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Research Note

An Internet-Enabled Move to the Market in Logistics

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Logistics outsourcing has increased with the commercialization of the Internet, implying a reduction in the corresponding transaction costs. The Internet—with its universal connectivity and open standards—radically enhanced information technology (IT) capabilities, and we hypothesize this has reduced external transaction costs relatively more than internal governance costs. Using transaction cost theory as a lens, we examine whether the commercialization of the Internet coincided with a move to the market in logistics—one of the most connected industries in the economy. We estimate the relationship between IT and outsourced logistics in a production function based on two data sets from 1987 to 2008. We find that the effects of IT on outsourced logistics have changed in the post-Internet era. After the commercialization of the Internet, an industry's own IT investment and outsourced logistics became complements, whereas they were not before. It suggests that because of the unique characteristics of the Internet as an enabler, IT reduced external transaction costs relatively more than internal governance costs. Consequently, industries favored the market form of the provision of logistics. We also find similar impacts of customers' IT investments on a focal industry's outsourced logistics. Previous studies argued that IT led to the shift from hierarchies to markets, or provided indirect evidence through measures of firm size or integration. Using a production theory model, our study provides systematic empirical evidence to support that the Internet enabled a move to the market in the provision of logistics.

Keywords: information technology; IT; organizational boundaries; hierarchies and markets; logistics outsourcing; IT spillovers; production function framework; input–output tables
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1. Introduction

Logistics is a process of planning, implementing, and controlling the effective and efficient flow of goods, services, and information between the point of origin and the point of consumption (Rutner and Langley 2000). Its activities typically include inbound and outbound transportation, warehousing, inventory management, etc. It is through logistics that raw materials flow into production and finished goods are delivered to customers. Logistics are costly: in 2011, logistics expenditure was 8.5% of the gross domestic product (GDP), reaching about $1.28 trillion (Wilson 2012).

Logistics outsourcing, the use of external organizations to perform logistics activities that alternatively could be conducted by firms themselves, plays an important role in logistics management. Since the 1980s, logistics outsourcing has grown substantially. For example, in U.S. manufacturing industries, one of the largest users of logistics outsourcing, the usage rate of logistics outsourcing remained stable in the early 1990s, but increased sharply after the commercialization of the Internet. In a survey of top 500 manufacturing firms in the United States, 37% of firms used third-party logistics services (3PLs) in 1991 and 38% in 1994, reaching 60% in 1995 and climbing to 80% by 2004 (Lieb and Randall 1996, Ashenbaum et al. 2005). This climb from the mid-1990s to the mid-2000s was reflected in other surveys and was even more pronounced in estimated expenditures on 3PLs moving from under $31 billion in 1996 to almost $90 billion in 2004 (Ashenbaum et al. 2005).

The substantial growth of logistics outsourcing starting in 1994/1995 suggests that the transaction costs of outsourcing logistics have fallen and the benefits have risen relative to in-house logistics, and consequently the trend has been toward external provision. As we can see from the Transportation Satellite Accounts (TSAs) data in Table 1, for-hire or outsourced logistics accounts for around 80% of transportation costs for manufacturing industries in the United States. Although these

Table 1 Transportation Costs of Manufacturing Industries in 1992 and 1996

	1992		1996		
	1992 nominal value	1997 Real value (A)	1996 nominal value	1997 real value (B)	Percentage of change ((B−A)/A)
Total transportation costs	102,054	116,747.45	116,591	119,266.13	2.2
For-hire	80,248	91,801.88	94,275	96,438.10	5.1
In-house	21,806	24,945.57	22,316	22,828.03	−8.5
Total output	2,951,303		3,666,001		
For-hire/Total transportation costs	0.786		0.809		
In-house/Total transportation costs	0.214		0.191		
Total transportation costs/Total output	0.035		0.032		
For-hire/Total output	0.027		0.026		
In-house/Total output	0.007		0.006		

Notes. The nominal values of transportation costs in 1992 and 1996 are from Table 5 of 1996 TSAs (Fang et al. 2000). The nominal value of total output of manufacturing industries in 1992 and 1996 is from Table 3 of 1992 TSAs (U.S. Department of Transportation 1999) and Table 2 of 1996 TSAs (Fang et al. 2000), respectively. For-hire transportation includes railroad and related services; passenger ground transportation, except transit; motor freight transportation and warehousing; water transportation; air transportation; and pipelines, freight forwarders, and related services. In-house transportation includes transportation by trucks and buses provided by manufacturing industries for their own use. The values are in millions of dollars at producers' prices. Refer to U.S. Department of Transportation (2011), nominal 1992 dollars and 1996 dollars are adjusted using the current series of consumer price index (CPI) published by the U.S. Bureau of Labor Statistics for all transportation. CPIs for all transportation are 140.3, 156.9, and 160.5 in 1992, 1996, and 1997, respectively.

transportation costs rose over 2% in real terms between 1992 and 1996, the for-hire component grew by 5%, and the in-house component fell by over 8%, consistent with the percentage using 3PLs and estimated expenditures on 3PLs surveys quoted above.

Our premise is that the commercialization of the Internet changed the relationship between information technology (IT) and outsourced logistics, leading to an increase in outsourced logistics. The predominant IT innovation in logistics in the pre-Internet era was electronic data interchange (EDI), which could not meaningfully support logistics outsourcing.[1] The post-Internet era logistics strategies are often combined in a modern integrated collaborative planning, forecasting, and replenishment (CPFR) solution, and some of the most sophisticated technologies include Internet-based solutions. Internet-based CPFR include web-based collaboration for information sharing about forecasts, point-of-sale data, inventory, and visibility-in-transit logistics; event management and analysis highlighting exceptions and consequent options; and real-time tracking and reporting against plan (Danese 2006).

1.1. Logistics Sourcing, the Internet, and Transaction Costs

The decision to outsource logistics depends on the transaction costs of market versus in-house (internal) provision. IT has reduced both market transaction costs and internal governance costs (Malone et al. 1987, Gurbaxani and Whang 1991). We argue that in the case of logistics, the Internet has reduced market transaction costs relatively more than internal governance costs. Transaction costs depend on bounded rationality and opportunism, two assumptions about decision makers' behaviors, and on asset specificity, uncertainty, and frequency, three dimensions of transactions (Williamson 1981).[2] In the context of logistics, the Internet loosens bounded rationality and reduces the potential for opportunism. The Internet reduces buyer search costs (Bakos 1997), so that buyers of 3PL services can access information about price, capacity, and services at low cost. In addition, it can be costly or even impossible to check shipment records through traditional EDI for a manufacturer that has many shipments delivered by a variety of carriers because of the low diffusion of EDI and its limited implementation. However, using visibility in transit enabled by the Internet, a manufacturer can track and trace shipments in real time and check the records of all carriers' on-time delivery performance.

