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Information Technology and Boundary of the Firm: Evidence from Plant-Level Data

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PRELIMINARY

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Abstract

We study the relationship between different margins of information technology (IT) use and vertical integration using plant-level data from the U.S. Census of Manufactures. Focusing on the short-run decision of whether to allocate production output to downstream plants within the same firm or to external customers, we find that customer-focused IT, by itself, has surprisingly little impact. In contrast, adoption of upstream supplier-focused IT at a plant is associated with a significant decline in downstream vertical integration. However, the greatest decline in within-firm transfers occurs when supplier- and customer-facing IT are adopted together, suggesting the presence of complementarities in supply chain technology adoption. These results are consistent with the view that, by reducing external coordination costs, IT investments promote a decline in plant-level vertical integration, but only when those investments are made jointly with both suppliers and customers. Our results provide less support for the view that IT investments led to a decline in vertical integration by lowering transactions risks.

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1. Introduction

It has long been believed that information technology (IT) has the potential to shift the boundaries of where production takes place.[1] Specifically, networked IT investments can reduce the costs of monitoring the behavior of internal and external partners, thereby improving incentives and reducing the risk of opportunistic behavior. Networked IT investments can also reduce the costs of coordinating economic activity within and between firms. As has been noted elsewhere, the implications of networked IT investments for the boundary of the firm will therefore depend upon how they improve internal and external incentives and internal and external coordination costs (e.g., Malone, Yates, and Benjamin 1987; Gurbaxani and Whang 1991; Baker and Hubbard 2003).

One hypothesis is that, because generic IT capital spending has been associated with a greater decline in external costs of monitoring than internal ones (e.g., Malone, Yates, and Benjamin 1987; Gurbaxani and Whang 1990), increases in general IT capital spending should be associated with smaller (less integrated) firms. Large-scale multi-industry empirical studies (e.g., Brynjolsson, Malone, Gurbaxani, and Kambil 1994; Dewan, Michael, and Min 1998; Hitt 1999; Ray, Wu, and Konana 2010) have generally supported this hypothesis.[2] These studies measure the extent of vertical integration using industry averages from the input-output tables; the location of the firm boundary is therefore measured either at the industry level or using the industry composition of multi-industry firms. While work has also explored the causes of shared ownership of production chains using plant-level data (Hortacsu and Syverson 2009), the implications of IT investment in these micro-level studies remains unexplored.

In particular, despite the important advances made in this area, there has been, to our knowledge, no empirical work that has examined how IT investments influence integration in supply chain relationships. This is a surprising gap in understanding. A long line of work has argued theoretically (e.g.,

[1] For examples of theoretical work that have articulated variants of this hypothesis, see Malone, Yates, and Benjamin (1987), Gurbaxani and Whang (1991), Clemons and Row (1992), and Brynjolfsson (1994).

[2] See, for example, Brynjolsson, Malone, Gurbaxani, and Kambil (1994), Dewan, Michael, and Min (1998), Hitt (1999), Ray, Wu, and Konana (2010).

Aviv 2007; Cachon and Fisher 2000; Chen and Lee 2009, 2011; Lee, Padmanabhan, and Whang 1997) and empirically (Bray and Mendelson Forthcoming; Cachon et al. 2007) that investments in information technology will increase the efficiency of supply relationships between heterogeneous partners. This should increase the benefits of arm's length transactions relative to vertical integration, promoting less integrated production in equilibirum. While a variety of work has asserted this hypothesis, it has not been tested directly to our knowledge.

We attempt to make a first step towards addressing this gap in understanding through an empirical investigation of how IT influences vertical integration in supply chain relationships. Taking existing value chain relationships as given, how does IT use shift ownership of those relationships on the margin? We draw upon prior literature to generate a set of predictions about how different margins of IT use will lower the costs of coordinating economic activity with downstream customers through improvements to resource allocation decisions and incentives.[3] We emphasize in particular the role of IT in improving resource allocation decisions by providing adopters of the technology with more transparent and accurate flow-through of information about downstream demand signals and upstream supply information.

To examine the empirical salience of each of these predictions, we focus on the implications of Internet-enabled IT investments that lower the costs of coordinating economic activity with external suppliers and with external customers. We label these margins *supplier-focused IT* and *customer-focused* IT. We assemble these data using a 1999 survey addendum to the U.S. Census Annual Survey of Manufacturers called the Computer Network Use Supplement (CNUS). These data are unusual for the wealth of networking technologies and their uses addressed by the survey as well as its attempt to document with whom networking technologies are used to share information, a requirement for our research design.

We combine our IT measures with information on the production activities of establishments

[3] See, for example, Baker and Hubbard (2003, 2004), Forman, Goldfarb, and Greenstein (2005), Forman and Gron (2011), Hubbard (2000).

from the 1992 Census of Manufacturers (CMF) and 1999 Annual Survey of Manufacturing (ASM). Our dependent variable is a measure of the value of plant shipments that is transferred to other plants within the same firm, normalized by the total plant shipment value; we label this margin of activity *percentage of within-firm transfers.* The advantage of this measure is that it directly captures the extent of output that is used for downstream production within the same firm, providing us with a plant-level measure of the extent to which commodity flows are vertically integrated.

Our econometric approach examines the impact of Internet-enabled coordinating technologies on the extent of downstream vertical integration. Using differences-in-differences estimation, we compare the percentage of within-firm transfers before Internet technology diffused (i.e., in 1992) to the intensity of transfers after diffusion (i.e., in 1999) for adopters and non-adopters of the technology applications. Our sample covers a period over which Internet technology diffused but which is short enough to preclude significant long-run organizational changes such as building new plants. Thus, our results should be viewed as identifying how a short-run change in coordination costs affect the intensive margin of downstream vertical integration.

Our first set of analyses assumes that adoption of Internet-enabled collaborative IT is exogenous with respect to the intensity of within-firm transfers. Perhaps surprisingly, our results show that customer-focused IT that lowers the costs of coordinating downstream economic activity has no significant impact on the intensity of within-firm transfers. However, we find that IT that lowers coordination costs with *suppliers* is associated with a 3.3 percentage point decline in the percentage of within-firm transfers. Relative to a mean percentage of 17.9%, this represents an economically as well as statistically significant impact. All of these results are robust to changes to the definitions of our margins of IT investment, changes to our sample, as well as changes to the distributional assumptions of our econometric model. We find they are also robust to including a measure of IT investment that reduces within-firm coordination costs.

We next address the potentially problematic assumption that the IT adoption of interest is exogenous. One particular concern is that there may exist time-varying omitted variables that are

correlated both with IT adoption and the extent of within-firm transfers. For example, firm quality could be correlated with both adoption and within-firm transfers (WFT). There might also exist reverse causality: changes in a firm's desire to transfer goods and services within or outside the firm may give rise to investment in Internet-based IT applications. To address these concerns, we examine whether our results are robust to the use of instrumental variables. Two of our instruments capture local variance in telecommunications costs that will influence the costs of Internet-enabled IT adoption: the year of state-level price cap regulation and an estimate of local telecommunications costs from the Federal Communication Commission's Hybrid Cost Proxy Model. Our third instrument captures location-level variance in the propensity to adopt IT, as proxied by the percentage of plants in other locations in the same 3-digit NAICS industry adopting enterprise resource planning (ERP) technology. Our results are robust to the use of these instruments.

