Abstract

Using a refined version of the Custseg database from Compustat for the period 1995 – 2006, we employ the Data Envelopment Analysis (DEA) methodology to compute productivity and show that productivity spillovers occur from customers to suppliers in the supply chain. Our results, which demonstrate an additional means of enhancing firm productivity, will greatly interest strategic managers. The accompanying productivity enhancements that will accrue to the entire economy will be of interest to the economic policy makers.
1. Introduction

A firm can use better technology, improved processes and methodologies and more efficient practices to improve its productivity. However, over time other firms improve their own productivity by copying the better technology and processes of the first firm. This phenomenon is referred to as productivity spillover. Production spillover can also occur as a result of active collaboration between firms’ business partners (i.e. suppliers or customers) where both parties take steps to ensure transfer of required knowledge, or through the diffusion of knowledge without any deliberate action on the part of the firm with higher productivity.

Productivity spillovers have been extensively studied in economic literature. For example, Javorcik (2004) observed productivity spillover in foreign direct investments contributing to improved productivity of the domestic firms in the host country.\(^1\) Both horizontal spillovers (intra-industry) and vertical spillovers (firms linked by a supply chain relationship with the multi-national) have been documented (Driffield et al. 2002; Blalock and Gertler 2007; Javorcik 2004). Productivity spillovers have also been recorded in R&D expenditure (Griliches 1979) and through geographic proximity (Audretsch and Feldman 1996; Orlando 2004).

In this paper we employ the Data Envelopment Analysis (DEA) methodology to examine the productivity spillovers that occur along the supply chain. Due to the rapid advance of Enterprise Resource Planning systems (ERP), Customer Relationship Management systems (CRM) and other supply chain management technologies, we have seen a seamless integration of firms in the value chain which links raw material providers, manufacturers, distributors and marketers. Firms linked in a supply chain share resources and information and eliminate duplications; thereby enabling rapid information flow, which ultimately results in a smooth

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\(^1\) See Gorg and Greenway (2004) for a survey of such studies.
product flow (Agrawal and Pak 2001). Furthermore, firms such as Wal-Mart and Boeing consistently work with their suppliers in order to improve the processes and methodologies followed by them (the suppliers). This use of common information resources and sharing of knowledge can have strong implications for productivity spillovers.

Although supply chain spillovers have been documented before, such studies have been conducted in one specific setting, namely the host country firms involved in a supply chain relationship with multi-nationals (Driffield et al. 2002; Blalock and Gertler 2007; Javorcik 2004). Moreover such studies have almost exclusively taken place in foreign countries. Therefore, it may not be appropriate to generalize the conclusions of such studies to the overall economy. To the best of our knowledge, this is the first study to investigate this issue using a broad sample of firms drawn from the US.

Using the CUSTSEG database available on COMPUSTAT, we identify firms that are involved in a supply chain relationship. We use a two-stage approach of DEA as specified in Banker and Natarajan (2008) to first estimate the productivity of each firm and then regress the productivity of each firm with potential control variables and the productivity of firms that are involved with the first firm in a supply chain relationship. We find that there are significant relationships between the productivity of firms involved in supply chain relationships indicating the presence of productivity spillovers along the supply chain. We further find that the degree of productivity spillover is determined by the economic bond between the two parties in the supply chain relationship. Our findings add to the growing literature on spillover effects on the overall economy in general and in the supply chain in particular.

The rest of the paper is organized as follows. Section 2 contains the literature survey and hypothesis development. Section 3 describes data collection process. Section 4 describes our
research methodology. Section 5 presents and discusses our empirical results. Section 6 provides
the conclusion and suggests possible extensions.