The Internet also reduces asset specificity of 3PL providers by facilitating an online logistics market that helps match logistics capacity and demand, and

[1] "The objective of EDI was to standardize the content of a reasonably complete commercial transaction set—the set of documents required to execute a variety of business transactions.... Thus, EDI is an initial step in the use of IT in transportation, automating the exchange of business documents" (Nault 1998, pp. 248–249). Moreover, EDI was not implementable in all business relationships (Brousseau 1994). The Internet, by contrast, enabled a variety of new logistics strategies that generated value beyond that available from EDI. These strategies included vendor-managed inventory, merge-in-transit policy, time-definite delivery, and freeze-point delay (Rabah and Mahmassani 2002).

[2] The online appendix (available as supplemental material at http://dx.doi.org/10.1287/isre.2016.0625) discusses these assumptions and dimensions in the context of logistics outsourcing.

resource sharing among 3PL providers (e.g., Nault and Dexter 2006). Online brokers can match carrier capacity and shipping demand, enabling 3PL providers to redeploy their human- and physical-specific assets over more users and uses to achieve economies of scale and scope. By outsourcing logistics, firms avoid holding transportation and warehousing assets, allowing 3PL providers to hold those assets because they have lower asset specificity because they can redeploy those assets to other customers. At the same time, firms can obtain additional efficiency by exploiting the logistics expertise of 3PL providers (Deepen 2007).

Information sharing among supply chain partners facilitated by Internet-based CPFR reduces uncertainty by improving supply chain visibility and enabling firms to adaptively control logistics activities. When a shipment is delayed or lost, an event management system can notify shippers or customers, and both can adapt to minimize or prevent potential problems. Finally, the Internet reduces the cost and technological barriers that restricted EDI adoption: the Internet supports a range of transaction frequency at low communication costs, which reduces costs across transactions.

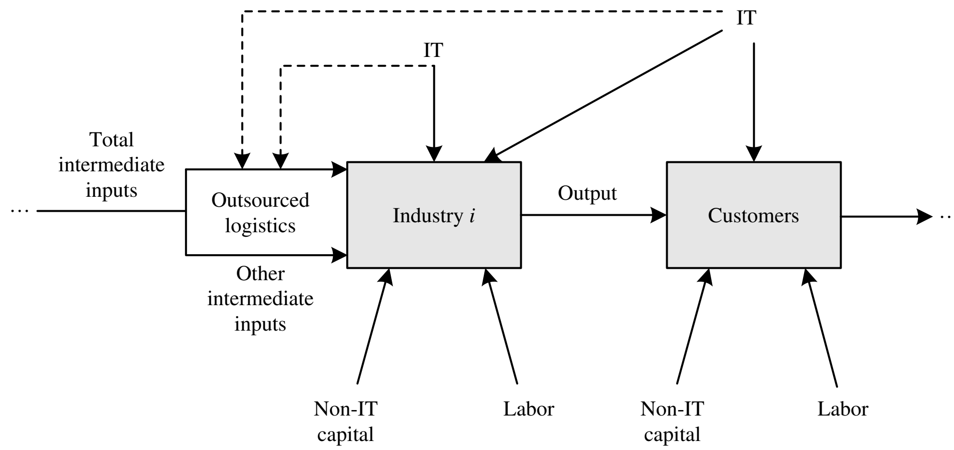
Previous studies suggest that IT shaped the change in organizational boundaries. Some studies argue theoretically that IT led to the shift from hierarchies to markets by reducing transaction costs (Malone et al. 1987, Gurbaxani and Whang 1991, Clemons et al. 1993). Brynjolfsson et al. (1994) find that IT was associated with smaller firm size, which the authors suggested was a shift to externally provided services by reducing external coordination costs relative to internal. Hitt (1999) find that IT was associated with the decrease in vertical integration, which suggested that the increase in IT was related to the change in organizational structure toward less in-house making. These studies provide important initial insights regarding the impact of nascent IT on organizational boundaries, and the commercialization of the Internet radically enhanced IT capabilities, which, in turn, fundamentally redefined the role of IT in organizations (Zhu and Kraemer 2002, Zhu 2004). Given this, we juxtapose the impact of IT on organizational boundaries in the pre- and post-Internet eras. Our study examines whether the commercialization of the Internet—with its universal connectivity and open standards—coincided with a move to the market in logistics: one of the most connected industries in the economy. The contribution of our work is systematic economywide empirical evidence that IT in its most interconnected instance—the Internet—favors a market form of the provision of logistics.

To show evidence of this move to the market, we take a novel approach using production theory—an approach that allows us to model the production of output in terms of capital, labor, and intermediate inputs: purchased goods and services from the market rather than generated within the organization. A production function specifies outputs as a function of inputs, and these inputs include capital (IT and non-IT), labor, and intermediate inputs. The latter are goods and services purchased on the market and used in the production process to produce output—one might think of these as "materials" that go into the production process. These are not only the goods and services that go into the production process—some are made or provided by the firm itself. Consequently, a firm chooses whether to make these materials or purchase them from the market. If a firm chooses to make the materials, then they make them with capital and labor; thus the inputs are capital and labor rather than intermediate inputs. Alternatively, if a firm chooses to purchase certain goods and services from the market rather than make or provide them, then they are intermediate inputs.

We separate logistics inputs from the rest of the intermediate inputs, and within a production model are able to determine if more or less logistics inputs are purchased from the market over time. In this way, the production function approach is ideal. We adopt the lens of transaction cost economics in interpreting the results because that provides the basis for whether goods and services should be provided within the firm or purchased as intermediate inputs.

We create two data sets by employing input–output (I–O) tables and industry productivity data: one for Standard Industrial Classification (SIC)-defined manufacturing industries from 1987 to 1999 and the other for North American Industrial Classification System (NAICS)-defined manufacturing industries from 2000 to 2008. We estimate the relationship between an industry's own IT investment and outsourced logistics and simultaneously estimate the relationship between the given industry's customers' IT investments and outsourced logistics, in the pre- and post-Internet eras. We find that the relationship between IT investments and outsourced logistics changed in the post-Internet era: as measured through our variable coefficient model, IT investments and outsourced logistics became complements only after the Internet was widely used. Together with the growth in the percentage of firms using 3PLs, the growth of expenditures on 3PLs, the move from in-house logistics to for-hire logistics, and the fact that there were no substantial regulatory or transportation-related technological changes, this suggests that the Internet is responsible for the shift to the market in the context of logistics. We recognize that we use secondary data that does not directly measure Internet usage, and, although we have time precedence and a theory-based explanation, we cannot directly attribute causality to the Internet in interpreting our results. We do, however, consider and negate many plausible alternative explanations in the online appendix.