Last, we examine the possibility that supplier- and customer-focused IT are complementary. We argue that declines in the costs of coordinating economic activity with downstream customers arising from customer-focused IT will be more impactful if they are accompanied by adoption of downstream customer-focused IT –and vice versa. The adoption of this combination of applications will improve customers' resource allocation decisions by improving their ability to observe upstream production and inventory decisions. We test this hypothesis by interacting our measure of customer-focused IT with supplier-focused IT. Our results are consistent with the presence of complementarities.

Our research is consistent with the view that IT investments are associated with a decline in the extent of vertical integration in supply chain relationships. Moreover, by demonstrating which margins of IT have influenced vertical integration, our results shed light on the specific mechanisms though which IT may lead to less integration in production chains. In particular, while our results are consistent with the view that IT has decreased the size of Coasian transaction costs such as search, transportation, inventory holding and communication costs,[4] we find little role for IT in reducing the costs of opportunism and

[4] These costs have also been labeled operational coordination costs (Gurbaxani and Whang 1991) and simply coordination costs (e.g., Clemons and Row 1992).

hold-up, at least for our margin of investment and over this time period.

2. Theoretical Motivation

We examine the factors influencing a firm's decision to retain the output of one of its establishments for use in the firm's internal value chain or to sell the output outside of the firm boundary. We label this problem the *within-firm sales* decision. Given some existing short-run production capacity at the focal plant, the parent firm has the choice to allocate all or some fraction of this capacity to internal downstream customers. At one extreme is complete forward integration, with 100% of the output in question allocated to internal use. Outside of this boundary case, remaining productive capacity at the plant may be used to produce output for sale on the external market.

How much of that capacity is allocated to external sales will depend upon a range of internal and external supply and demand conditions. We focus on the factors that are most likely to be influenced by the introduction of Internet-enabled information technology (IT) applications. We follow prior research by focusing primarily on factors external to the firm.

An important external factor is the productivity of the establishment in question relative to others in the same industry. While the firm may choose to retain a relatively unproductive establishment to conserve on transaction costs or maintain a stable source of supply, such an unproductive establishment may find it challenging to compete in an external market if its production costs are higher than those of competitors.[5] Specifically, if the costs of production at the plant are higher than other plants within the same industry, this will decrease the propensity to sell externally.

The decision of where to allocate sales will also be influenced by the non-production costs of coordinating economic activity with firms in the external market. These costs can include the costs of opportunistic behavior as well as the costs of coordinating resource allocation decisions between firms. We explore the source of each of these costs below.[6]

[5] However, see Hortacsu and Syverson (2009) for evidence that vertically integrated firms may be more productive if they have better management.

[6] Of course, there is a long literature on the risks of opportunism in cross-firm transactions, which we will not attempt to summarize here. For summaries see, for example, Williamson (1985) or Hart (1995). For a specific

2.1 Incentive Problems in Supply Chain Relationships

Supply chain relationships between independently owned firms are subject to a range of potential incentive problems that may give rise to opportunistic behavior by customers and suppliers. These risks have been documented extensively elsewhere (e.g., Clemons and Row 1992; Lee, Padmanabhan, and Whang 1997a; Lee and Whang 2000), so we describe them only briefly here. One potential risk is downstream customers misstating delivery performance, claiming late or incomplete delivery when goods have in fact been received on-time and in full.[7] Another common problem is order rationing by suppliers in times of shortages that may lead downstream partners to overstate their orders and forecasts (e.g., Lee, Padmanabhan, and Whang 1997a). The risks of opportunistic behavior are not confined to customers, however. In the absence of real-time information, suppliers may misstate order status to customers, hoping to make up any unreported delays through expedited production or shipping.

2.2 Coordination Problems in Supply Chain Relationships

Another factor influencing the extent of within-firm sales will be the cost of coordinating economic activity within and between firms.[8] The implications of imperfect information flows for coordination costs and resource allocation decisions have been explored in the literature on supply chain management.[9] In particular, one common problem arises when upstream suppliers observe only orders and not final demand and when demand signals are correlated. In this case, when there is a demand shock and downstream firms issue large orders based on their updated forecasts, there is a distortion of demand information that increases the farther one moves up the supply chain. The demand information received by the downstream firm is transmitted in an exaggerated firm to the upstream supplier. This leads to the well-known "bullwhip effect"—the variance in orders is strictly larger than that of sales and distortion in

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discussion about the role of these costs in supply chain relationships and how they can be influenced by IT investments see, for example, Clemons and Row (1992).

[7] For one example, see Langer et al. (2007)

[8] As Hubbard (2000) notes, analysis of the value of information in these contexts arises from decision theory (e.g., Raiffa and Schlaifer (1961), Raiffa (1968), and DeGroot (1970)). However, issues surrounding the costs of information in supply chains has played a prominent role in the operations management literature, perhaps most prominently in work on the bullwhip effect (e.g., Lee, Padmanabhan, and Whang 1997a, 1997b).

[9] Prior work on the implications of IT for firm boundaries have also explored these issues. For further details, see Gurbaxani and Whang (1991), Clemons and Row (1992), and Clemons, Reddi, and Row (1993).

demand signals increases the farther up one moves through the supply chain. This inefficiency typically hurts all participants in the supply chain in the form of excess raw materials inventory, unplanned purchases of supplies, inefficient asset utilization and overtime, excess warehousing expenses, and premium shipping costs (Lee and Whang 2000).

High coordination costs have other implications. In particular, the costs of transacting with external partners often lead to order batching that likewise contributes to increases in order variability (Lee, Padmanabhan, and Whang 1997a). Similarly, high-low pricing will lead to order clustering as customers attempt to take advantage of price discounts. These increases in order variability will contribute to higher inventory and order-fulfillment costs (Aviv 2007; Chen and Lee 2009, 2011).

2.3 The Implications of IT

In this previous section we discussed how incentive and coordination problems increased the costs associated with transacting in arm's length supply chain relationships. In this section, we discuss the potential for IT to reduce each of these costs, thereby potentially influencing the net benefits of such arm's length relationships relative to vertical integration and increasing the propensity to sell outside of the firm.

Customer-focused IT. We label the first type of IT we study as customer-focused IT. As has been highlighted above and elsewhere in the literature, customer-focused IT has the potential to reduce both the costs of coordinating operational activity among firms and the risks of opportunistic behavior. We detail each of these mechanisms briefly below.

Customer-focused IT can enable the sharing of information to customers such as design specifications, product descriptions or catalogs, order status, production schedules, and inventory data. It can also facilitate transactions with customers by facilitating ordering and payment by customers. This heterogeneity in applications and uses means that investment in customer IT can give rise to a variety of different implications for the costs of transacting in supply chain relationships. Below we discuss how we measure the effects of customer IT given this heterogeneity in use; here we focus upon the implications of

a generic decline in the costs of information flows that are enabled by IT investments.