2. Literature survey and hypothesis development

A large body of literature documents the presence of productivity spillovers. Research on
spillovers associated with foreign direct investments (FDIs) show conclusive evidence for the
presence of vertical production spillovers associated with FDIs. Dunning (1993) shows that
foreign investors in an economy can have effects on suppliers through both their volume of
purchase, as well as through the impact on the quality of inputs, and the efficiency with which
those inputs are supplied. Summarizing the evidence, the paper asserts that research has been
‘virtually unanimous’ on the presence of a positive impact on the productivity of domestic
suppliers. More recently, Javorcik (2004) documents the presence of positive spillover effects
amongst suppliers of multi-national firms in Lithuania. This study identifies some of the means
by which such a spillover could occur: 1) Direct knowledge transfer from foreign customer to
supplier (Moran 2001), 2) The multi-national firm forcing local suppliers to improve their
quality, and 3) Multi-nationals increasing demand for intermediate products enabling the local
suppliers to obtain economies of scale.

Additional evidence of vertical productivity spillovers from multi-national firms is
provided by Blalock and Gertler (2007). They claim that multi-national firms often deliberately
transfer technology to suppliers in order to reduce input costs. Their results show that the
presence of a foreign multi-national downstream induces greater competition and lower prices,
as well as higher output and valued addition in the upstream supply markets. Pack and Saggi
(2001), Driffield et al. (2002) and Bitzer et al (2007) document further evidence as to the presence of positive productivity spillovers from multi-national firms along the supply chain.

Careful examination of the reasons provided for the presence of productivity spillovers when there is a multi-national firm along the supply shows that the same reasons will apply to any firm that has efficient technology or processes and wants to initiate similar improvements amongst its suppliers. A firm which has access to such improved processes will attempt to extract as much impact as possible through their implementation in the firm. However, the firm will be able to obtain additional benefits by sharing such technology and processes with their suppliers. The resultant savings will presumably be shared with the supplier. Although, to the best of our knowledge, no studies have tested this proposition empirically, anecdotal evidence abounds.

Perhaps the most ubiquitous example of a customer working with its suppliers to improve efficiency is Wal-Mart. Ray Bracy, in an interview with PBS Frontline on February 17th 2004, Wal-Mart’s vice president for federal and international public affairs argued that by being candid and negotiating with its suppliers to get merchandise at the lowest possible cost, Wal-Mart is helping its suppliers become more efficient. (NPR Frontline Sept. 17, 2004.) Goodman and Pan (2004) in an otherwise negative article on Wal-Mart, says that meeting Wal-Mart's strict requirements could improve the supplier’s efficiency and make it easier to land contracts from other major retailers. In the aerospace industry, Boeing is noted for working with its suppliers, in order to improve their efficiency. In Boeing’s internal journal Boeing Frontiers, Horton (2007)

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documents how Boeing works with their suppliers in order to improve productivity. The article lists several suppliers who were able to improve productivity through the expertise provided by Boeing. The article says “…At Boeing, suppliers account for the majority of the product cost. So it makes sense that if the company can help its partners be more efficient, both parties are better positioned to meet customer needs and capture new business. That’s exactly what’s taking place. Boeing is replicating its productivity improvements—not only in its own operations, but in those of its suppliers. That improves the competitiveness of both Boeing and its partners. “In order to satisfy our customers and stay in front of the competition, we have to reduce cost and improve efficiency throughout the value stream. That takes pushing ourselves as well as maximizing the potential of our global suppliers,” said Ron Shelley, vice president and leader of the company’s Global Sourcing initiative. “We can drive growth for Boeing—and for our supplier partners—through increased productivity.” In addition, Behrens (2008) documents how “Boeing has developed a supplier engagement model that involves several approaches based on the strategic importance of suppliers and their ability to improve by themselves.

In a more general article, Handfield et al (2000) suggests that the average manufacturing firm spends over 50 percent of its revenues on purchased inputs. Hence, they assert the importance of “Supplier Development” defined as “…as any activity that a buyer undertakes to improve a supplier’s performance and/or capabilities…” Sako (2004) asserts that “Supplier Development” has been an integral part of the Japanese manufacturing philosophy for several decades, and documents how it operates at Honda, Nissan and Toyota, the 3 automotive giants of Japan.

Therefore, it is evident that customers work with their suppliers in order to improve the productivity along the supply chain. Therefore, we state our hypothesis in alternate as below:
Hypothesis: There are upward productivity spillovers along the supply chain.

