THE IMPACT OF CUSTOMER-SIDE IT INVESTMENTS ON FIRM PRODUCTIVITY

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ABSTRACT

This paper develops and empirically tests theory on the impact of IT investments made by customers on focal firm’s productivity. It is found that in general an increase in IT investment made by customers is associated with an increase in the focal firm’s productivity. On the other hand, the benefits a firm receives from its customers are moderated by (1) how the firm is forwardly integrated in the supply chain and (2) the relative concentration level of its customer industries.

Key words: Information Technology, Vertical Integration, Industry Concentration, Supply Chain Integration

INTRODUCTION

There is a large body of literature that examines the impact of IT on firm productivity and performance (Brynjolfsson, Hitt, & Yang, 2002; Clemons, Reddi, & Row, 1993; Dewan, Michael, & Min, 1998; Hitt, 1999; Hitt, Hoskisson, & Kim, 1997). This literature also examines the impact of IT on specific business activities to study the process through which the IT affects firm level productivity and performance. However, the literature has begun to recognize that firms don’t exist in a vacuum; they exist in networks where they interact with their suppliers on one hand customer on the other hand. This suggests that though a firm may derive value from its own IT investments, the value firms derive from their own IT investments are contingent on the IT investments made by their suppliers and customers. The idea that a focal firm’s suppliers’ and customers’ IT investments affect the return a focal firm derives from its IT investment is recognized by literature studying digital supply chains. This literature (e.g., Rai, Patnayakuni,
and Seth (2006); Rai and Tang (2010)) finds that electronic integration with suppliers and customers increases the focal firm’s performance. Similarly (Barua, Konana, Whinston, & Yin, 2004) find that electronic integration with suppliers is a prerequisite for firms seeking to serve its customers digitally.

The literature on supplier-driven and customer-driven spillovers has explicitly recognized the impacts of supplier and customer IT capital on the returns to the focal firms’ IT capital. In two seminal papers (Cheng & Nault, 2007, 2012) authors examine the impact of supplier and customer industry IT capital on the productivity of the focal sector. They find that competition in the supplier industry may lead the benefits of the supplier industry IT capital being passed to the downstream sector. Similarly, they find that competition in the customer industry may lead the benefits of the customer industry IT capital being passed to the upstream sector. However, the empirical analyses of the studies (Cheng & Nault, 2007, 2012) are at the industry level.

We build on the work of Cheng and Nault (2007, 2012) and study if a firm derives value from IT investments made by its customers. The returns a firm derives from its customers’ IT investments are likely to be contingent on how integrated a firm is in its supply chain and how concentrated the upstream and downstream industries are. If a firm is integrated upstream and/or downstream, then it is less likely to derive value from its customers’ IT investments as its customers are more reluctant to share information with the focal firm. On the other hand, if a focal firm’s customers are concentrated, the focal firm can achieve closer/deeper integration with its customer and derive greater returns from its customer’s IT investments.

These ideas are tested using a dataset from years 2000-2005. The analysis suggests that in general firms’ sales will increase with the IT investments of its customers. However, if the focal firm is more forwardly integrated it derives less value from the IT investments of its customers. On the other hand, if the downstream industries are more concentrated, the focal firm derives greater value from the IT investments of its customers.

The paper is organized as follows. Section 2 presents the theory and the hypotheses. Section 3 discusses the data and the variables, and section 4 is devoted to the description of the model and the empirical analyses. Section 5 concludes.

**THEORETICAL BACKGROUND AND RESEARCH HYPOTHESES**

In this section we develop a set of hypotheses about how a focal firm’s performance is affected by IT investments made by its supply chain partners. These hypotheses are based on different theoretical perspectives, such as the resource based view, relational view of the firm (Dyer & Singh, 1998), the network view of the economy (Straub, Rai, & Klein, 2004), and modular organizations (Schilling & Steensma, 2001). Together these theories imply that when firms use information technologies to interconnect their activities, they create value through the cumulative resources and capabilities of the coalition of the interconnected firms.