Adoption of this kind of IT can reduce the costs of coordinating economic activity between firms. For example, customer-focused IT can reduce customers' search costs of identifying a trading partner. Customer-focused IT investments can also reduce many coordination costs in the supply chain that engender increases in order variability. For example, if downstream customers share demand data with manufacturers, the latter can better forecast demand and make better production plans. Lee et al. (2000) have quantified the value of this information-sharing in an analytical model of a two-level supply chain, showing that information-sharing can provide significant inventory reduction and cost savings to a manufacturer. By reducing the costs of transacting with supply chain partners, customer-focused IT will also decrease incentives for order batching. The value of such declines in order batching have been quantified by Cachon and Fisher (2000), who show that cutting batch sizes in half can reduce supply chain costs by over 20%.

By facilitating monitoring of the focal establishment's operations, customer-focused IT also has the potential to reduce the risks of opportunism and hold-up. For example, by sharing information such as order status, production schedules, and inventory data with customers, the latter can more easily monitor the focal establishment's adherence to contracted production schedules. Further, the risks that customers will overstate their orders will be less if suppliers can observe customer demand and inventory. Last, electronic monitoring of the supply chain can verify delivery performance, reducing the risks that customers may claim late or incomplete delivery of goods that have been received on-time and in full. [10]

In short, the discussion above suggests that, if anything, adoption of customer IT will decrease the percentage of production allocated to within-firm sales.

Supplier-focused IT. The other margin of IT investment that we investigate in-depth is supplier-

[10] We note that customer IT can potentially reduce the costs of producing output in several ways. For example, by automating customers' ordering and payment customer IT will reduce the costs of the sales order process. Further, because customers will have better information about the focal establishment's production and inventory, they are less likely to make large orders for buffer stocks (e.g., Lee and Whang 2000) which will lower the focal establishment's inventory holding costs. However, we classify these benefits as reflecting the value of lower external coordination costs. This reflects our classification of costs. We classify production costs as those that influence production regardless of the final customer for the product, internal or external.

focused IT. Supplier-focused IT includes the sharing of information such as design specifications, order status, production schedules, and inventory data with suppliers. It can include automated ordering from and payment to vendors, vendor-managed inventory, and the use of electronic marketplaces. Supplier-focused IT has the potential to reduce the costs of transacting with external suppliers. However, as noted earlier, we do not study the implications of IT investment for the make-or-buy decision due to data constraints. Rather, we focus on the indirect effects that supplier IT will have on the intensity of external downstream sales.

By sharing information with suppliers such as order status, production schedules, inventory data, and logistics, supplier IT has the potential to reduce not only the coordination costs of transacting with external suppliers but also those of transacting with external customers. The information-sharing enabled by supplier-focused IT will be particularly important in reducing the costs associated with inaccurate demand signals. As noted above, when downstream customers share only order information with suppliers, the distortion in demand signals becomes greater the farther one moves up the supply chain (Lee, Padmanabhan, and Whang 1997). Lack of information-sharing between the focal establishment and upstream suppliers hurts all participants in the supply chain in the form of excess raw material inventory, unplanned purchases of supplies, inefficient utilization and overtimes, excess warehousing expenses, and premium shipping costs (Lee and Whang 2000). Sharing performance metrics such as product quality data, lead times, and service performance will therefore help not only the focal establishment but also its downstream customers (Lee and Whang 2000). For example, inaccurate demand signals from the focal establishment to its supplier will lead the latter to hold excess inventories, increasing its costs and lower its service levels in ways that will affect downstream firms.

Thus, improved information-sharing between the focal establishment and upstream suppliers can also improve service levels and costs between for the focal establishment's downstream customers. The value of upstream information-sharing to downstream customers will be even greater when used in conjunction with customer-focused IT. In this latter case, the flow-through of information will be greatest, benefiting all supply chain participants. Further, downstream customers will be able to benefit more

directly from information-sharing with the focal establishment's upstream suppliers. In other words, the improvement in demand signal-processing that arises from better flow-through of information will be greatest when both customers and suppliers are linked electronically.

Thus, like customer-focused IT, supplier-focused IT has the potential to reduce the coordination costs between the focal establishment and downstream customers. Because of these efficiencies, we expect that adoption of supplier-focused IT will also be associated with an increase in external sales relative to internal sales. However, while supplier-focused IT will reduce the coordination costs between the focal establishment and downstream customers, there is no comparable effect on **incentive** costs of transacting downstream. In other words, while supplier-focused IT will decrease the incentive costs of transactions between the focal establishment and ***upstream*** suppliers—such as those arising from shortage gaming on the part of the focal establishment—there is no mechanism through which this decrease in incentive-based frictions will influence the costs of ***downstream*** external sales relative to downstream internal sales. That is, we do not expect that ex ante improvements to incentives between the focal establishment and upstream supplier arising from supplier IT will influence the downstream within-firm sales decision.

3 Empirical Approach

We argue above that adoption of customer-focused IT and supplier-focused IT ought to be associated with an increase in the extent of external sales, all else equal. To examine whether the empirical evidence is consistent with this hypothesis, we use fixed effects panel data models to study whether adoption of IT is associated with a decline in within-firm transfers. In short, we use a difference-in-difference identification strategy, comparing the percentage of within-firm transfers prior to adoption of customer- and supplier-focused IT to the percentage after adoption. This approach allows us to remove time-invariant features that may be correlated both with IT adoption and within-firm transfers. We estimate separate regression equations for the margins of IT investment we examine. Thus, for customer-focused IT, we estimate:

$$WFT_{it} = \alpha X_{it} + \beta Customer - IT_{it} + \mu_{it} + \tau_t + \varepsilon_{it} \quad (1)$$

Here WFT_{it} is the percentage of total shipments that are transferred internally within the firm, a measure of the extent of vertical integration. $Customer - IT_{it}$ measures whether the establishment has adopted Internet-enabled customer-focused IT by time *t.* Internet technology had not diffused among firms prior to 1995 except in very rare cases, so the value of this variable will be equal to zero prior to this date. The variable X_{it} includes a constant term and a set of time-varying establishment-level controls for factors that may influence the propensity of an establishment to sell outside the firm. We estimate our model using two periods of data, 1992 and 1999. We expect that adoption of customer-facing IT will be associated with a decline in the percentage of within-firm transfers, i.e. $\beta < 0$. We estimate similar regressions using supplier-focused IT as the key independent variable. In other words, we estimate

$$WFT_{it} = \alpha X_{it} + \beta Supplier - IT_{it} + \mu_{it} + \tau_t + \varepsilon_{it} \quad (2)$$

There are several things to note about our estimating equation. First, our estimation approach is equivalent to a two-period difference-in-difference model. We estimate the above equation using robust, cluster standard errors so the approach above will give identical results to a cross-sectional two-period difference regression. Second, as noted above our differencing approach will remove time-invariant cross-sectional differences across establishments that may influence the propensity to engage in inter-firm sales due to supply chain differences and differences in transaction costs across industries.[11]

Third, the regression equation above is a linear model although our dependent variable is a percentage and so bounded between 0 and 1. Thus, our estimating approach shares similar shortcomings to that of the linear probability model: namely, our model can predict values outside of the 0/1 range and the errors in the model will be heteroskedastic. We choose this approach because it facilitates the use of establishment-level fixed effects and a more straightforward interpretation of the implied marginal effects from our model.[12]

[11] For a discussion of how product characteristics can influence transactions costs and optimal supply chain structure, see Fisher (1997). For empirical tests of this hypothesis, see Randall and Ulrich (2001) and Randall, Morgan, and Morton (2003).