Figure 1 **The Model of IT, Outsourced Logistics, and Output**



The next section provides our conceptual and mathematical models. Section 3 presents the estimation, including a description of the data, variables, econometric adjustments, and results. Section 4 discusses our contributions, implications, and limitations.

2. Our Model of IT, Outsourced Logistics, and Output

Figure 1 is our conceptual model of productivity along a supply chain. To generate output that is supplied to customers, an industry uses non-IT capital, labor, IT capital, and intermediate inputs from the market. Intermediate inputs consist of purchased (outsourced) logistics and other purchased goods and services. An industry benefits from the IT investments of customers because information sharing and coordination facilitated by customers' IT leads to more efficient production and operation (Cheng and Nault 2012).

As a multifaceted input, IT has a direct impact on production—similar to other inputs—and has indirect impacts on production by affecting other inputs (Mittal and Nault 2009). In particular, the Internet, characterized by global connectivity and open standards, helps remove incompatibility of legacy information systems within and between firms, greatly enhancing these systems' performance by allowing information sharing and coordination among trading partners (Zhu and Kraemer 2002, Zhu 2004). In our view, the Internet-enabled information sharing and coordination in supply chain logistics reduces external transaction costs, leading to an increased provision of logistics from the market. Outsourced logistics is typically more efficient than in-house logistics because 3PL providers have logistics-dedicated assets, economies of scale and scope, and logistics expertise.

From a supply chain perspective, customers' IT investments may affect an industry's output by affecting its inbound logistics. The bullwhip effect, whereby customers' demand uncertainty causes greater demand fluctuations upstream, could trigger uncertainty in logistics demand, which would be amplified back along a supply chain (Lee et al. 1997). An increase in logistics uncertainty in a supply chain increases transaction costs. In particular, the external transaction costs of outsourcing inbound logistics would increase. If transaction costs were high enough that they exceed operational advantages of the market, then industries would prefer to use their own in-house logistics. However, on-time demand and inventory information sharing enabled by customers' investments in the Internet-based interorganizational systems (IOSs) relieves information distortion in a supply chain, which in turn reduces demand uncertainty for goods and logistics (Lee et al. 2000, Cachon and Fisher 2000). As a result, transaction costs in a supply chain are reduced, allowing an industry to outsource more logistics, making the industry more productive. These effects are depicted in Figure 1.

We are interested in how IT, including an industry's own IT and customers' IT, affects its outsourced logistics and then consequently affects its output. We develop our mathematical form of the model based on the Cobb–Douglas (CD) production function

$$Y = AK^{\alpha}L^{\beta}Z^{\gamma}M^{\phi},$$

where Y is the quantity of gross output; A is the technology change parameter; K, L, Z, and M are the quantities of non-IT capital, labor, IT capital, and total intermediate inputs, respectively; and α, β, γ, and ϕ are the output elasticities of non-IT capital, labor, IT capital, and total intermediate inputs, respectively. The total intermediate inputs consist of outsourced logistics, W, and nonlogistics intermediate inputs, X

$$M = \{W, X\}.$$

Taking outsourced logistics and nonlogistics intermediate inputs into the CD production function and incorporating the impact of customers' IT on industry i's output, we specify the model with customers' IT investments as

$$Y_i = A_c K_i^{\alpha} L_i^{\beta} Z_i^{\gamma} X_i^{\theta} W_i^{\delta} C_i^{\varphi},$$

or in log form

$$y_i = a_c + \alpha k_i + \beta l_i + \gamma z_i + \theta x_i + \delta w_i + \varphi c_i, \qquad (1)$$

where A_c is the corresponding technology change parameter, Z_i is industry i's own IT investment, C_i is the IT spillovers from industry i's customers, θ is the output elasticity of nonlogistics intermediate inputs, and φ is the output elasticity of the customer-driven IT spillovers. The lowercase variables are the log forms of the uppercase variables. Next, to analyze how an industry's own IT investment and its customers' IT investments affect its outsourced logistics, we use a variable coefficient approach to specify the output elasticity of outsourced logistics, δ, as a linear function of industry i's own IT investment and IT investments from customers

$$\delta(Z_i, C_i) = b + \mu Z_i + \nu C_i. \qquad (2)$$

Taking (2) into (1), we have our estimation model corresponding to the conceptual model in Figure 1

$$\begin{aligned} y_i = {} & a_c + \alpha k_i + \beta l_i + \gamma z_i + \theta x_i + b w_i \\ & + \varphi c_i + \mu Z_i w_i + \nu C_i w_i. \end{aligned} \qquad (3)$$

Our estimation model differs from the variants of CD forms used in prior studies, and Table A1 in the online appendix compares our model with those. Recognizing that conceptually diverse models can lead to similar estimation forms, the critical novelty of our model is the use of the variable coefficient approach to specify the relationship between IT and outsourced logistics and incorporating that relationship into an extended CD production function. Through this approach we can focus on whether our specified relationship between IT and outsourced logistics has changed in the post-Internet era.

We are able to assess the relationship between IT and outsourced logistics and examine the impact of IT on output through outsourced logistics by examining the coefficients of the two interaction terms in (3). Specifically, we examine the complementarity relationship between IT and outsourced logistics. The term "complementarity" is used in different contexts with slightly varying meanings. We adopt a broad notion of complementarity and substitutability that does not depend on the special structure of prices and quantities and that permits analysis of complex phenomena such as organizational structures (Edgeworth 1925). Edgeworth's (1925) definition of complementarity and substitutability between goods is such that, assuming the first derivatives of a production function $f(\cdot)$ with respect to r_i and r_j are positive, if the cross partial derivative is positive, $\partial(\partial f(\cdot)/\partial r_i)/\partial r_j = \partial^2 f(\cdot)/\partial r_i \partial r_j > 0$, then the goods r_i and r_j are complements; if the cross partial derivative is negative, then the two goods are substitutes. We use this conceptualization to determine the complementarity between IT and logistics pre- and post-Internet. Others have adopted this generic definition for studying related issues. Milgrom and Roberts (1992, p. 597) defined the complements as "a set of activities with the property that doing more of any subgroup of the activities raises the marginal return to the other activities," and Milgrom and Roberts (1994, 1995) suggest that this conceptualization allows analysis of organizational structures and government policies.

The coefficient of the interaction term between own IT capital and outsourced logistics, μ in (3), demonstrates how own IT investment affects the contribution of outsourced logistics to output, holding other inputs fixed. The coefficient μ is defined as

$$\begin{aligned} \mu = \frac{\partial \delta(Z_i, C_i)}{\partial Z_i} &= \frac{\partial((\partial Y_i/\partial W_i)\cdot(W_i/Y_i))}{\partial Z_i} \\ &= \frac{W_i}{Y_i} \cdot \frac{\partial^2 Y_i}{\partial W_i \partial Z_i}. \end{aligned} \qquad (4)$$

The magnitude of μ is determined by the input share of outsourced logistics and a cross partial derivative of output with respect to own IT investment and outsourced logistics, and the sign of μ depends on the sign of the cross partial derivative. When μ is positive, an industry's own IT investment and outsourced logistics are complements; when μ is negative, they are not. Similarly, from the coefficient of the interaction term between customers' IT investments and an industry's outsourced logistics, ν in (3), we can know that customers' IT investment and an industry's outsourced logistics are complements when ν is positive, and not when ν is negative. In addition, based on the estimates of two interaction terms and (2), we are able to calculate the impact of IT on the output elasticity of outsourced logistics.