Resource based view (RBV) states that differential firm performance can be explained by the resources owned by firms. A firm that is able to accumulate and combine resources that are
valuable, rare, non-substitutable, and difficult to imitate will achieve competitive advantage over its competitors (Barney, 1991; Dierickx & Cool, 1989; Rumelt, 1984). In this regard, IT resources can lead to competitive advantages (Delmonte, 2003; Mata, Fuerst, & Barney, 1995; Teece, Pisano, & Shuen, 1997; Zhu & Kraemer, 2002).

In the resource-based view resources are assumed to be owned and controlled by a single firm. However, in reality, resources may span firm boundaries. In the relational and network view of the firm (Dyer & Singh, 1998; Lavie, 2006) a firm’s competitive advantage is not only influenced by its internal resources but also the resources of its business partners. Based on these perspectives, a focal firm and its partner may collaborate and intentionally invest in resources to benefit both sides. Such benefits cannot be generated individually by either of the partners. A focal firm may also receive spillover benefits from its partner “in an involuntary way for unintended purposes” (Lavie, 2006). What the resource-based, relation, and network view of the firm imply is that, when looking at how IT impacts a focal firm’s performance, we should consider not only the focal firm’s IT investment, but also IT investments made by its partners in its supply chain network, as the latter may also directly influence the focal firm’s performance.

The value of IT used in supply chain is well recognized. As the traditional competition among individual firms has shifted to the competition among production and distribution networks, firms’ capabilities to cooperate and coordinate with their supply chain partners are directly linked to their organizational performances (Rai et al., 2006). Previous studies have highlighted IT’s role in reducing the transaction cost of managing interactions between partners through information sharing (Clemons et al., 1993; Clemons & Row, 1992). This IT-enabled cooperation and collaboration along the supply chain improves organizational performances (Sanders, 2007).

From a manufacturer’s point of view, customers (i.e., retailers’) IT investments enable the focal manufacturer to receive real-time information about consumer demand and inventory level. From the information offered by customers, the focal manufacturer can develop a better understanding of ultimate consumers’ changing preferences to redesign products to better fit consumers, forecast future demand more accurately and adjust its production plan to reduce the level of stock out on the retail market (Lee, Padmanabhan, & Whang, 1997; Subramani, 2004). Based on the discussion above, we propose the first hypothesis:

**H1:** Higher IT investment on the customer/supplier side is associated with a higher productivity of the focal supplier.

**Moderating Impact of Vertical Integration**

Studies have found correlation between relational rent and partners’ investments in relation-specific assets (Klein, Rai, & Straub, 2007). Vertical information sharing requires both suppliers and customers to adopt information integration strategy. However, concerns about information leakage and potential channel conflicts may reduce a firm’s incentive to share information with its supply chain partners (Li, 2002). A focal firm’s vertical structure may influence its partner’s willingness to share information with it, and therefore influence the focal firms’ capability to reap the benefits from its partner’s IT investments. More specifically, if a firm is more forwardly integrated (i.e., the firm is competing with its main customers), there will be a higher level of
channel conflict with its customers. As a result, its customers will be more reluctant to share their information about sales and inventory with the focal firm, leading to reduced benefits from its customers’ IT investments. Therefore, we propose the following hypothesis:

**H2**: a higher level of forward integration is associated with a reduced level of benefit (in terms of increased sales) from IT investments by customers.

**Moderating Impact of Industry Concentration**

Concentration levels in different stages of supply chain influence the bargaining powers of supply chain partners to negotiate contracts to share benefits from IT and other investments made in the supply chain. Previous studies have shown that less concentrated industries have lower ability to appropriate the benefits of IT and other investments made, from more concentrated industries, due to its disadvantages in bargaining power (Cheng & Nault, 2012). However, in the context of IT based coordination, bargaining power may not be the only or even the main impact of concentration level on the benefits from information sharing with partners. A focal firm may get higher benefits from IT investments made by its customers in more concentrated downstream industries. The reason is that information sharing and IT infrastructure integration require a focal firm and its customers to conform to standards on data and process integration. Previous studies have found that in more concentrated industries, the barriers to form industry-level EDI standards are low as high concentration reduces the complexity of negotiating standards about EDI communications (Graham, Lobet-Maris, & Charles, 1994). A focal firm dealing with concentrated customers will achieve data and process integration with a lower number of customers, thereby increasing the level of data and process integration with its customer. The ease in the ability to achieve data and process integration with a limited number of established customers increases the benefit the focal firm receives from its customers’ IT investments. Therefore we propose that,

**H3**: A relatively higher concentration level at the supplier/customer side is associated with a higher benefits (in terms of increased sales) received from IT investment made by customers.