[12] An alternative approach would be to model the log-odds ratio as a linear function. However, this function is not defined for values of 0 and 1. While adjustments are possible using the Berkson's minimum chi-square method (detailed in Maddala (1983)), this method is unattractive given that our data have significant mass points at

As a robustness check, we employ the fractional probit approach detailed in Papke and Wooldridge (1996, 2008). This model is estimated using the generalized estimating equations (GEE) approach (Zeger et al. 1988). To control for fixed effects, we follow Papke and Wooldridge (2008) in employing the device used by Mundlak (1978) and Chamberlain (1980) of directly modeling the conditional distribution of the unobserved effects as a linear combination of the means of the independent variables.

Fourth, the regression above assumes that unobserved factors can be decomposed into an additively separable time-invariant component and a time-varying component that is constant across establishments (Athey and Stern 2002). This assumption will be violated if, for example, there exists reverse causality: for example, if changes in the intensity of within-firm transfers cause IT adoption. Prior work has identified a relationship between the extent of vertical integration and investment spending in information technology (e.g., Dewan, Michael, and Min 1996; Hitt 1999). We have chosen not to examine this relationship directly because of the nature of our investigation. Specifically, while prior work has examined the equilibrium relationship between IT and vertical integration, our focus is to study the short-run change in the extent of vertical integration that arises from the adoption of new IT. More broadly, our results may be influenced not only by reverse causality but also other unobserved factors that may be correlated both with IT investment and the extent of vertical integration.

We address these concerns by examining whether our results are robust to the use of instrumental variables. Two of our instruments proxy for variance in the costs to adoption across locations. One instrument we employ is the year of price cap regulation in the state where the establishment is located. The second is an estimate for the cost of delivering telecommunications services to a local area using the FCC's hybrid cost proxy model in January 2000 (Prieger 2003). Further details on these instruments are included below. Our third instrument proxies for other local factors that will influence the propensity to invest in IT: we compute the percentage of establishments in the same location but in other three-digit NAICS industry classifications adopting enterprise resource planning (ERP) technology.

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both 0 and 1. For further details, see Papke and Wooldridge (1996).

4 Data

We use data from a variety of data sources to examine how IT adoption influences the intensity of inter-firm sales. In particular, we match data from the 1999 Computer Network Use (CNUS) supplement to data from the 1999 Annual Survey of Manufacturers and the 1992 Census of Manufacturers. We describe each of these data sources below.

IT data. The dependent variables capturing the uses of new internet technology by firms come from the Computer Network Use Supplement (CNUS) included in the US Census Bureau's 1999 Annual Survey of Manufacturers. The approximately 35,000 plants in the sample accounted for more than 50% of manufacturing employment and output in the US at the time. They belonged to more than 20,000 firms in 86 different manufacturing industries, providing data across a wide range of market contexts.

The CNUS contains detailed information on establishment-level adoption of a variety of networked technologies. We group the responses into two categories that we label *customer-focused IT* and *supplier-focused IT.* These margins of IT investment correspond to the two that were discussed in section 2, and identify changes in coordination costs between the establishment and its external customers and between the establishment and its upstream suppliers. To define these variables we proceed in two steps. First, we identify questions in the CNUS survey that specifically ask about sharing information over computer networks with external customers and external suppliers, and identify establishments involved in each of these practices.[13] [14] Once we identify establishments that are engaged in information-sharing with each of the groups, we add the condition that the information-sharing must be conducted

[13] To identify customer-focused IT, question 6 on the CNUS survey asks if the establishment shares any of the following with external customers, external suppliers, or other company units: design specifications; product descriptions or catalog; demand projections; order status; production schedules; inventory data; or logistics and transportation. Further question 7(b) asks if the establishment has currently computer networked any of the following business processes: access to your products or catalog; ordering by your customers; payment by your customers; management of your customer's inventory; or customer support. We identify establishments as practicing customer-focused IT if it answers yes to any of these questions.

[14] To identify supplier-focused IT, we again use the items in question 6 that correspond to information sharing with suppliers. We augment this with responses to question 7(a) that asks if the establishment has computer networked any of the following business processes: access to vendor products or catalogs; ordering from vendors; payment to vendors; vendor management of your inventory; online bidding; or using electronic marketplaces linking specialized business buyers and sellers. We identify establishments as practicing supplier-focused IT if it answers yes to any of these questions.

using internet technology. For example, for an establishment in our sample to be included as adopting customer-focused IT, it must both be involved in digitized information-sharing with customers and be using internet technology. We add the latter condition because older networked technologies for cross-establishment and cross-firm interaction like EDI have significant limitations such as multiple industry-specific standards, may be batch-oriented, and have severe limitations for information-sharing (Lee and Whang 2000). However, our results are robust to relaxing this condition.

Within-firm transfers. The main dependent variable is the percentage of total shipments that are transferred internally within the firm. This variable is equal to the dollar value of within-firm transfers divided by the dollar value of total shipments. These variables are from the 1992 Census of Manufacturers (CMF) and the 1999 Annual Survey of Manufacturers (ASM). Due to the nature of our study, we place a number of restrictions on our estimation sample. This is to reduce the likelihood that our results would be biased by the inclusion of establishments that would not, under any circumstances, transfer output to other units within the same firm. First, we remove all establishments from single-establishment firms. Second, we remove establishments that are the most downstream in the production chain within that firm: specifically, we remove establishments that are in the largest four-digit NAICS industry, under the assumption that value is progressively added as production moves down the value chain. Third, following Hortacsu and Syverson (2009) we include only establishments that produce products that are used downstream within the firm as part of a substantial link in the vertical production chain. We follow Hortacsu and Syverson in defining these establishments: specifically, a substantial vertical link exists between an industry A and an industry B when industry A produces a commodity which industry B buys at least five percent of for its intermediate materials, according to the BEA's 2002 Benchmark Input-Output tables. Our results are robust to excluding this condition. Last, we exclude establishments for which the value of our dependent variable was either 0 or above the 95th percentile for multiple years prior to our estimation sample. We do this to account for the possibility of production technologies that are resistant to any sort of within-firm transfer (e.g. glass production) as well as captive plants whose output allocation may be determined for reasons unrelated to transaction costs (e.g.

restricting outside access to sensitive intellectual property). It turns out that our results are robust to relaxing these conditions as well.

