The Efficient Use of Information Technology:  
An Industry-Level Analysis

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Abstract

Despite the salience of information technology investments in many firms, industry and firm-specific variations exist in the efficient use of information technology. Recent evidence suggests that industries vary in terms of how they use information technology (IT) and that the business benefits that firms receive from IT are strongly influenced by industry factors. This research examines some of factors that influence variations in the efficient use of IT resources across industries. Using COMPUSTAT data from the years 1998-2004 and data from the Bureau of Economic Analysis (BEA) and Bureau of Labor Statistics (BLS), we apply the Data Envelope Analysis (DEA) to trace industry-level efficiency of IT capital. Subsequently, our analysis of covariates reveals that the competitive intensity of the industry, industry growth, industry outsourcing intensity, and industry capital intensity significantly influence the extent to which industries are efficient in their use of IT. We find industry growth rate has significant interactions with both industry concentration and capital intensity. More interestingly, we find contrasting results about the relationships between these factors and IT use efficiency across the services and manufacturing sectors.

Introduction

Recent evidence has suggests that industries vary in terms of how they use information technology (IT) and the business impacts that firms receive from IT are strongly influenced by these industry factors. Investigation of the economic impacts of IT spending has primarily looked at the firm-level of analysis, this paper looks at the impacts of information technology at the industry-level in order to investigate what industry factors influence differences in economic outcome resulting from IT spending. Further more this research note looks at IT form an efficiency lens, which is markedly different from the central-tendency measures commonly used in economic analysis of IT expenditure. The paper performs two analyses. First, the paper identifies key industry-level factors the impact the efficient use of IT. Second, using a exploratory approach the paper demonstrates how these factors are have very different effects in manufacturing industries compared with service industries. The findings of this note are: 1) industry concentration, outsourcing intensity, and capital intensity impact industry-level IT efficiency, 2) industry growth rate moderates the impact of industry concentration, 3) capital intensity moderates the impact of industry growth and 4) the impact of these factors vary significantly between manufacturing and services.
Concept Development

Anecdotal evidence and practitioner studies indicate that industries differ in the extent to which they use information technology as well as the effectiveness with which they leverage IT functionalities and capabilities (Farrell, 2003). This study investigates why efficiency in the use of IT resources varies across industries. Following the logic of the research question, this review will first provide an overview of existing literature on empirical industry-level IT economic studies and then provide an overview literature of possible industry-level explanatory variables. Before beginning discussions of industry-level studies it is important to discuss relevant data issues. In 1997 the U.S. census replaces the 1987 standard Standard Industrial Classification (SIC) with the North American Industry Classification System (NAICS) system which provided greater differentiation for newer industries and the change of definitions lie at the heart of the inability of researchers (Baily and Gordon, 1988; Dedrick et. al., 2003) to make definitive industry-level statements about the impact of IT spending. For example as late as 1997 researchers were unable to detect noticeable effects from IT investments and were limited to study only the manufacturing sector of the economy (Morrison, 1997).

Our study focuses upon the impact of IT spending upon efficiency at the industry-level. It is necessary to frame the focus of our study before beginning an overview of existing empirical examinations of the industry-level economic studies of IT investment. Efficiency measures (Charnes et. al, 1994) such as Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) provide measures relative to the efficiency bounds are and of central tendencies. To date most industry-level research has been central-tendency research, as that is type of research that is of most interest to economists, but we are attempting to provide a study that will have prescriptive value to managers. As a result our research will have a different focus, but the central-tendency research can be used to inform both what the approaches and data sources of the industry-level analysis of the economic impacts of IT spending are. The most recent literature review (Dedrick, et. al., 2003) provided a point of reference for the author and provides an excellent overview empirical research on the economics of IT investment at the process, firm, industry, and country-level. Empirical studies of industry-level economic impacts of IT spending can categorized as focusing on IT-producing industries and IT-consuming industries. Also studies vary widely in the degree to which they study industry level effects, as many are using the IT consuming or producing as an input factor to explain productivity effects at the macroeconomic country-level and do not provide industry-by-industry analysis. This review will focus first on industry-level studies where the primary focus is the industry-level effects, which will be referred to as industry-centric studies. Second the review will include macro-centric studies on occasion when it can inform this research as to possible data sources and relevant variables.