**DATA AND VARIABLES**

We collected data from many sources. Firm-level IT spending data from 2000 to 2005 are from InformationWeek 500. These IT spending data are matched with data from COMPUSTAT. For industry-level IT spending, following Stiroh (2002) we use the fixed assets data from the Bureau of Economic Analysis (BEA), and sum up the net stocks of private fixed assets including computer and peripheral hardware, software, and telecommunication equipment.

We also use the Input-Output data and GDP-by-industry data from BEA, and industry concentration data from US Census Bureau.
Customer-side IT Investment

Suppose there are \( m \) industries. Let \( U_{ij} \) be the amount of industry \( i \)'s products (in terms of dollar value) consumed by industry \( j \) based on data from input-output table, therefore, \( \sum_{k=1}^{m} U_{ik} \) is the total input by industry \( i \) and \( \sum_{k=1}^{m} U_{lk} \) is the total output by industry \( i \). As a result \( \phi_i = (\sum_{k=1}^{m} U_{ik})/(\sum_{k=1}^{m} U_{lk}) \) is the amount of input needed by industry \( i \) to make each dollar of its output. On the other hand, \( \omega_{ij} = U_{ij}/(\sum_{k=1}^{m} U_{ik}) \) is the proportion of industry \( i \)'s sales made to industry \( j \), which reflects how important industry \( j \) is as a customer industry to industry \( i \).

Let \( G_j^y \) be the total output made by industry \( j \) (\( j = 1, 2, ..., m \)) in year \( y \). Therefore, the total input consumed by industry \( j \) in year \( y \) is \( G_j^y \cdot \phi_j \).\(^1\) Let \( IT_j^y \) be IT investment made by industry \( j \) in year \( y \). We use \( IT_j^y \cdot (G_j^y \cdot \phi_j) \) as a proxy to measure the intensity of IT investment made by industry \( j \) to coordinate with its suppliers.

For a specific industry \( a \), based on IT investment intensities of its customer industries, we can calculate its aggregated customer-side IT investment intensity:

\[
\gamma_a = \sum_{j=1}^{m} \left( \omega_{ij} \cdot \frac{IT_j^y}{G_j^y \cdot \phi_j} \right)
\]

Suppose a firm has a set of segments\(^2\) denoted by \( A \). For any segment \( a \in A \), let \( R_a^y \) be the sales made by the focal firm in segment \( a \) in year \( y \), and let \( S_a^y = \sum_{a \in k} R_a^y \) be the total sales made by the focal firm. Then for the focal firm, its customer-side IT investment is:

\[
\sum_{a \in k} \frac{R_a^y}{S_a^y} \gamma_a
\]

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\(^1\) Total output by each industry in each year is directly available, but the corresponding total input is not. Therefore, we need to calculate it based on total output and \( \phi_i \) which is from input-output table.

\(^2\) In this illustration, we distinguish between two terms: industry A and segment A. They are associated with the same NAICS code. However, industry A is about the whole industry which includes many firms. On the other hand, segment A (or the firm’s segment-A unit) is the focal firm’s segment/unit that is operating in industry A.
**Forward Vertical Integration**

We take the following steps to calculate forward vertical integration of each firm. First, from COMPUSTAT’s segment database we identify each firm’s primary segment as the segment with the largest sales, and the firm’s other segments are considered its secondary segments. Second, as suggested by (Fan & Lang, 2000), for each secondary segment we calculate its corresponding forward relatedness as the dollar value of the primary segment’s output required to produce each dollar of the secondary segment’s output, based on data from the Input-Output table from BEA. Third, the focal firm’s forward vertical integration is:

$$\sum_j W_j F_j$$

In the formula above, $W_j$ is the sales made by the firm’s $j^{th}$ secondary segment divided by the sum of sales made by all of its secondary segments, and $F_j$ is the forward vertical relatedness of the $j^{th}$ secondary segment.