We include several controls using the CMF and ASM data for our analyses. To control for how differences in inventory levels may influence the propensity to sell outside the firm– in particular, the possibility that firms may increase external sales in order to dispose of excess inventory, we include a control for the log of the dollar value of the current stock of inventories. To control for the skill mix of workers in the firm, we include a control for the ratio of production to nonproduction workers. Further, as noted above, more productive plants are likely to be more successful in selling externally. To control for variation in a plant's external market opportunities as a result of varying productivity, we include a measure of total factor productivity at the establishment computed following Cooper et al (1999).[15]

Table 1a provides some descriptive statistics for our estimation sample. The average percentage of shipments that are transferred internally is approximately 17.9%. Table 1b shows the average percentage of within-firm transfers across three-digit NAICS in our sample. The table demonstrates that there is significant variance in the intensity of WFT across industries. Excluding miscellaneous manufacturing (NAICS 339), average industry percentage WFT ranges from 5.9% in food manufacturing to 45.2% in textile mills. We will attempt to control for this variance using establishment-level fixed effects in our estimation.

Table 1a displays the remainder of the descriptive statistics. 21.6% of the establishments have supplier-focused IT in our sample, while 17.9% have customer-focused IT and 39.5% have internally-focused IT.

5 Results

We first examine the relationship between the two margins of IT adoption we study and the percentage of interplant transfers. We show that these results are robust to a variety of changes in sample, changes to the IT variables, and estimation approach. We next combine customer-focused IT, supplier-

[15] This is essentially the residual of a three-factor log-linear production function controlling for capital, labor, and material inputs, where capital stocks are accounted for following Cooper, Haltiwanger, and Powell (1999).

focused IT, and another internal margin of IT investment (which we label internally-focused IT) together into the same regression to explore which is most salient in explaining within-firm transfers. Next we explore the robustness of our results to the use of instrumental variables. Last we explore whether there exist complementarities between supplier-focused IT and customer-focused IT.

5.1 Baseline Results

Table 2a reports a difference-in-difference analysis of the percentage of within-firm transfers between 1992 and 1999 and according to the adoption of customer-focused IT. The results show that there is no significant difference in the percentage of WFT between adopters and non-adopters of customer-focused IT. In contrast, Table 2b suggests a statistically and economically significant increase in the percentage of within-firm transfers occurred for establishments adopting supplier-focused IT. Establishments that adopted supplier-focused IT experienced an increase in percent WFT over this period that was 3.2 percentage points higher than establishments who did not adopt supplier-focused IT (this difference is significant at the 1% level). This increase is economically significant when compared to an average level of percentage WFT of 17.4% for adopters at the beginning of the sample period. Table 2c shows that there is no significant difference in the percentage of WFT between adopters and non-adopters of customer-focused IT and internally-focused IT over the sample period.

In table 3 we use the regression in equation (1) to examine the implications of customer-focused IT for the percentage of interplant transfers. Somewhat surprisingly, while the coefficients for customer-focused IT are negative they are not statistically significant in any of the specifications. We explore some potential reasons for this result below.

In table 4 we use the regression model in equation (2) to examine the implications of supplier-focused IT for the percentage of within-firm transfers. Column 1 shows the correlation between supplier-focused IT and the percentage of within-firm transfers. Column 2 shows what we view as our baseline specification: it includes time-varying establishment controls. The coefficient on supplier-focused IT is -0.032; in other words, if an establishment adopts supplier-focused IT this translates into a 3.2 percentage point decline in the percentage of within-firm transfers (or, equivalently a 3.2 percentage point increase in

inter-firm transfers). Recall that across the entire sample the average percentage of within-firm transfers is approximately 17.9%, so this is economically a very significant impact. The rest of the columns show that our results are robust to a variety of changes in the sample and construction of key dependent and independent variables. Column 3 shows that our results are robust to a narrower definition of supplier-focused IT that is equal to one only when the establishment adopts three or more supplier-focused IT applications: we label this margin of investment advanced supplier-focused IT. In column 4 we relax the requirement that an establishment's percentage of within-firm transfers be greater than zero and less than the 95th percentile prior to our sample period. In column 5 we exclude both the prior year conditioning as well as the condition that we include only establishments that are producing commodities that are used as a significant input by other establishments within the same firm. The results remain robust. In column 6 we explore the impact of supplier-focused IT on the **extensive** margin of within-firm transfers: i.e., whether the plant transfers any product within the firm at all. While the coefficient remains negative, it is not statistically significant at conventional levels. This confirms our intuition that over our sample period IT investments increase the propensity for establishments to sell externally, but only among those who are already doing so. In column 7 we estimate our model using the fractional probit model described in Papke and Wooldridge (2008). Our results remain robust.

In Table 5 we explore the impact of internally-focused IT on the percentage of within-firm transfers. We do not hypothesize a separate role for internally-focused IT on the extent of inter-firm sales, in part because the ex-ante predictions are ambiguous. Because internally-focused IT applications reduce internal coordination costs, they may increase the value of within-firm transfers relative to external sales, leading to an increase in within-firm transfers. However, because internally-focused IT may also make the plant more productive, it may increase the intensity of external sales. Thus, the results for internally-focused IT are of independent interest. The results in Table 5 show that while the coefficients for internally-focused are negative they are not statistically significant in any of the specifications.

If IT applications are adopted together, then adoption of supplier-focused IT may reflect the unobserved effects of adopting other margins of IT such as internally-focused IT or customer-focused IT.

In table 6 we explore this possibility by including supplier-focused IT, customer-focused IT, and internally-focused IT in the same regression. The results are very similar to when the effects of each of these IT variables were estimated separately. Supplier-focused IT remains significant across all specifications where the dependent variable represents the intensive margin of within-firm transfers; the only significant change is that the results excluding vertical link conditioning are significant now only at the 10% level. Customer-focused IT and internally-focused IT remain insignificant as before.

5.2 Justifying a causal link

To address concerns about reverse causality and omitted variable bias, in Table 7 we present the results of instrumental variables estimates. Because prior work has suggested that, if anything, the bias of our coefficient estimates is likely to be downward (less negative), we focus our attention on the instrumental variable estimates for supplier-focused IT (Table 4). Two of our instruments capture cross-sectional variance in the costs to Internet adoption. Our first instrument captures differences in local regulatory policy.[16] We identify the year in which price cap regulation is instituted in the state where the establishment is located. Greenstein and Mazzeo (2006) argue that this variable captures local variance in regulatory stringency: lower values of this variable should indicate a regulatory environment in which there is a friendlier attitude toward experimenting with competition, which should translate into lower costs for an entering competitive local exchange carrier (CLEC). Such environments will be associated with potentially lower operating costs for Internet Service Providers and should translate into lower Internet adoption costs for firms.

Our second instrument indicates an estimate of the cost of delivering telecom services to a region based on the FCC's Hybrid Cost Proxy Model (HCPM). The HCPM is an economic engineering model that computes the local cost of providing telecommunications services, given a location's geographic terrain and subscriber density. Thus, we expect increases in local proxy costs will be associated with higher operating costs for Internet service providers, which should translate into higher Internet adoption costs for firms. The HCPM is computed from wire centers; we follow Prieger's (2003) matching of wire

[16] We thank Shane Greenstein and Avi Goldfarb for providing this instrument for us.

centers to ZIP code areas and then match to establishments using their ZIP codes.[17]

Our third instrument captures industry-level variance in the propensity to adopt IT. We compute the average adoption rate for the establishment's three-digit NAICS industry across establishments outside of the establishment's metropolitan statistical area (MSA) and outside of the same firm.