3. Data Description

Under FASB 14, if a customer accounts for more than 10% of a firm’s total sales, the firm is obliged to report the name and the total sales value made to that customer in the 10-K statements. This information is compiled in the COMPUSTAT Customer Segment Database. However, FASB-14 does not specify the way in which the name should be declared and so there is no uniformity in the way these customer firms are named, nor is there any identifier code. Hence the information cannot be used without significant processing and data cleaning.

To link the non-uniform names in the Customer segment database to actual firm names and come up with the firm’s cusip identifier we adopt the following method. First, a visual check identified some commonly used terms in the customer column which contained terms such as “GOVSTATE”, "2 Customers", "10 Companies" etc. Since such data items are not useful to us, they were deleted. Next, we compare the firm names given under the customer column in the customer segment database with the exact firm name obtained from the Compustat database. We compare the two sets of names by using word matching software code which analyze the individual letters of the firm names in the two datasets and arrives at the possible matches. The strength of the match is indicated in terms of percentages, with 100% being a perfect match. Due to the algorithm used, it is possible for one firm name from the Customer Segment Database to have several matches in the Compustat database. When this happens, we go through the list visually to identify the best possible match using online resources. Once the list is complete, we do a further visual check to ensure that the matches are as accurate as possible.
Next we take the names that do not have a match and do an online check to see if the names are similar to subsidiaries of public firms. For example, “Sikorsky Aircraft” is listed as a customer in the Customer Segment Database. Since this firm is not a publicly traded firm, we match it to its parent company “United Technologies Corporation”. Hence we obtain a dataset of firms with their significant customers in an adjacent column, which we will call the ‘supply chain dataset’. We use the entire Compustat database to compute the DEA variables for each firm. We merge the supply chain dataset with the DEA variables so that both the supplier firm’s and the customer firm’s DEA measures are on the same row. Finally, we obtain the control variables from Compustat.

4. Research Methodology

4.1 Data Envelopment Analysis (DEA)

DEA is a nonparametric linear programming method used in management science and economics for the estimation of productivity. Introduced by Charnes et al. (1978) and extended by Banker et al. (1984) DEA has become an important tool to estimate the relative productivity of business firms and other organizations. The popularity of DEA is because, unlike traditional parametric methods, it is not necessary to specify the underlying production function in order to measure the productivity of a firm or an entity. This popularity is demonstrated by the bibliography compiled by Emrouznejad et al. (2008) which lists 3236 publications which use DEA to deal with productivity evaluation problems in 42 countries over the period 1978–2003.

Following Banker and Natarajan (2008), we use the DEA model of Banker et al. (1984) in the first stage of the empirical analysis to estimate the productivity scores the firms in the Compustat database. We use three inputs and one output in the DEA model. The three inputs we
considered consist of cost of goods sold (CoGS, Compustat Data 41), selling and distribution (SGA, Compustat Data 189) and capital expenditure (Cap Ex, Compustat Data 128) while the output is sales revenue (Compustat Data 6). Since DEA is a relative measure that is computed relative to all other firms in the dataset, we separate our main dataset into the different industry categories and compute the DEA variable for each industry dataset separately. We use the Fama-French 12 industry classification and eliminate 3 categories (groups 8, 11 and group 12, which are utilities, financial services and ‘other’ respectively), leaving us with 10 industry specific subsets of firms.

The productivity measure of firm $j$, $\theta_j$, is computed as the reciprocal of the inefficiency measure $\Phi_j$ which is obtained from the following linear program:

$$\Phi_j = \max \Phi \quad (1.0)$$

s. t. \begin{align*}
X_{ji} \geq \sum_{j=1}^{N} \lambda_j X_{ji} & \quad i = 1,2,3 \quad (1.1) \\
\Phi Y_j \leq \sum_{j=1}^{N} \lambda_j Y_j & \quad (1.2) \\
\sum_{j=1}^{N} \lambda_j &= 1 \quad (1.3) \\
\lambda_j &\geq 0 \quad (1.4)
\end{align*}

where

$X_{ij}$: quantity of input $i$ consumed by Firm$_j$

$Y_j$: quantity of output produced by Firm$_j$

$\lambda_j$: weight placed on inputs/output of Firm$_j$

$X_{ij}, Y_j$: quantities of inputs, output for Firm$_j$ being evaluated
The linear program is solved for each observation j. Model (1) is constructed under the assumption of variable returns to scale and referred to as the BCC model of DEA (Banker et al., 1984). If a constant return to scale is maintained instead, equation (1.3) is removed and the resulting model is labeled as the CCR model of DEA (Charnes et al., 1978).