**Customer-side Relative Concentration Level**

We take the following steps to calculate customer-side relative concentration ratio. First, we collect information about the four-firm concentration ratio for each industry from US Census Bureau. For each industry $i$, we calculate its customer-side concentration ratio using the following formula:

$$CS_i = \sum_{j=1}^{m} (\omega_{ij} \cdot FOUR_j)$$

In the formula above, $\omega_{ij} = U_{ij}/(\sum_{k=1}^{m} U_{ik})$ is the proportion of industry $i$’s sales made to industry $j$, which reflects how important industry $j$ is as a customer industry to industry $i$. On the other hand, $FOUR_j$ is the four-firm concentration ratio of industry $j$.

For each industry $i$, we then calculate its customer-side relative concentration ratio:

$$CR_i = \frac{CS_i}{FOUR_i}$$

Intuitively this ratio is higher when an industry’s major customer industries are more concentrated compared with the industry itself. Finally, for each firm let $W_i$ be the sales made by the firm’s $i^{th}$ segment divided by the sum of sales made by all of its segments, then its customer-side relative centration ratio is:

$$\sum_i W_i CR_i$$
Control Variables

In the model, we control for firm size (number of employees) and total industry size as they directly affect a firm’s productivity. Similarly, we also include growth rate of customer industries and demand uncertainty as control variables because firms tend to increase their sales if their customer industries are growing steadily. Finally, we include year dummy variables to control for unobserved heterogeneity related to time.

For each firm, we identify its primary segment as the segment with the largest sales. Let the corresponding industry be $B$. Then the focal firm’s total industry size is the total sales made in industry $B$.

Following Keats and Hitt (1988), for each industry in each year, we collect its past five years’ data and use them in the following regression:

$$\ln(y_t) = a + bx_t + e_t$$

(3)

In the equation above, $y_t$ is the sales of the industry in year $x_t$. An industry’s growth rate is the antilog of the estimate of the regression slope ($b$), and demand uncertainty is the antilog of the standard error of the regression slope ($b$). Then for each firm, its demand uncertainty is

$$\sum_j W_j U_j$$

In the formula above, $W_j$ is the sales made by the firm’s $j^{th}$ segment divided by the sum of sales made by all of its segments, and $U_j$ is the demand uncertainty of the corresponding industry of the $j^{th}$ segment.

On the other hand, customer-side growth rate is calculated using

$$\sum_j W_j \left( \sum_{k=1}^{m} \omega_{jk} G_k \right)$$

(4)

In the formula above, $W_j$ is the sales made by the firm’s $j^{th}$ segment divided by the sum of sales made by all of its segments, $\omega_{jk} = U_{jk}/(\sum_{h=1}^{m} U_{jh})$ is the proportion of industry $j$’s sales made to industry $k$, which reflects how important industry $k$ is as a customer industry to industry $j$. $G_k$ is the growth rate of industry $k$ based on regression of equation (3).
**MODEL AND DATA ANALYSIS**

We use the following panel-data model to study the impacts of customer-side IT investment on sale, and how firms’ characteristics and environments moderate the impacts.

\[
\log(SALES) = \alpha_0 + \alpha_1 CIT + \alpha_2 IT + \alpha_3 FV + \alpha_4 CC + \beta_1 CIT \cdot FV + \beta_2 CIT \cdot CC + Control\ Variables + u
\]  

(5)

In the equations above, customer-side IT investment \((CIT)\), IT investment \((IT)\), forward integration \((FV)\), and customer concentration \((CC)\) are independent variables of interests. It is to be noted that the model is a panel data models, though for simple illustration the individual indicator \((i)\) and year indicator \((t)\) are not included in the equations.