Table 7 presents the second stage results of our instrumental variables, which are based upon the specification in column 2 of Table 4. While the direction of the estimated effect of supplier-focused IT on the percentage of within-firm transfers is negative and stable across specifications, the magnitude and significance of the coefficients differ slightly across specifications. Our just-identified results in columns (2) (proxy cost instrument) and column (3) (ERP instrument) are both negative and statistically significant; this is encouraging since just-identified IV will be median unbiased (e.g., Angrist and Pischke 2009). The coefficient estimates in Table 7 are consistently more negative than those in column 2 of Table 1. We speculate that this may be because of heterogeneous effects of supplier-related IT on within-firm transfers. That is, the local average treatment effect for supplier-focused IT may be largest for those establishments whose adoption is most affected by regulatory regime, the cost of delivering local telecommunications services, and industry-level propensity to invest in IT.

In sum, our instrumental variable results provide additional evidence in support of a causal interpretation that adoption of supplier-focused IT will lead to a decline in the percentage of within-firm transfers.

5.3 Complementarities Between Supplier-Focused IT and Customer-Focused IT

In Table 8 we show the results of regressions that include the interaction of supplier-focused IT with customer-focused IT. Column 2 presents the baseline results including the full set of controls and the margins of IT investment explored in previous tables. The results show that adoption of supplier-focused IT is associated with a decline in the percentage of within-firm transfers as before, but only when

[17] We think Jim Prieger for providing these data for us. Proxy costs are not available from the model for about one third of the wire centers, we follow Prieger (2003) in using the proxy cost of the nearest wire center. Further, not all zip codes in our data had a matching zip code with a proxy cost; we use the proxy cost of the closest zip code.

accompanied by adoption of customer-focused IT. Adoption of supplier-focused IT is associated with a 7.1 percentage point decline when accompanied by customer-focused IT (statistically significant at the 5% level), however has no statistically significant impact when adopted alone. This result is consistent with the view that supplier-focused IT increases the value of inter firm transfers by lowering the costs of supply chain coordination: adoption of supplier-focused IT will decrease coordination costs with customers only if coupled with the information-sharing enabled by customer-focused IT. These results remain robust when we substitute our baseline margins of IT investment with advanced supplier-focused and customer-focused IT, and if we exclude our prior year conditioning restrictions. In contrast, with the exception of our correlational results in column (1) that exclude controls, adoption of customer IT has no significant impact on the extent of within-firm transfers. This is true both when customer-focused IT is and is not accompanied by supplier-focused IT.

6 Discussion and Conclusion

Our results show that adoption of supplier-focused IT has an economically and statistically significant negative impact on the percentage of downstream within-firm transfers. However, somewhat surprisingly, adoption of customer-focused IT has no significant effect on the percentage of downstream transfers. Adoption of supplier-focused IT has the largest impact on within-firm transfers when adopted in conjunction with customer-focused IT.

One open question is why we see no direct impact of customer-focused IT on the percentage of WFT. While this remains a puzzle that will be a focus of future research, right now we have two hypotheses. One is that supplier-focused IT and customer-focused IT are complements. We hypothesize that on its own (i.e., without the adoption of complementary supplier-focused IT) customer-focused IT may have had relatively little value. Second, as McElheran (2011) notes, customer-focused IT over this period represented an innovation that involved significant co-invention and was very costly for firms to do. Thus, adoption of customer-focused IT in isolation may be identifying a set of firms that had as yet obtained little value from their investments and which actually, on the margin, made them less competitive in the marketplace.

We focus on the implications of IT investment for the short run decision to sell a plant's output internally or externally, taking the supply chain of the firm as fixed. This focus reflects the nature of our setting and research design: the short-run response of a manufacturing plant to a decline in communication costs that was enabled by the commercialization of the Internet. However, our results are also suggestive about the implications of supplier IT for the extensive margin of within-firm transfers,--whether the plant sells its output internally at all. This suggests that these same IT investments will also have implications for the long run configuration of a firm's supply chain. We leave exploration of this question for future work.

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Figure 1: Conceptual Framework

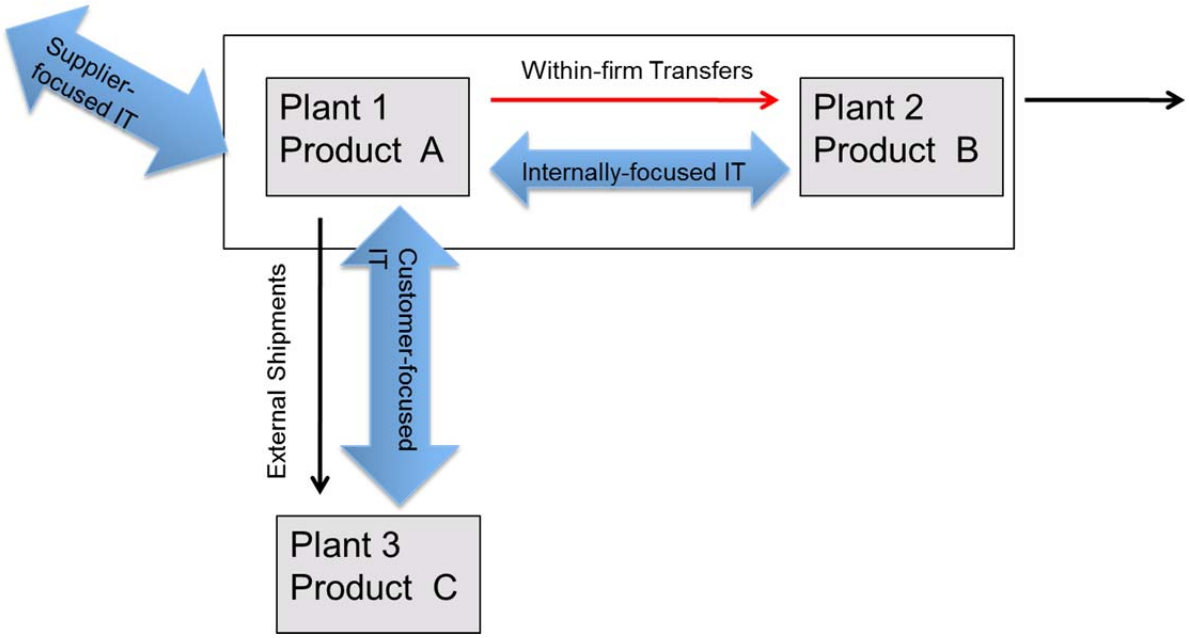

Table 1a: Descriptive Statistics

	Mean	Standard Deviation	Number of observations
Percent within-firm transfers	0.179	0.299	~4000
Supplier-focused IT	0.216	0.411	~4000
Advanced Supplier-focused IT	0.076	0.264	~4000
Customer-focused IT	0.179	0.383	~4000
Advanced customer-focused IT	0.052	0.223	~4000
Internal company-focused IT	0.395	0.489	~4000
Advanced internal company-focused IT	0.336	0.472	~4000
Log(inventories)	6.126	3.154	~4000
Production to nonproduction workers	0.309	0.168	~4000
Log(Total factor productivity)	1.631	0.550	~4000