4.2. Hypothesis evaluation.

To evaluate our hypothesis regarding productivity spillovers along the supply chain, we specify and estimate following equation

\[ \text{Prods} = \alpha_0 + \alpha_1 \times \text{Prodc} + \alpha_2 \times \text{Size} + \alpha_3 \times \text{Scale} + \alpha_4 \times \text{Age} + \alpha_5 \times \text{R&D} + \text{Ind Dummies} + \varepsilon \]  

(2)

Prods denotes the productivity of the supplier, and is obtained from the DEA model in (1). Prodc, the independent variable, is the productivity of the customer and is equal to \( \theta_j \) when firm j is the customer. If our hypothesis is correct, \( \alpha_1 \) will be positive and significant. Our control variables, Size, Scale, Age and R&D expenditure are based on Bulan et al. (2008). As firms grow larger, they are expected to be more efficient due to economies of scale (Soderbom and Teal 2001; Bulan et al 2008). Past literature documents that as firms grow older, they will improve their productivity presumably with the experience they accumulate (Huergo and Jaumandreu 2004; Haltiwanger et. al. 1999; Bulan et al 2008). Industry structure and competition (Tang and Wang 2005; Rogers 2004) and research and development expenditure (Griliches 1980; Griliches 1986; Griliches and Lichtenberg 1984; Bulan et al. 2008), are other significant factors that impact productivity.

We use the log of Assets (Compustat data 6) to proxy for firm size. Scale is computed the sales (Compustat data 6) of the firm in question as a percentage of the total sales of that firm’s industry category to proxy for the competitive pressures faced by the firm. We compute firm age
by determining the year in which the firm first appeared in the COMPUSTAT database. R&D is computed as research and development expenditure of the firm (Compustat Data 46) scaled by total assets (Compustat Data 6). Finally, industry dummies are determined using the Fama-French 12 industry classification.

5. Results and discussion

We present descriptive statistics in Table 1. We obtain a data set of 7,795 data items from 1995 to 2006 onwards. The mean productivity of a customer firm is 0.8361. According to the formulation of DEA, the maximum productivity a firm can achieve is 1 and the minimum is 0. Therefore, it can be observed that firms that can be classified as customers have a productivity level at the higher end. The productivity of suppliers is somewhat lower at 0.5545. Untabulated results show that for the entire Compustat sample for this period (1995 – 2006) the mean productivity level is 0.7161. Hence, we can see that firms classified as customers have a higher than average productivity, and firms classified as suppliers have a lower than average productivity. Hence, there is more scope for productivity spillovers to occur from customers to their suppliers than in the opposite direction.

[Insert Table 1 around here]

The rest of the descriptive statistics show that supplier firms are smaller that customer firms (total assets of $ 751.44 million vs. $ 14,707.12 million), and have lower sales ($ 713.84 million vs. $ 17,240.18) have lower net income ($ 7.51 million vs. $ 672.57 million). Suppliers face more competitive pressure than customers since the competition measure is 0.000924 for suppliers vs. 0.018 for customers. Customers are generally older than suppliers. However, suppliers spend more on research and development compared to customers. This may be due to
customers being older than suppliers and so, have achieved certain levels of productivity, while suppliers which are younger firms need to spend more money to improve their productivity.

The correlations between the variables are given in Table 2. The correlation coefficients show that our dependent variable, Prods, correlates with the independent variable Prodc significantly. Furthermore, Prods significantly correlates to all of the control variables.

