>Electronic Market</th>
<th>Private Network EDI</th>
<th>Traditional Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information Discovery</td>
<td>Electronic</td>
<td>Limited Electronic</td>
<td>Traditional</td>
</tr>
<tr>
<td>Transaction Processing</td>
<td>Electronic</td>
<td>Electronic</td>
<td>Traditional</td>
</tr>
</tbody>
</table>

Table 2: Federal Supply Service Transaction Channels

<table>
<thead>
<tr>
<th>Information Available for Government Buyer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Channel</td>
</tr>
<tr>
<td>Pricing, delivery. (Paper-based product catalog that is updated twice a year)</td>
</tr>
<tr>
<td>Private Network EDI</td>
</tr>
<tr>
<td>Real-time pricing, delivery, inventory status.</td>
</tr>
<tr>
<td>Electronic Market (GSA Advantage!)</td>
</tr>
<tr>
<td>Real-time pricing, delivery, inventory status, and real-time vendor and product search and comparison.</td>
</tr>
</tbody>
</table>

Table 3: Descriptive Statistics on Transaction Frequencies by Channels

<table>
<thead>
<tr>
<th>Product Category</th>
<th>Number of Transactions (Percent of Product Category Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Internet-Based GSA Advantage!</td>
</tr>
<tr>
<td>1. Hand Tools and Hardware</td>
<td>75,539 (7.30%)</td>
</tr>
<tr>
<td>2. Office Supplies and Devices</td>
<td>686,187 (42.93%)</td>
</tr>
<tr>
<td>3. Brushes, Paints, Sealers, and Adhesives</td>
<td>18,083 (9.93%)</td>
</tr>
<tr>
<td>4. Containers, Packaging and Packing supplies</td>
<td>33,787 (23.83%)</td>
</tr>
</tbody>
</table>
Table 4: Descriptive Statistics and Correlation Matrix (N=2,956,325)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>S.D.</th>
<th>Min.</th>
<th>Max.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. COMPLETE</td>
<td>2.85</td>
<td>0.46</td>
<td>0</td>
<td>3</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. SHORT</td>
<td>0.07</td>
<td>0.24</td>
<td>0</td>
<td>1</td>
<td>-0.65***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. CYCLE</td>
<td>6.65</td>
<td>15.75</td>
<td>0</td>
<td>350</td>
<td>-0.22***</td>
<td>0.37***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. EDI</td>
<td>0.67</td>
<td>0.47</td>
<td>0</td>
<td>1</td>
<td>0.01***</td>
<td>-0.01***</td>
<td>0.10***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. INTERNET</td>
<td>0.28</td>
<td>0.45</td>
<td>0</td>
<td>1</td>
<td>0.004***</td>
<td>-0.002***</td>
<td>-0.11***</td>
<td>-0.88***</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. PRICE</td>
<td>25.69</td>
<td>393.99</td>
<td>0.02</td>
<td>98,605</td>
<td>0.003***</td>
<td>-0.002**</td>
<td>0.07***</td>
<td>0.00</td>
<td>-0.02***</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. QUANTITY</td>
<td>14.24</td>
<td>156.45</td>
<td>1</td>
<td>99,312</td>
<td>-0.08***</td>
<td>0.02***</td>
<td>0.02***</td>
<td>-0.01***</td>
<td>-0.01***</td>
<td>-0.003***</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>8. BVOL</td>
<td>426,720</td>
<td>1,178,963</td>
<td>0.06</td>
<td>1.83e+07</td>
<td>-0.04***</td>
<td>-0.004***</td>
<td>0.07***</td>
<td>0.21***</td>
<td>-0.21***</td>
<td>0.01***</td>
<td>0.03***</td>
<td>1</td>
</tr>
<tr>
<td>9. FREQ</td>
<td>1,888.86</td>
<td>2,753.45</td>
<td>1</td>
<td>22,617</td>
<td>0.03***</td>
<td>-0.04***</td>
<td>-0.11***</td>
<td>-0.09***</td>
<td>0.10***</td>
<td>-0.02***</td>
<td>0.02***</td>
<td>-0.04***</td>
</tr>
</tbody>
</table>