Table 1b: Percent Within-firm Transfers by 3-Digit Industry

Industry	Frequency	Average Percent Within-firm Transfers
Food Manufacturing (311)	~800	0.059
Textile Mills (313)	~400	0.452
Textile Product Mills, Apparel Manufacturing, and Leather and Allied Product Manufacturing (314-316)	~40	0.383
Wood Product Manufacturing (321)	~450	0.095
Paper Manufacturing (322)	~700	0.138
Chemical Manufacturing (325)	~1000	0.102
Plastics and Rubber Products Manufacturing (326)	~500	0.079
Nonmetallic Mineral Product Manufacturing (327)	~200	0.158
Primary Metal Manufacturing (331)	~400	0.152
Fabricated Metal Product Manufacturing (332)	~300	0.106
Machinery Manufacturing (333)	~100	0.113
Computer and Electronic Product Manufacturing (334)	~200	0.091
Electrical Equipment, Appliance, and Component Manufacturing (335)	~200	0.090
Transportation Equipment Manufacturing (336)	~500	0.281
Miscellaneous Manufacturing (339)	~100	0.054

Note: NAICS 312, 323, 324, and 337 were omitted for disclosure purposes. Sample includes prior year conditioning.

Table 2a: Percent Within-firm Transfers by Year and Whether Treated by Customer-Focused IT

	Before Treatment (1992)	After Treatment (1999)	First Difference (row)
Received IT Treatment	0.200 (N~700)	0.152 (N~700)	-0.048*** (N~700)
Did Not Receive IT Treatment	0.203 (N~1200)	0.159 (N~1200)	-0.044*** (N~1200)
First Difference (column)			*Difference in Difference* -0.004 (N~1800)

We base this analysis on the sample of establishments that are observed before and after the treatment between 1992 and 1999. * p<0.05, ** p<0.01, *** p<0.001 ^Test statistic not computed.

Table 2b: Percent Within-firm Transfers by Year and Whether Treated by Supplier-Focused IT

	Before Treatment (1992)	After Treatment (1999)	First Difference (row)
Received IT Treatment	0.174 (N~800)	0.110 (N~800)	-0.065*** (N~800)
Did Not Receive IT Treatment	0.223 (N~1000)	0.191 (N~1000)	-0.032*** (N~1000)
First Difference (column)	-0.049^ (N~1800)	-0.081^ (N~1800)	*Difference in Difference* -0.032** (N~1800)

We base this analysis on the sample of establishments that are observed before and after the treatment between 1992 and 1999. * p<0.05, ** p<0.01, *** p<0.001 ^Test statistic not computed.

Table 2c: Percent Within-firm Transfers by Year and Whether Treated by Company-Focused IT

	Before Treatment (1992)	After Treatment (1999)	First Difference (row)
Received IT Treatment	0.205 (N~1400)	0.156 (N~1400)	-0.048*** (N~1400)
Did Not Receive IT Treatment	0.192 (N~400)	0.156 (N~400)	-0.036*** (N~400)
First Difference (column)	0.013^ (N~1800)	0.000^ (N~1800)	*Difference in Difference* -0.012 (N~1800)

We base this analysis on the sample of establishments that are observed before and after the treatment between 1992 and 1999. * p<0.05, ** p<0.01, *** p<0.001 ^Test statistic not computed.

Table 3: Is Adoption of Customer IT Associated with a Decline in Within-firm Transfers?

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	No Controls	Baseline	Advanced Customer IT	Excludes Prior Year Conditioning	Excludes VL Conditioning	Extensive Margin	Fractional Probit
External Customers IT	-0.004	-0.005	-0.003	-0.014	-0.009	-0.011	-0.012
	(0.014)	(0.014)	(0.026)	(0.011)	(0.005)	(0.022)	(0.056)
Log of inventories		-0.009*	-0.009*	-0.011***	-0.004**	-0.012*	-0.033*
		(0.004)	(0.004)	(0.003)	(0.001)	(0.005)	(0.014)
Production to nonproduction workers		-0.038	-0.038	-0.025	-0.040**	-0.015	-0.193
		(0.050)	(0.050)	(0.033)	(0.015)	(0.074)	(0.224)
Log of TFP		-0.039	-0.038	-0.041**	-0.012	-0.011	-0.131
		(0.021)	(0.021)	(0.015)	(0.008)	(0.026)	(0.081)
1999 Year Dummy	-0.044***	-0.043***	-0.044***	-0.022***	-0.009**	-0.045***	-0.187***
	(0.009)	(0.009)	(0.007)	(0.006)	(0.003)	(0.012)	(0.034)
Constant	0.202***	0.330***	0.330***	0.297***	0.149***	0.560***	0.141
	(0.003)	(0.047)	(0.047)	(0.035)	(0.018)	(0.059)	(0.102)
R-squared	0.023	0.031	0.031	0.024	0.006	0.010	
N	~4000	~4000	~4000	~6000	~18000	~6000	~4000

Robust standard errors, clustered by establishment, in parentheses. * p<0.05, ** p<0.01, *** p<0.001

Table 4: Is Adoption of Supplier IT Associated with a Decline in Wihin-firm Transfers?

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	No Controls	Baseline	Advanced Supplier IT	Excludes Prior Year Conditioning	Excludes VL Conditioning	Extensive Margin	Fractional Probit
External Supplier IT	-0.033*	-0.032*	-0.046*	-0.023*	-0.012**	-0.037	-0.173**
	(0.014)	(0.014)	(0.019)	(0.010)	(0.005)	(0.021)	(0.056)
Log of inventories		-0.008*	-0.009*	-0.011**	-0.004**	-0.012*	-0.032*
		(0.004)	(0.004)	(0.003)	(0.001)	(0.005)	(0.014)
Production to nonproduction workers		-0.039	-0.043	-0.025	-0.039**	-0.014	-0.190
		(0.050)	(0.050)	(0.032)	(0.015)	(0.074)	(0.222)
Log of TFP		-0.039	-0.038	-0.042**	-0.012	-0.012	-0.137
		(0.021)	(0.021)	(0.015)	(0.008)	(0.026)	(0.080)
1999 Year Dummy	-0.032**	-0.031**	-0.038***	-0.016*	-0.007*	-0.033*	-0.127***
	(0.010)	(0.010)	(0.008)	(0.007)	(0.003)	(0.013)	(0.034)
Constant	0.202***	0.329***	0.330***	0.296***	0.148***	0.559***	0.132
	(0.003)	(0.047)	(0.047)	(0.035)	(0.018)	(0.058)	(0.100)
R-squared	0.026	0.033	0.034	0.025	0.007	0.011	
N	~4000	~4000	~4000	~6000	~18000	~6000	~4000

Robust standard errors, clustered by establishment, in parentheses. * p<0.05, ** p<0.01, *** p<0.001

Table 5: Is Adoption of Internal Company IT Associated with a Decline in Within-firm Transfers?