**Model Specification**

In the model, IT investment may be affected by sales. For example, firms may increase their IT investments when their revenues are increasing. This simultaneity bias may lead to inconsistent estimates if OLS is used. Therefore, a Durbin-Wu-Hausman test is performed and in the test the null hypothesis that IT investment may be treated as exogenous is rejected. As a result, two stage least squares estimate \((2SLS)\) is used in the model.

We also run Hausman tests to decide whether fixed-effect estimates or random-effect estimates need to be used. The test favors the fixed effects. Therefore, the model is estimated with Fixed Effects FGLS using R (Croissant & Millo, 2008; Wooldridge, 2002).

**Instrument variables and tests**

Instrumental variables used for IT investment include lagged value of number of employees and lagged value of industry primary IT (industry-level IT investment made in the focal firm’s primary industry).

Instrument variables should satisfy two requirements: relevance and exogeneity (Wooldridge, 2002). The relevance assumption requires that the excluded instrument variables need to be correlated with endogenous variables. We performed under-identification test to assess whether instrumental variables are correlated to the endogenous variable. The result rejects the null hypothesis that they are irrelevant. On the other hand, the exogeneity requirement imposes that excluded instrument variables must be uncorrelated with error terms. We performed over-identification test which doesn’t reject the null hypothesis that the instrumental variables are exogenous.
Data Analysis

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Std. Error</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer IT ($\alpha_1$)</td>
<td>0.019</td>
<td>0.009</td>
<td>*</td>
</tr>
<tr>
<td>IT</td>
<td>0.053</td>
<td>0.010</td>
<td>***</td>
</tr>
<tr>
<td>Customer IT * Forward Integration ($\beta_1$)</td>
<td>-3.816</td>
<td>0.724</td>
<td>***</td>
</tr>
<tr>
<td>Customer IT * Customer Concentration ($\beta_2$)</td>
<td>0.135</td>
<td>0.018</td>
<td>***</td>
</tr>
<tr>
<td>Forward Integration</td>
<td>2.240</td>
<td>1.135</td>
<td>*</td>
</tr>
<tr>
<td>Customer Concentration</td>
<td>-0.206</td>
<td>0.056</td>
<td>***</td>
</tr>
<tr>
<td>Industry Sales</td>
<td>0.017</td>
<td>0.008</td>
<td>*</td>
</tr>
<tr>
<td>Firm Size</td>
<td>0.507</td>
<td>0.018</td>
<td>***</td>
</tr>
<tr>
<td>Customer Growth</td>
<td>1.568</td>
<td>0.244</td>
<td>***</td>
</tr>
<tr>
<td>Demand Uncertainty</td>
<td>-2.636</td>
<td>0.427</td>
<td>***</td>
</tr>
<tr>
<td>Y2002</td>
<td>-0.035</td>
<td>0.014</td>
<td>*</td>
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<tr>
<td>Y2003</td>
<td>0.005</td>
<td>0.014</td>
<td></td>
</tr>
<tr>
<td>Y2004</td>
<td>0.078</td>
<td>0.011</td>
<td>***</td>
</tr>
<tr>
<td>Y2005</td>
<td>0.112</td>
<td>0.011</td>
<td>***</td>
</tr>
</tbody>
</table>

Note: *** p<0.001; ** p<0.01; * p< 0.05

The table above shows how customer-side IT investment is related to sales, and how forward integration and customer-side concentration moderate this relationship. Here, as we have centered customer-side IT, forward integration, and customer-side relative concentration by subtracting each original value from its mean, $\alpha_1$ reflects the impact of customer-side IT investment on sales when forward integration and customer-side concentration are at their average levels. On the other hand, $\beta_1$ and $\beta_2$ reflect the moderating impacts of forward integration and customer-side concentration on how customer-side IT investment affects sales.

According to the regression result, $\alpha_1$ is positive and significant, suggesting that an increase in customer-side IT investment is associated with an increase in productivity. $\beta_1$ is negative and significant, implying that more forwardly integrated firms may receive less benefits from their customers’ IT investments. On the other hand, $\beta_2$ is positive and significant, suggesting that
sales increase more from customer-side IT investment if customer industries are more concentrated. Therefore, all of the three hypotheses are supported.