* *p < 0.05; **p < 0.01; ***p < 0.001
Table 5 Estimation Results  
(Huber-White Robust Standard Errors in Parentheses)

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Order Cycle Time</td>
<td>Complete Orders Fulfilled</td>
<td>Short Shipment Percentage</td>
</tr>
<tr>
<td>INTERCEPT</td>
<td>3.398*** (0.045)</td>
<td>-2.874*** (0.041)</td>
<td>3.377*** (0.047)</td>
</tr>
<tr>
<td>EDI</td>
<td>-0.054 (0.042)</td>
<td>0.100* (0.050)</td>
<td>-0.040 (0.044)</td>
</tr>
<tr>
<td>INTERNET</td>
<td>-0.452*** (0.037)</td>
<td>0.401*** (0.048)</td>
<td>-0.276*** (0.029)</td>
</tr>
<tr>
<td>Price (x10⁻³)</td>
<td></td>
<td>0.222*** (0.053)</td>
<td>-0.049*** (0.007)</td>
</tr>
<tr>
<td>Quantity (x10⁻³)</td>
<td>0.464*** (0.067)</td>
<td>-2.836*** (0.345)</td>
<td>0.296*** (0.062)</td>
</tr>
<tr>
<td>Buyer’s Total Purchase Volume (x10⁻⁶)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item’s Transaction Frequency (x10⁻⁶)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product Category Dummies</td>
<td>Included</td>
<td>Included</td>
<td>Included</td>
</tr>
<tr>
<td>Warehouse Dummies</td>
<td>Included</td>
<td>Included</td>
<td>Included</td>
</tr>
<tr>
<td>Month Dummies</td>
<td>Included</td>
<td>Included</td>
<td>Included</td>
</tr>
<tr>
<td></td>
<td>Log Likelihood</td>
<td>-7,872,460</td>
<td>-1,142,802</td>
</tr>
</tbody>
</table>

*p < 0.05; **p < 0.01; ***p<0.001
Table 6: Wald Tests Between EDI and INTERNET Coefficients

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>EDI Coefficient</th>
<th>INTERNET Coefficient</th>
<th>Chi2</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>CYCLE</td>
<td>-0.041</td>
<td>-0.409</td>
<td>456</td>
<td>0.000</td>
</tr>
<tr>
<td>COMPLETE</td>
<td>0.018</td>
<td>0.278</td>
<td>193</td>
<td>0.000</td>
</tr>
<tr>
<td>SHORT</td>
<td>-0.040</td>
<td>-0.246</td>
<td>445</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table 7: Likelihood Ratio Test

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Log Likelihood (Restricted Model)</th>
<th>Log Likelihood (Full Model)</th>
<th>Likelihood Ratio</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CYCLE</td>
<td>-7,873,647</td>
<td>-7,856,875</td>
<td>-33,544</td>
<td>&lt;0.000</td>
</tr>
<tr>
<td>COMPLETE</td>
<td>-1,130,851</td>
<td>-1,129,298</td>
<td>-3,106</td>
<td>&lt;0.000</td>
</tr>
<tr>
<td>SHORT</td>
<td>-1,038,513</td>
<td>-1,036,283</td>
<td>-4,460</td>
<td>&lt;0.000</td>
</tr>
</tbody>
</table>

The restricted model refers to estimations without the EDI and Internet variables. Likelihood ratio is calculated by using the differences in log likelihood between two models and times -2 (Greene 1997).
Table 8: Estimation Results – Subsample of Single Channel Buyers  
(Huber-White Robust Standard Errors in Parentheses)