Based on I–O use tables, we calculate the IT investments from the customers of industry i, C_i, as a weighted average of IT investments of downstream industries. We use the relative transaction values in the total transactions made by customers as weights. In (5), C_i is

$$C_i = \sum_{j \neq i} \frac{V_{ij}}{\sum_{j \neq i} V_{ij}} Z_j, \qquad (5)$$

where V_{ij} is the dollar transaction volume of industry i's sales to the customer industry j. Our constructions of customers' IT investments are consistent with those in Mun and Nadiri (2002) and Cheng and Nault (2012).

3. Empirical Estimation

3.1. Data and Variables

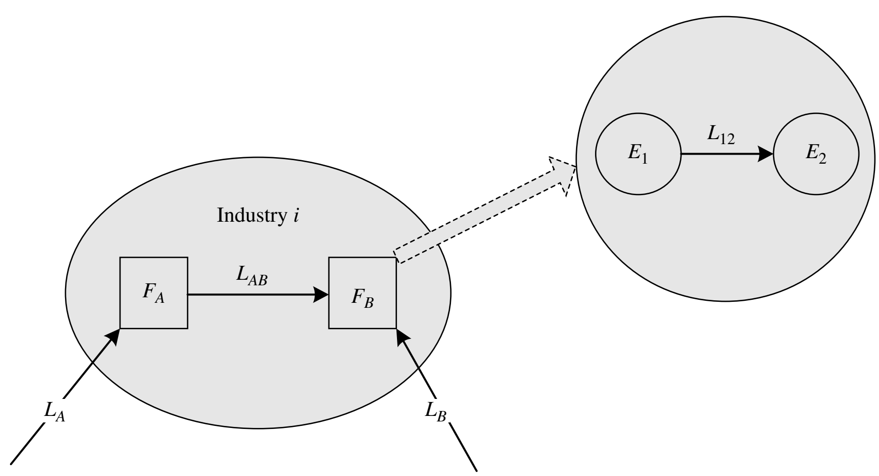
3.1.1. Our Measure of Outsourced Logistics. Our construct of outsourced logistics consists of an industry's inbound outsourced logistics and is measured by an industry's for-hire transportation costs and warehousing and storage costs, needed to move intermediate inputs from producers to users. After an industry purchases goods and services from upstream suppliers, those intermediate inputs can be transported to the given industry in three ways: through the given industry's in-house logistics (possibility 1), through suppliers' in-house logistics (possibility 2), and through 3PL providers (possibility 3). For all practical purposes, our measure of transportation and warehousing costs of an industry based on I–O tables (accounts) capture the costs in possibility 3. In addition, according to TSAs, even if a supplier may have paid the transportation costs, the transportation activity is credited to the downstream industry; for example, "if a for-hire truck carries wheat from a farm to a mill, the I–O use table credits this activity to the mill, even though the farm may have purchased the transportation service" (U.S. Department of Transportation 2011, p. 14). Therefore, we use an industry's transportation and warehousing and storage costs to capture its inbound outsourced logistics.

The sum of for-hire transportation costs and warehousing and storage costs is a good proxy of outsourced logistics. Transportation and warehousing costs generally account for the largest proportion of total logistics expenditures—72.2% of the total in 2011 (Wilson 2012)—and more than half of those costs are dedicated to outsourcing (Langley and Capgemini 2012). We calculate transportation and warehousing costs based on I–O use tables whereby "Transportation costs are the freight charges paid to move the commodity from the producer to the intermediate user or the final user" (Streitwieser 2009, p.42). These costs consist of rail, truck, water, air, oil pipeline, and gas pipeline charges (Horowitz and Planting 2009, Streitwieser 2009).

Understanding what goes into our measure of logistics outsourcing is critical to interpreting our results, and we provide the scope of the measure of outsourced logistics in Figure 2. The measure of outsourced logistics includes purchased logistics for moving goods from producers to users between and within industries. Assume nontransportation industry i has firms F_A and F_B, and it purchases transportation and warehousing for moving intermediate inputs from other industries to F_A and F_B. Variables L_A and L_B are the purchased logistics for moving goods from other industries to F_A and F_B, respectively. Both L_A and L_B are captured as the for-hire logistics of industry i in I–O accounts, even if producers in other industries pay for the logistics service. The measure of outsourced logistics for industry i also includes the purchased logistics used to move goods within industry i: L_{AB} is the freight charge and warehousing costs paid to logistics service providers for moving goods from F_A to F_B. At the establishment level, assume F_B has establishments E_1 and E_2; the outsourced logistics of industry i for moving goods from E_1 to E_2, L_{12}, captures purchased transportation and warehousing services from transportation industries. Therefore, our measure of outsourced logistics by an industry includes for-hire transportation expenses associated with moving intermediate inputs to the firms and establishments of an industry.

Because of the definition of I–O accounts, a negligible portion of in-house transportation is captured under for-hire transportation when it is provided by an establishment that is owned and operated by a nontransportation enterprise (U.S. Department of Transportation 2011, p. 14). To evaluate the contribution of transportation activities to the U.S. economy, the

Figure 2 The Scope of Outsourced Logistics



U.S. Department of Transportation provides TSAs that measure in-house and for-hire transportation separately. TSAs only differ from the I–O accounts in that they separately measure in-house transportation (U.S. Department of Transportation 2011, p. 14). There are three sets of available TSAs—1992, 1996, and 1997. TSAs for 1992 and 1996 follow the same methodology, whereas TSAs for 1997, published in 2011, differ because of the change in industry classification systems and the measure in for-hire and in-house transportation services. The 1997 TSAs isolate freight from passenger transportation and are thus comparable to our measure of outsourced transportation costs that focus on freight transportation. These TSAs show that our measure of outsourced logistics is more than 97.5% outsourcing—Table 2 shows that with TSAs numbers from 1997, only 2.3% of the transportation costs are in-house (insourcing).

To provide more evidence that the mixed in-house transportation costs are negligible, we compare for-hire transportation costs reported in 1992 and 1996 TSAs with what we calculated based on 1992 and 1996 I–O tables. We find that our measurements of for-hire logistics costs in 1992 and 1996 are even lower than those reported in 1992 and 1996 TSAs, respectively: outsourced logistics costs that we calculate based on the 1992 I–O table are smaller than what is reported by 1992 TSAs by 3.49%, and outsourced logistics costs that we calculate based on the 1996 I–O table are smaller than what is reported by 1996 TSAs by 0.02%. Further details are available on request.