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	No Controls	Baseline	Advanced Company IT	Excludes Prior Year Conditioning	Excludes VL Conditioning	Extensive Margin	Fractional Probit
Internal Company IT	-0.008	-0.009	-0.012	-0.009	-0.006	0.009	-0.034
	(0.017)	(0.017)	(0.015)	(0.011)	(0.005)	(0.024)	(0.066)
Log of inventories		-0.009*	-0.009*	-0.011***	-0.004**	-0.012*	-0.033*
		(0.004)	(0.004)	(0.003)	(0.001)	(0.005)	(0.014)
Production to nonproduction workers		-0.037	-0.037	-0.025	-0.040**	-0.014	-0.193
		(0.050)	(0.050)	(0.032)	(0.015)	(0.074)	(0.223)
Log of TFP		-0.039	-0.038	-0.041**	-0.011	-0.011	-0.132
		(0.021)	(0.021)	(0.015)	(0.008)	(0.026)	(0.081)
1999 Year Dummy	-0.040*	-0.038*	-0.037**	-0.020*	-0.007	-0.056**	-0.165**
	(0.015)	(0.016)	(0.013)	(0.010)	(0.005)	(0.021)	(0.059)
Constant	0.202***	0.330***	0.330***	0.296***	0.149***	0.559***	0.088
	(0.003)	(0.047)	(0.047)	(0.035)	(0.018)	(0.058)	(0.112)
R-squared	0.023	0.031	0.031	0.023	0.006	0.010	
N	~4000	~4000	~4000	~6000	~18000	~6000	~4000

Robust standard errors, clustered by establishment, in parentheses. * p<0.05, ** p<0.01, *** p<0.001

Table 6: Supplier-focused IT, Customer-focused IT, and internally-focused IT together

	(1)	(2)	(3)	(4)	(5)	(6)
	No Controls	Baseline	Excludes Prior Year Conditioning	Excludes VL Conditioning	Extensive Margin	Fractional Probit
External Suppliers IT	-0.041**	-0.039*	-0.022*	-0.010	-0.047	-0.227***
	(0.016)	(0.016)	(0.011)	(0.005)	(0.025)	(0.067)
Internal Company IT	0.002	0.000	0.001	-0.001	0.025	0.007
	(0.019)	(0.019)	(0.012)	(0.006)	(0.026)	(0.071)
External Customers IT	0.017	0.014	-0.003	-0.003	0.006	0.102
	(0.017)	(0.017)	(0.012)	(0.006)	(0.026)	(0.068)
Log of inventories		-0.008*	-0.011**	-0.004**	-0.012*	-0.031*
		(0.004)	(0.003)	(0.001)	(0.005)	(0.014)
Production to nonproduction workers		-0.039	-0.025	-0.040**	-0.014	-0.193
		(0.050)	(0.032)	(0.015)	(0.074)	(0.222)
Log of TFP		-0.039	-0.042**	-0.012	-0.012	-0.138
		(0.021)	(0.015)	(0.008)	(0.026)	(0.080)
1999 Year Dummy	-0.035*	-0.034*	-0.017	-0.006	-0.050*	-0.150*
	(0.016)	(0.016)	(0.010)	(0.005)	(0.021)	(0.060)
Constant	0.202***	0.328***	0.296***	0.149***	0.558***	0.037
	(0.003)	(0.047)	(0.035)	(0.018)	(0.058)	(0.111)
R-squared	0.026	0.033	0.025	0.007	0.011	
N	~4000	~4000	~6000	~18000	~6000	~4000

Robust standard errors, clustered by establishment, in parentheses. * p<0.05, ** p<0.01, *** p<0.001

Table 7: Supplier IT and Within-firm Transfers: Second Stage of Instrumental Variable Regressions

	(1)	(2)	(3)	(4)
	All instruments	Proxy Cost	ERP in other industries	Price Cap
External Supplier IT	-0.358***	-0.548*	-0.325**	-0.368
	(0.099)	(0.231)	(0.104)	(0.354)
Log of inventories	-0.004	-0.002	-0.004	-0.004
	(0.005)	(0.005)	(0.005)	(0.006)
Production to nonproduction workers	-0.099	-0.116	-0.096	-0.100
	(0.062)	(0.076)	(0.060)	(0.069)
Log of TFP	-0.051*	-0.055*	-0.050*	-0.051*
	(0.020)	(0.023)	(0.020)	(0.022)
1999 Year Dummy	0.109*	0.190	0.094*	0.113
	(0.043)	(0.100)	(0.044)	(0.152)
N	~3500	~3500	~3500	~3500

Robust standard errors, clustered by establishment, in parentheses. * p<0.05, ** p<0.01, *** p<0.001

Note: the first-stage IV results are pending disclosure review. The first-stage coefficients are significant and in the expected direction, with the exception Price Cap in a model with all three instruments included. The Hansen J-Statistic has a p-value of greater than .50.

Table 8: Are There Complementarities Between Supplier-focused IT and Customer-focused IT?

	(1)	(2)	(3)	(4)
	No Controls	Baseline	Advanced Supplier and Advanced Customer IT	Baseline, Excludes Prior Year Conditioning
External Suppliers IT	-0.023	-0.021	-0.044+	-0.013
	(0.018)	(0.018)	(0.023)	(0.012)
External Customer IT	0.047+	0.044	0.055	0.015
	(0.028)	(0.028)	(0.044)	(0.022)
External Suppliers IT × External Customer IT	-0.052	-0.051	-0.054	-0.029
	(0.034)	(0.034)	(0.057)	(0.026)
Log of inventories		-0.008*	-0.009*	-0.011**
		(0.004)	(0.004)	(0.003)
Production to nonproduction workers		-0.045	-0.043	-0.026
		(0.050)	(0.050)	(0.033)
Log of TFP		-0.039+	-0.037+	-0.042**
		(0.021)	(0.021)	(0.015)
1999 Year Dummy	-0.039***	-0.038***	-0.040***	-0.018*
	(0.010)	(0.011)	(0.008)	(0.007)
Constant	0.202***	0.329***	0.329***	0.296***
	(0.003)	(0.047)	(0.047)	(0.035)
R-squared	0.028	0.036	0.036	0.026
N	~4000	~4000	~4000	~6000
Marginal Effects				
External Suppliers IT (External Customers IT=0)	-0.023	-0.021	-0.044+	-0.013
	(0.018)	(0.018)	(0.023)	(0.012)
External Suppliers IT (External Customers IT=1)	-0.075**	-0.071*	-0.098+	-0.042+
	(0.029)	(0.029)	(0.053)	(0.023)
External Customers IT (External Suppliers IT=0)	0.047+	0.044	0.055	0.015
	(0.028)	(0.028)	(0.044)	(0.022)
External Customers IT (External Suppliers IT=0)	-0.005	-0.007	0.001	-0.014
	(0.020)	(0.020)	(0.037)	(0.013)

Robust standard errors, clustered by establishment, in parentheses. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001