Next, we look at the regression analysis. When estimating model (2), we remove influential observations with studentized residuals greater than three or Cook’s D statistic greater than one (Belsley, Kuh and Welsch 1980). We also applied the Belsley, Kuh, and Welsch (1980) diagnostic to test for multicollinearity, all the condition indices were less than ten, well below the suggested cutoff of thirty. This suggests that multicollinearity is not a problem in our estimation. The Durbin-Watson test indicates that auto-correlation is not a problem as well. The results are shown in Table 3.

The results show that the customer’s productivity level is significantly related to the supplier’s productivity. This confirms our hypothesis that there are productivity spillovers along the supply chain. The rest of the control variables, except for R&D have the expected signs. However, it must be noted that Bulan et al (2008) also get a negative (albeit insignificant) result for R&D. Moreover this could be due to the interaction effects of R&D and Age as Table 2 shows that R&D and Age are significantly and negatively correlated. Therefore, smaller and younger firms which are currently at low productivity levels will tend to spend more on R&D in order to increase their productivity. Therefore, there will be a mechanical relationship between
smaller younger firms with low productivity and higher R&D expenditure. The negative relationship observed in Table 3 may be capturing that effect.

6. Conclusions

We examine the productivity spillovers along the supply chain. Using a refined version of the Custseg database from Compustat for the period 1995 – 2006, we show that productivity spillovers occur from customers to suppliers in the supply chain. To the best of our knowledge, ours is the first study to document this evidence for a broad cross section of the economy, although others have shown this result in foreign countries amongst the host country suppliers of multi-national firms.

Due to the rapid advance of Enterprise Resource Planning systems (ERP), Customer Relationship Management systems (CRM) and other supply chain management technologies, the study of the dynamics within the supply chain takes ever more importance. Productivity enhancement too, is a matter of importance to firm strategists and policy makers since the only means of continuously improving the living standards of a country is through sustained improvement of productivity. Therefore, our results which demonstrate an additional means of enhancing firm productivity will greatly interest strategic managers, and the productivity enhancements that will accrue to the entire economy will be of interest to the economic policy makers.
References


Dunning, J. 1993, Multinational Enterprises and the Global Economy. Reading: Addison Wesley,


Krugman, P., 1994, Competitiveness: A dangerous obsession, Foreign Affairs, Mar/Apr


### Table 1 - Descriptive Statistics

Panel A – Firms classified as suppliers

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Quartile</th>
<th>Median</th>
<th>Quartile</th>
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<tbody>
<tr>
<td>Prod(_c)</td>
<td>7795</td>
<td>0.836127</td>
<td>0.156707</td>
<td>0.757531</td>
<td>0.88047</td>
<td>0.95507</td>
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<td>0.554453</td>
<td>0.200702</td>
<td>0.414884</td>
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<td>0.69723</td>
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<td>Assets (MM$)</td>
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<td>53.239</td>
<td>158.511</td>
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<tr>
<td>Sales (MM$)</td>
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<td>713.8472</td>
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<td>49.083</td>
<td>141.918</td>
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<td>1.395</td>
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<td>0.022752</td>
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Panel B – Firms classified as customers

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<tr>
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<td>Assets (MM$)</td>
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<td>Sales (MM$)</td>
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| Prod\(_c\)  | Productivity of the customer |
| Prod\(_s\)  | productivity of the supplier  |
| Assets      | Total Assets of the firm in $ millions - Compustat data item 6 |
| Sales       | Sales revenue of the firm in $ millions - Compustat data item 12 |
| Net Income  | Net income earned by the firm in $ millions - Compustat data item 18 |
| Scale       | Sales of the firm scaled by the sales of all of the firms in the same industry category |
| Age         | Based on the year in which the firm first appeared in the Compustat database |
| RND         | Research and Development expenditure computed as data 46 / data 6 |
Table 2 - Correlation Coefficients

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<th>Prod&lt;sub&gt;c&lt;/sub&gt;</th>
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Variable definitions appear in Table 1.

Table 3 - Regression Analysis

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<td>AR2</td>
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Size = log of assets (Data 6), all other variable definitions appear in Table 1.