As long as the methods of allocating transportation costs to industries in I–O accounts remain consistent across years, our measure of outsourced transportation costs consistently reflect purchases of transportation from the market. In addition, because outsourced transportation costs account for the largest proportion of the total outsourced logistics costs—on average, 99.8% in data set I and 91.4% in data set II—our measure of outsourced logistics consisting of outsourced transportation costs and warehousing and storage costs represents purchases of logistics from the market.

Table 2 **Transportation Costs of Manufacturing Industries in the 1997 I–O Table and 1997 TSAs**

		1997 TSAs	
Transportation costs	1997 I–O table	For-hire	In-house
Total transportation	96,126.11 (A)	93,927 (B)	36,740
Air	15,082.43	14,904	3,751
Rail	15,308.45	12,371	717
Water	968.94	2,624	1,969
Truck	59,990.57	57,427	30,303
Pipeline	4,775.72	6,601	
Percentage of change ((A−B)/A)	2.3		

Notes. For-hire and in-house transportation costs are from Table 7 (TSA's Use of Major Commodity Groups by Industry Sector: 1997) in the 1997 TSAs (U.S. Department of Transportation 2011). In-house transportation costs captured in 1997 TSAs cover the costs for moving an industry's intermediate inputs or output. For-hire transportation costs based on 1997 TSAs and the 1997 I–O table are the costs for moving intermediate inputs from producers to users. Transportation costs are in millions of dollars at producers' prices.

3.1.2. Data Set I: 1987–1999. Data set I consists of the multifactor productivity (MFP) data set for three-digit SIC manufacturing industries from 1987 to 1999 and the I–O tables from 1983 to 1999.[3] Both were requested from the Bureau of Labor Statistics (BLS). The data about output, intermediate inputs, labor, and capitals are similar to those used by Cheng and Nault (2007), Han et al. (2011), and Cheng and Nault (2012). Table A2 in the online appendix shows the data source and construction procedure of data set I. The MFP data contain 140 three-digit SIC manufacturing industries. They provide us with the series of output and the series of intermediate purchase compensation in millions of nominal dollars, and also have the output deflator and the intermediate purchase price deflators with 1987 as the base year. Dividing the series of output and intermediate inputs by their corresponding deflators, we obtained the series for output Y and intermediate inputs M in millions of 1987 dollars, respectively. We also obtained the labor input L in millions of all employee hours from the MFP data.

We obtained information capital stock that was used as IT capital Z from the BLS. The information capital stock consisted of computers and related equipment, office equipment, communication, instruments, photocopy, and related equipment, and all are in millions of 1987 dollars. Capital stock in millions of 1987 dollars consists of equipment, structures, inventories, land, and special tools. To obtain non-IT capital K, we summed the equipment and structure components and then subtracted the IT capital stock from the total.

Following the method of measuring outsourced logistics above, we obtained data on outsourced logistics W for each manufacturing industry by summing the transportation commodities and warehousing and storage commodity in use tables: railroad transportation (SIC 40); trucking and courier services, except air (SIC 421, 423); water transportation (SIC 44); air transportation (SIC 45); pipelines, except natural gas (SIC 46); and warehousing and storage (SIC 422).[4]

[3] The Economic Census collects data to develop the I–O tables at the establishment level, where an establishment is defined as "a business or industrial unit at a single physical location that produces or distributes goods or that performs services." It classifies establishments into industries according to SIC or NAICS and aggregates establishment-level data to obtain industry-level data (Horowitz and Planting 2009, p. 3-3).

[4] The U.S. statistical system does not currently have a separate classification system for commodities. Each commodity is assigned the code of the industry in which the commodity is the primary product (Horowitz and Planting 2009).

We calculated nonlogistics intermediate inputs X by subtracting outsourced logistics from total intermediate inputs. Again, outsourced logistics and the nonlogistics intermediate inputs are in 1987 dollars.

Based on I–O tables, we calculated customers' IT investments. I–O tables contain manufacturing industries and nonmanufacturing industries, and some of the rows/columns for manufacturing industries are the combination of three-digit SIC codes. We dropped all nonmanufacturing industries in the I–O tables and aggregated the corresponding industries in the MFP data according to the manufacturing industries listed in I–O tables, which generated 98 manufacturing industries in the MFP data and the I–O tables. After matching MFP data and I–O data, we set the diagonals in the I–O tables to zero to isolate the transactions with other industries, and then we followed (5) to calculate the transaction weighted customer IT capital.

Based on 98 manufacturing industries, we dropped the industries with missing data and those without customer industries. Because of missing intermediate inputs data from 1997 to 1999, we dropped six industries: logging (SIC 241), newspapers (SIC 271), periodicals (SIC 272), books (SIC 273), miscellaneous publishing (SIC 274), and greeting cards (SIC 277). Next, we eliminated seven industries that did not supply to others: ordnance and ammunition (SIC 348), aerospace (SIC 372, 376), ship and boat building and repairing (SIC 373), railroad equipment (SIC 374), toys and sporting goods (SIC 394), footwear except rubber and plastic (SIC 313, 314), and tobacco products (SIC 21). In total, we have a balanced panel of 85 industries across 13 years.

3.1.3. Data Set II: 2000–2008. The second data set was acquired in December 2011 from the BLS, is based on three-digit 2002 NAICS codes, and contains nine years, from 2000 to 2008. It consists of the MFP data for three-digit NAICS codes, providing our measures of IT capital, non-IT capital, and labor. Gross output, Y, was obtained from the GDP by industry accounts on the Bureau of Economic Analysis (BEA) website. Total intermediate inputs, M, from the I–O use tables were also obtained from the BEA. Table A3 in the online appendix shows the data source, construction procedure, and deflators used for each variable. We used chain-type quantity indexes as deflators to obtain the real values by multiplying the 2005 current dollar value of the series by the corresponding chain-type quantity indexes and then dividing by 100.

IT capital stock includes computers, software, communication, and others, and we use the total as IT capital, Z. The IT assets in data set II differ from those in data set I because software is included. Capital includes equipment, structures, rental residential capital, inventories, and land. To calculate non-IT capital, K, we aggregated equipment and structures and then subtracted IT capital. Our measure of labor, L, is in millions of hours.

We calculated outsourced logistics based on the I–O use tables and by following the method above. We measured outsourced logistics as the purchases of air transportation (NAICS 481), rail transportation (NAICS 482), water transportation (NAICS 483), truck transportation (NAICS 484), pipeline transportation (NAICS 486), and warehousing and storage (NAICS 493). Subtracting outsourced logistics from total intermediate inputs, we obtained nonlogistics intermediate inputs, X. We converted the nominal values of outsourced logistics and nonlogistics intermediate inputs to chained 2005 U.S. dollars by using the chain-type quantity indexes for gross output of the warehousing and transportation sector and for intermediate inputs, respectively.