<table>
<thead>
<tr>
<th></th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Order Cycle Time Complete Orders Fulfilled Short Shipment Percentage</td>
</tr>
<tr>
<td>INTERCEPT</td>
<td>3.490*** (0.060)</td>
</tr>
<tr>
<td></td>
<td>-2.891*** (0.052)</td>
</tr>
<tr>
<td>EDI</td>
<td>-0.182** (0.056)</td>
</tr>
<tr>
<td></td>
<td>0.279*** (0.067)</td>
</tr>
<tr>
<td></td>
<td>-0.192*** (0.039)</td>
</tr>
<tr>
<td>INTERNET</td>
<td>-0.554*** (0.054)</td>
</tr>
<tr>
<td></td>
<td>0.461*** (0.066)</td>
</tr>
<tr>
<td></td>
<td>-0.367*** (0.038)</td>
</tr>
<tr>
<td>Price (x10⁻³)</td>
<td>0.167** (0.063)</td>
</tr>
<tr>
<td></td>
<td>-0.035*** (0.008)</td>
</tr>
<tr>
<td></td>
<td>0.007 (0.006)</td>
</tr>
<tr>
<td>Quantity (x10⁻³)</td>
<td>0.708*** (0.103)</td>
</tr>
<tr>
<td></td>
<td>-3.466*** (0.531)</td>
</tr>
<tr>
<td></td>
<td>0.420*** (0.109)</td>
</tr>
<tr>
<td>Buyer’s Total Purchase Volume (x10⁶)</td>
<td>0.217*** (0.047)</td>
</tr>
<tr>
<td></td>
<td>-0.283*** (0.040)</td>
</tr>
<tr>
<td></td>
<td>0.158*** (0.020)</td>
</tr>
<tr>
<td>Item’s Transaction Frequency (x10⁶)</td>
<td>-44.70*** (1.06)</td>
</tr>
<tr>
<td></td>
<td>83.60*** (2.62)</td>
</tr>
<tr>
<td></td>
<td>-54.70*** (1.76)</td>
</tr>
<tr>
<td>Warehouse Dummies</td>
<td>Included Included Included</td>
</tr>
<tr>
<td>Month Dummies</td>
<td>Included Included Included</td>
</tr>
<tr>
<td>Product Category Dummies</td>
<td>Included Included Included</td>
</tr>
<tr>
<td>Model Statistics</td>
<td>N 2,196,777 2,196,777 2,196,777</td>
</tr>
<tr>
<td></td>
<td>Log Likelihood -5,681,848 -805,000 -745,244</td>
</tr>
</tbody>
</table>

* p < 0.05; ** p < 0.01; ***p<0.001
Table 9: Estimation Results – Product Categories between 1,000 and 10,000 Annual Transactions
(Huber-White Robust Standard Errors in Parentheses)

<table>
<thead>
<tr>
<th></th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Order Cycle Time</td>
</tr>
<tr>
<td>INTERCEPT</td>
<td>3.578*** (0.072)</td>
</tr>
<tr>
<td>EDI</td>
<td>0.032 (0.054)</td>
</tr>
<tr>
<td>INTERNET</td>
<td>-0.438*** (0.054)</td>
</tr>
<tr>
<td>Price (x10^-3)</td>
<td>0.266*** (0.056)</td>
</tr>
<tr>
<td>Quantity (x10^-3)</td>
<td>0.428 (0.708)</td>
</tr>
<tr>
<td>Buyer’s Total Purchase Volume (x10^6)</td>
<td>0.728*** (0.543)</td>
</tr>
<tr>
<td>Item’s Transaction Frequency (x10^6)</td>
<td>-170.80*** (10.20)</td>
</tr>
<tr>
<td>Warehouse Dummies</td>
<td>Included</td>
</tr>
<tr>
<td>Month Dummies</td>
<td>Included</td>
</tr>
<tr>
<td>Product Category Dummies</td>
<td>Included</td>
</tr>
</tbody>
</table>

Model Statistics
- Log Likelihood: -164,412 - 25,091 - 21,635
- N: 65,695 65,695 65,695

* p < 0.05; ** p < 0.01; ***p<0.001

Table 10: Performance Comparison of Transaction Channel Choice

<table>
<thead>
<tr>
<th></th>
<th>Cycle Time (Days)</th>
<th>Complete Orders Fulfilled</th>
<th>Short Shipment Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Channel</td>
<td>4.844</td>
<td>0.917</td>
<td>4.779%</td>
</tr>
<tr>
<td>EDI Channel</td>
<td>4.646</td>
<td>0.918</td>
<td>4.445%</td>
</tr>
<tr>
<td>Internet Channel</td>
<td>3.026***</td>
<td>0.937***</td>
<td>2.914%***</td>
</tr>
</tbody>
</table>

Calculated based on regression estimates of model 3 in table 5.
* p < 0.05; ** p < 0.01; ***p<0.001