The overall impact of customer-side IT investment is $\alpha_1 + \beta_1 FV + \beta_2 CC$. Here $FV$ and $CC$ are forward integration and customer concentration respectively. In this paper, when we illustrate the role of a specific moderator variable, we let the other moderator take its mean (i.e., it is equal to zero as the moderator is centered). Therefore, respectively $\alpha_1 + \beta_1 FV$ and $\alpha_1 + \beta_2 CC$ can be used to demonstrate how forward integration and customer-side concentration affects the relationship between customer IT investment and sales. Following the procedures and formulas discussed in Aiken and West (1991), we calculated the expected value, standard deviation, and significant level at each possible value of forward integration or customer concentration, and the results are display in the two figures below.

**Moderating Impact of Forward Integration** The figure above shows how forward integration moderates the impact of customer-side IT investment on sales. As illustrated earlier, we have centered forward integration. Therefore, a negative forward integration means it is below average as the mean of forward integration is zero. When forward integration is between -0.003 and 0.0004, customer-side IT investment has positive and significant (at 5% level) impact on sales. This means that an increase in customer-side IT investment is associated with an increase in sales. However, the downward line shows that as forward integration increases, the positive impact of customer-side IT investment becomes weaker. This suggests that when firms becomes

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3 The regular linear scale of the x axis doesn’t reflect the distribution of firms. For example, More than 80% of the firms fall between -0.003 and 0.0004.
more and more forwardly integrated, the benefits they receive from their customers’ IT investments are reduced due to reasons such as channel conflicts. Please note that when forward integration is greater than 0.0088, the impact of customer IT on sales turns negative. Moreover, when forward integration is above 0.0167, this negative impact becomes significant, which suggests that if a firm is very forwardly integrated, an increase in its customer side IT investment may be associated with a decrease in its sales because its competitors benefit more from customer-side IT investment than the focal firm does.

![Impact of Customer IT Investment on Sales](image)

**Moderating Impact of Customer-side Relative Concentration** The figure above shows the moderating role of customer-side relative concentration level on the relationship between customer-side IT investment and sales. When customer-side concentration level is below -0.32, customer-side IT investment has negative and significant impacts on sales. This suggests that when customer industries have very low concentration ratio and the focal firm’s forward integration is on average, an increase in IT investment made by customer industries may reduce the focal firm’s revenues.

On the other hand, when customer-side relative concentration ratio is above -0.008, the impact of customer-side IT investment is positive and significant, which shows that in this range, an increase in IT investment made by customer industries is associated with an increase in the revenue made by the focal firm. The upward line suggests that in this range the benefits a focal firm receives from its customers’ IT investment may increase when its customer industries are concentrated with fewer large companies.
CONCLUSION

Prior empirical studies considered how each firm was affected by its own IT investments. Recent studies have begun to empirically investigate the benefits organizations receive from their supply chain partners’ IT investments. However, they primarily look at the industry level.

Based on the relational and network view of organizations, this paper develops and tests theory relating firms’ productivity to the IT investments made by their customer industries at the firm level. The paper contributes to the IS literature by providing empirical evidences that (1) on average supplier firms benefit from their customers’ IT investments, (2) benefits from customers’ IT investment are moderated by how integrated the focal firm is in its supply chain, and (3) the relative level of customer industries’ concentration level also moderates the impacts of customers industries’ IT investments on the focal firm’s productivity. More specifically, if a firm is more forwardly integrated, it receives lower benefits from its customer industries’ IT investment due to factors such as channel conflicts and customers’ reluctance to share information with the focal firm. On the other hand, a focal firm receives higher benefits from customers’ IT investment if customer industries are more concentrated with fewer players as higher concentration level in the customer industries reduces the complexity of negotiating standards on network communication and process integrations.

This paper focuses on the impact of customer industries’ IT investment on productivity from a supplier’s perspective. Future studies will look at how a firm’s performance is affected by IT investments made by their supply chain partners, including both suppliers and customers, which will demonstrate a broader picture of the impacts of supply chain partners’ IT investments on each focal firm. For example, suppliers’ IT investment may enable the focal firm to share production plans with its suppliers and reduce its own inventory cost.

REFERENCES