We followed the same method as that used in data set I to obtain customers' IT investments. In particular, I–O tables show transactions among manufacturing industries and transactions between manufacturing and nonmanufacturing industries. To be consistent with data set I, we captured the transactions among manufacturing industries as weights for calculating customers' IT investments. In addition, to match the I–O tables with the MFP data, we combined codes 3361MV and 3364OT in I–O tables. Therefore, the final data set is a balanced panel of 18 manufacturing industries across nine years. Table A4 in the online appendix describes the 18 manufacturing industries in three-digit NAICS codes.

The summary statistics for both data sets I and II are provided in Table 3.

3.1.4. Econometric Adjustments. The years covered in our two data sets, 1987–1999 and 2000–2008, contain changes in political and economic activities, such as the e-commerce boom in the late 1990s, the e-commerce collapse and the 9/11 terrorist attacks after 2000, and the financial crisis in 2008. These changes took place along with the variations in fiscal, monetary, and trade policies. Consequently, to control for any economywide shocks that could affect all industries, we add year fixed effects. In addition, to better interpret the interaction terms and to reduce possible multicollinearity between the interaction effects and the main effects (Wooldridge 2009), we center the covariates, IT capital Z, log of logistics w, and customers' IT capital C, before constructing the interaction terms and without centering main terms in the estimation model.

Because both of our data sets are cross-sectional time series, we test for autocorrelation and heteroskedasticity (HE). First, we anticipate autocorrelation in error terms because the output of any industry is highly correlated with its output in the previous year under relatively smooth business cycles. Following the Wooldridge (2002) test for autocorrelation in panel data, we reject the null hypothesis of no first-order autocorrelation

Table 3 Summary Statistics

Variable	Obs.	Mean	Std. dev.	Min.	Max.
Data set I (1987–1999)					
Output (in millions of 1987 dollars)	1,105	30,294.40	46,044.20	557.62	738,130.80
Non-IT capital stock (in millions of 1987 dollars)	1,105	20,641.51	22,836.99	461.80	135,540.60
Labor (in millions of hours)	1,105	414.45	342.97	12.20	2,350.90
IT capital stock (in millions of 1987 dollars)	1,105	1,814.49	3,165.67	30.30	27,661.10
Total intermediate inputs (in millions of 1987 dollars)	1,105	16,970.93	20,999.34	313.18	202,082.50
Nonlogistics intermediate inputs (in millions of 1987 dollars)	1,105	16,112.12	20,043.91	307.17	193,899.60
Outsourced logistics (in millions of 1987 dollars)	1,105	858.81	1,115.23	4.48	8,211.68
Customers' IT investments (index)	1,105	2,969.07	2,444.52	69.16	19,508.81
Data set II (2000–2008)					
Output (in millions of 2005 dollars)	162	253,048.40	196,900.70	20,728	738,084
Non-IT capital stock (in millions of 2005 dollars)	162	139,626.80	95,180.63	22,269	336,823
Labor (in millions of hours)	162	1,644.82	989.78	239	4,227
IT capital stock (in millions of 2005 dollars)	162	14,693.33	16,815.21	919	62,336
Total intermediate inputs (in millions of 2005 dollars)	162	170,303.70	143,106.30	7,568.15	529,658.60
Nonlogistics intermediate inputs (in millions of 2005 dollars)	162	164,606.30	139,135.90	7,328.36	517,997.90
Outsourced logistics (in millions of 2005 dollars)	162	5,675.38	5,093.44	614.01	24,355.66
Customers' IT investments (index)	162	23,694.58	7,570.42	7,200.11	39,179.31

Notes. The NAICS is a six-digit system, and the SIC system is a four-digit system. Data set I is based on three-digit SIC codes, and data set II is based on three-digit NAICS codes. The three-digit NAICS level (subsector) corresponds roughly to the two-digit SIC level (major group). Data set II is at a higher aggregation level than data set I, so the number of observations in data set II is lower.

(AR1) at all reasonable levels of significance both in data set I ($F(1,84) = 73.60$ for the full sample, 117.40 for the sample from 1987 to 1993, and 33.42 for the sample from 1994 to 1999) and in data set II ($F(1,17) = 12.50$). In addition, the autocorrelation could differ in magnitude for different industries if the magnitudes of the responses to the changes in business cycles differ across industries, so the AR1 process could be panel-specific AR1 (PSAR1). We use the likelihood ratio test to check whether AR1 coefficients are common across the industries (Greene 2008). The null hypothesis that the regression with correction of AR1 is nested in the regression with the correction of PSAR1 is rejected at all levels of significance in data set I ($\chi^2(84) = 295.59$ for the full sample, $\chi^2(84) = 207.29$ for the sample from 1987 to 1993, and $\chi^2(84) = 224.77$ for the sample from 1994 to 1999), so we control for PSAR1 for data set I. In data set II, we fail to reject the null ($\chi^2(17) = 4.13$), so we adjust for AR1 in the estimations.

We also test for panel-level HE by using the likelihood ratio test (Greene 2008). We anticipate panel-level HE because the variances of the error terms for each industry are likely to fluctuate over time, and the variances of the error terms could differ across industries. The null hypotheses of no panel-level HE is rejected at all levels of significance in data set I ($\chi^2(84) = 1{,}624.82$ for the full sample, $\chi^2(84) = 572.89$ for the sample from 1987 to 1993, and $\chi^2(84) = 924.39$ for the sample from 1994 to 1999) and in data set II ($\chi^2(17) = 141.09$).

Consequently, after adding year fixed effects, we estimate our models by adjusting PSAR1 and panel-level HE for data set I, and AR1 and panel-level HE for data set II. We use feasible generalized least squares to generate our estimates (Wooldridge 2002).

3.2. Estimation Results

We estimate the simple CD production function, and the extended CD production function specified in (1) to compare our results with those from previous studies. Columns (1) and (6) of Table 4 report the estimation results for the simple CD for data set I and data set II, respectively. The estimation results for the extended CD are shown in Columns (2) and (7) of Table 4 for data set I and data set II, respectively. These results are similar across data sets and are consistent with those in previous studies.

Next, we estimate the model specified in (3) with corresponding econometric adjustments for data sets I and II. To capture whether the effects of IT investments on outsourced logistics change over time, we split data set I into the pre- and post-Internet eras. Commercialization of the Internet began in 1994 when business and media started to use the Internet (Zakon 2011). In April 1995, the NSFNET (National Science Foundation Network) backbone was decommissioned, which removed the last restriction on the use of the Internet to carry commercial traffic (Leiner et al. 1997). Since 1995, the Internet has grown dramatically. Therefore, we split our first data set at 1993, and define 1987–1993 as the pre-Internet era and 1994–1999 as the post-Internet era. To show whether the complementarity relationship between IT and outsourced logistics continues after 1999, we use data set II covering the later post-Internet era. Our estimation results for the three time periods are shown in Columns (4), (5), and (8) of Table 4, respectively.

3.2.1. The Effects of IT on Outsourced Logistics in the Pre-Internet Era. The estimated coefficient of the

Table 4 The Estimation Results for the Data Sets

	Data set I (1987–1999)					Data set II (2000–2008)		
			Main estimation					
Variable	The simple CD (1)	The extended CD (2)	Full sample 1987–1999 (3)	Pre-Internet 1987–1993 (4)	Post-Internet 1994–1999 (5)	The simple CD (6)	The extended CD (7)	Main estimation 2000–2008 (8)
Non-IT Capital	0.082*** (0.010)	0.037*** (0.010)	0.029*** (0.010)	0.062*** (0.009)	0.058*** (0.009)	0.196*** (0.044)	0.202** (0.083)	0.164*** (0.062)
Labor	0.237*** (0.008)	0.264*** (0.007)	0.272*** (0.007)	0.233*** (0.007)	0.264*** (0.009)	0.122*** (0.028)	0.209*** (0.041)	0.141*** (0.032)
IT Capital	0.080*** (0.006)	0.083*** (0.005)	0.073*** (0.005)	0.088*** (0.004)	0.085*** (0.006)	0.062** (0.0273)	0.042 (0.046)	0.061* (0.037)
Nonlogistics		0.539*** (0.009)	0.546*** (0.009)	0.581*** (0.007)	0.513*** (0.011)		0.521*** (0.026)	0.536*** (0.025)
Outsourced Logistics		0.104*** (0.006)	0.118*** (0.007)	0.052*** (0.005)	0.116*** (0.008)		0.068 (0.051)	0.107*** (0.038)
CustomerIT		0.025*** (0.005)	0.034*** (0.005)	0.012*** (0.004)	0.053*** (0.006)		0.011 (0.031)	0.082** (0.033)
OwnIT × *Outsourced_Logistics*			4.24e–06** (1.72e–06)	−8.13e–06*** (1.70e–06)	5.63e–06*** (1.79e–06)			3.88e–06*** (1.47e–06)
CUSIT × *Outsourced_Logistics*			6.19e–06*** (1.79e–06)	−8.57e–06*** (2.20e–06)	8.67e–06*** (2.10e–06)			2.35e–06** (1.10e–06)
Intermediate Inputs	0.639*** (0.010)					0.611*** (0.024)		
Constant	1.275*** (0.0518)	1.653*** (0.064)	1.526*** (0.073)	1.597*** (0.063)	1.355*** (0.082)	1.278*** (0.274)	1.138** (0.531)	0.697 (0.465)
Observations	1,105	1,105	1,105	595	510	162	162	162

Notes. *OwnIT* and *CUSIT* are an industry's IT investment and its customers' IT investments, respectively. *OwnIT* and *CUSIT* are in levels and other variables are in natural logs. We control for panel-level heteroskedasticity and panel-specific autocorrelation for data set I, and we control for panel-level heteroskedasticity and first-order autocorrelation for data set II. Details of the year fixed effects are suppressed. Standard errors are in parentheses following the estimated coefficients.
$^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

interaction term *OwnIT* × *Outsourced_Logistics*, μ, is negative and significant at the 1% level from 1987 to 1993 (Column (4) of Table 4). It suggests that an industry's own IT investment and outsourced logistics are not complements during the pre-Internet era, meaning that increasing IT investment reduces the marginal return of outsourced logistics. An example of such an investment is an information system that automates business activities; improves information timeliness, accuracy, and availability; and facilitates information sharing across functions within firms, leading to upgraded internal connectivity and integration. Thus, internal governance costs, such as information processing costs, monitoring costs, and opportunity costs due to poor information, etc., are reduced. Because of the reduction in internal governance costs, the efficiency of existing business processes are improved. In particular, in-house logistics become more efficient, and firms prefer the internal provision of logistics.

The estimated coefficient of the interaction term *CUSIT* × *Outsourced_Logistics*, ν, is negative and significant at the 1% level from 1987–1993 (Column (4) of Table 4). This suggests that customers' IT investments do not complement an industry's outsourced logistics, meaning that increasing customers' IT investments reduce the marginal return of an industry's outsourced logistics. For example, the IT investments in EDI from an industry's customers electronically send demand information to a given industry, which in turn uses the data to forecast, analyze, and plan for orders; to optimize its production plan and procurement plan; and to better utilize its transportation capabilities and manage inventory. Thus, the given industry can more efficiently manage its transportation and warehousing across a supply chain from procurement to distribution, and this works toward lowering the costs of conducting logistics in-house.

3.2.2. The Effects of IT on Outsourced Logistics in the Post-Internet Era. Columns (5) and (8) of Table 4 show the estimation results for data set I from 1994 to 1999 and for data set II from 2000 to 2008, respectively.

The estimated coefficient of the interaction term *OwnIT* × *Outsourced_Logistics*, μ, is positive and significant at the 1% level. This suggests that an industry's own IT investment and outsourced logistics are complements in the post-Internet era, which means that the greater the own IT investment, the higher the marginal return of outsourced logistics. For instance, an industry's IT investment in Internet-based IOSs substantially facilitates information sharing and coordination among a focal industry, its suppliers, and 3PL providers, reducing external transaction costs associated with logistics. Because transaction costs are reduced, the focal industry outsources more logistics to 3PL providers that typically conduct logistics activities more efficiently.

The estimated coefficient of the interaction term *CUSIT* × *Outsourced_Logistics*, ν, is positive and significant at the 1% level for the data set from 1994 to 1999 and at the 5% level for the data set from 2000 to 2008, respectively. This suggests that IT investments of a focal industry's customers and this focal industry's outsourced logistics are complements, meaning that an increase in customers' IT investments increases the marginal return of the focal industry's outsourced logistics. For example, an increase in customers' IT investments in Internet-based IOSs enables demand and inventory information sharing. Because of the Internet's global connectivity, open standards, and low communication costs, information can be transferred swiftly to suppliers and 3PL providers, enabling the focal industry and its supply chain partners to coordinate logistics at lower costs, leading to a greater demand for logistics outsourcing.

3.2.3. The Effects of IT on Output Through Outsourced Logistics. Based on our estimates of two interaction terms, we calculate the impact of an industry's own IT capital and the impact of customers' IT on the output elasticity of outsourced logistics. Table 5 shows that at the mean level of customers' IT and keeping other factors constant, a 1% increase in own IT on average is associated with 0.11% (for data set I) and 0.53% (for data set II) increases in the output elasticity of outsourced logistics in the post-Internet era. This suggests that at the mean level of customers' IT, keeping other variables constant, the higher the IT investment, the larger the effect of outsourced logistics on gross output.

Table 6 **The Impact of Own IT on the Output Elasticity of Outsourced Logistics—Examples**

I–O Codes (NAICS)	Industry	IT investment (in millions of 2005 dollars)	The output elasticity of outsourced logistics
315AL	Apparel and leather and allied products	1,109.778	0.054
311FT	Food and beverage and tobacco products	15,861.780	0.111
333	Machinery	33,761.220	0.181

To derive further economic intuition from our results, we provide examples of industries with different levels of IT investment based on data set II. Table 6 shows the IT investment and output elasticity of outsourced logistics for three industries: the apparel and leather industry (NAICS 315AL) has the lowest IT investment, the food industry (NAICS 311FT) has an average level of IT investment, and the machinery industry (NAICS 333) has a relatively higher level of IT investment. As seen, the higher the IT investment, the larger the output elasticity of outsourced logistics, and this suggests that, keeping other factors constant, IT increases the efficiency of outsourced logistics, leading to more logistics outsourcing.

The online appendix presents a plethora of robustness tests—including sector fixed effects and instrumental variable estimates—and a detailed discussion on alternative explanations we considered in interpreting the results.

Table 5 **The Impact of Own IT on the Output Elasticity of Outsourced Logistics**

	Data set I 1987–1993 (1)	Data set I 1994–1999 (2)	Data set II 2000–2008 (3)
The change in the output elasticity of outsourced logistics with respect to one more unit of own IT investment (μ in Equation (3))	−8.13E–06	5.63E–06	3.88E–06
The output elasticity of outsourced logistics at the mean level of own IT and customers' IT (b in Equation (3))	0.052	0.116	0.107
1% of own IT on average (in millions of dollars) (η)	13.992	22.989	146.933
The change in the output elasticity of outsourced logistics, given 1% increase of own IT on average ($\xi = \mu \cdot \eta / b \cdot 100$)	−0.22	0.11	0.53
Interpretation of ξ	1% increase in own IT on average is associated with a 0.22% decrease in the output elasticity of outsourced logistics	1% increase in own IT on average is associated with a 0.11% increase in the output elasticity of outsourced logistics	1% increase in own IT on average is associated with a 0.53% increase in the output elasticity of outsourced logistics

Note. We keep customers' IT at the mean level and other variables constant when interpreting the relationship.

4. Conclusion

4.1. Contributions

Our study makes three important contributions. First, we provide systematic empirical evidence that IT in its most interconnected instance—the Internet—enables a move to the market. Previous work theoretically argued that IT was associated with the shift from hierarchies to markets by reducing transaction costs, and other studies only provided indirect evidence in support of those arguments. In the context of logistics, we show that the increasing use of IT is associated with greater logistics outsourcing in the post-Internet era. In particular, our study identifies a change in the relationship between IT and outsourced logistics. In the pre-Internet era, an industry's own IT investment and outsourced logistics were not complements, and they became complements after the Internet was widely used. By focusing on logistics outsourcing, we can rule out the compounding factors that arise from offshoring in more general outsourcing.

Second, we show the impact of IT on output through logistics outsourcing. Previous studies about IT productivity converged to the contribution of IT to output. Our study shows the moderating role of IT in the contribution of logistics outsourcing to output. In particular, we show that an increase in IT is associated with an increase in the output elasticity of outsourced logistics in the post-Internet era. It suggests that after the Internet, IT contributed to greater output by increasing the efficiency of outsourced logistics. We also find similar impacts of customers' IT investments on outsourced logistics.

Third, our study reconciles the theoretical arguments about the effects of IT on reducing coordination costs within and between firms. Previous studies argued that IT could reduce internal governance costs and external transaction costs, and IT would have different impacts on organizational change depending on which effect predominated. However, it was not known which effect dominated a priori. Our study suggests that, at least in the context of logistics, the effect of IT on reducing internal governance costs dominates in the pre-Internet era, and the effect of IT on reducing external transaction costs dominates in the post-Internet era.

4.2. Implications

One implication is that activities with the potential to be outsourced and that use the Internet for coordination are more likely to be outsourced in the post-Internet era. Our findings are in the context of logistics, where coordination is key and Internet-based IOSs have been used to improve coordination between supply chain members. A current revolution, mobile computing, also affects coordination costs. It remains to be seen whether mobile computing has greater effects on internal or external coordination costs.

The other implication is that the popularity of outsourcing has a technological and theoretical basis. The Internet, with its universal connectivity and open standards, has enabled the integration of IT infrastructure between firms, facilitating information sharing and coordination, which in turn improves visibility and transparency of supply chains. In addition, the Internet enables online markets where firms can connect with potential providers of goods and services at low cost, resulting in reduced transaction costs for outsourcing.

4.3. Limitations and Qualifications

Our focus is on the impact of IT on outsourced logistics downstream in the supply chain. As such, this study examines the impact of IT, including a focal industry's own IT and customers' IT, on the focal industry's outsourced logistics in the pre- and post-Internet eras. Logistics outsourcing needs coordination among suppliers, 3PL providers, and customers. Thus, the IT capabilities of upstream supply chain members and 3PL providers also play an important role in improving coordination.

Suppliers' IT investments not only improve the coordination of logistics activities but also help increase downstream industry output through improved quality of goods and services, which are used as intermediate inputs for downstream industries (Cheng and Nault 2007). With summary data on IT capital, it is not possible to differentiate the quality and coordination effects from suppliers' IT. However, our study still sheds light on the impact of suppliers' IT on a focal industry's logistics outsourcing based on our unique data. In the I–O accounts, some supplying industries are also customer industries, so we can infer the impact of suppliers' IT from our results about the effects of customers' IT. Moreover, we avoid a double-counting issue by virtue of not estimating the impact of suppliers' IT in our model.

For similar reasons, our industry-level data do not enable us to directly estimate the impact of IT on logistics processes to get insight about which specific transaction costs are reduced by IT after the Internet. Consequently, we can only study the summary effects of make or buy decisions and infer that relative reductions in transaction costs have favored external provision. However, our industry-level data allow us to investigate the economywide impact of IT on outsourced logistics, which increases the generalizability of our study.

We also note that in the absence of a direct measure for Internet usage, we are limited to exploiting the complementarity in a CD production function to derive our insights. Although we can establish time precedence between pre- and post-Internet eras using our time series data sets and we have a powerful theoretical lens using transaction costs theory, there remains a chance of alternative explanations whose timing might have coincided with the commercialization of the Internet. Future work with finer measures of Internet usage may confirm our results.

Supplemental Material

Supplemental material to this paper is available at http://dx.doi.org/10.1287/isre.2016.0625.

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