The first study (Gordon, 2000) to address industry-level impacts of IT looked at the difference between labor productivity between industries and found that labor productivity growth was coming in large part from the IT producing industries. The Council of Economic Advisors (2001) was the first to report differences in labor productivity between IT-intensive and non IT-intensive industries but provide detailed
analysis beyond country-level aggregates over multiple years. Bailey and Lawrence (2001) were the first to show labor productivity growth based upon intensity of IT consumption, but the paper did not present detailed regression results. Stiroh (2002) produced the first industry-centric study to show industry-by-industry level effects of IT consumption with several measures of intensity of IT consumption and showed gains beginning in 1995 for both IT-consuming and IT-producing industries. Within information systems (IS) literature the only published study (Han et. al., 2005) to use industry-level data looked at the impact of IT-services industry as a proxy for outsourcing and its impact upon productivity via a Cobb-Douglas production function using BEA data. One study (Chang and Gurbaxani, 2005) has looked at industry-level efficiency using a SFA approach and found that firms in more competitive markets use IT more efficiently. A summary of the IT-consuming studies that focus at industry level are presented in table 1.

Table 1. IT-Consuming/Industry-centric studies

<table>
<thead>
<tr>
<th>Cite</th>
<th>Data Source</th>
<th>DVs</th>
<th>IVs</th>
<th>Model</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stiroh, 2002, AER, v92 no5, pp1559-1576</td>
<td>BEA GPO &amp; capital stock data, 2-digit</td>
<td>Ln of output per employee</td>
<td>&gt;1995 dummy (D), IT Capital (C), C*D, 4 measure of intensity</td>
<td>Invest in late 1980s gains by 1995</td>
<td></td>
</tr>
<tr>
<td>Han, Kauffman, and Nault, CIST 2005</td>
<td>BEA I/O, FA, BLS</td>
<td>Output</td>
<td>Non-IT Capital, non-IT Labor, IT capital, non-IT services, IT services</td>
<td>Outsource positive for high IT, no impact for low IT</td>
<td></td>
</tr>
<tr>
<td>Chang and Gurbaxani, 2005, working paper</td>
<td>CII and Compustat</td>
<td>Mark-up ratio</td>
<td>K, L, IT, IT/L, HHI</td>
<td>Firms use IT more efficiently in more competitive markets, high market power makes less efficient</td>
<td></td>
</tr>
</tbody>
</table>

Beyond the industry-centric studies there are a series of papers that use industry-level IT investment as an input for broader analysis of macroeconomic phenomena that could inform this work in regards to potential findings, possible data sources and relevant variables. Using BEA data from 1973-1991 Stiroh (1998) found little impact on productivity in IT-using industries, but found positive impacts from IT-producing industries. Stiroh (1998) used IT capital as the measure of IT usage, but did not include a service component because the data was not available based upon the SIC coding scheme. IT contributions to industry-level were used (Basu et. al., 2001) to study aggregate gross output from 1987-1999 and found IT consuming to have positive effects after 1995. Another series of papers (Basu et. al. 2003; Van Ark and Inklaar, 2005) compared macro-level productivity effects from IT between countries using IT related industry effects as input factors to the overall productivity functions. Comparisons between U.S. and U.K. (Basu et. al. 2003) were found to be feasible. Direct industry-to-
industry comparisons were not feasible across the entire E.U. IT-producing sectors could be examined, but IT-consuming effects could only be assumed indirectly. A summary of the macro-centric IT studies are shown in table 2.

Table 2. Macro-centric IT Industry-level studies

<table>
<thead>
<tr>
<th>Cite</th>
<th>Data Source</th>
<th>DVs</th>
<th>IVs</th>
<th>Setting/Context</th>
<th>Findings</th>
</tr>
</thead>
</table>

Key points are: a) IT industry-level studies have traditionally focused upon measures of central tendency that are of great interest to economists, but turn to be less prescriptive to managers and b) few IT industry-level studies have looked at the industry-level effects of consuming IT at the industry-level, but rather have looked at the impact of IT-related industries on the macroeconomy and are thus of less interest to information systems researchers.

A search for variables that have been used in past studies as industry-level constructs was conducted. Our search progressed by 1) looking for IT-related industry-level constructs, 2) finding industry-level constructs used in economic studies, and 3) industry-level constructs used in other literature. IT-related measures consist of measures of IT-intensity and IT-outsourcing within an industry. IT-related measures are presented in table 3. All of the observed constructs can be derived using BEA capital investment and input-output tables.

Table 3. Industry related covariates

<table>
<thead>
<tr>
<th>Construct</th>
<th>Author</th>
<th>Year</th>
<th>Data source</th>
<th>Journal</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT Capital Intensity (difference in difference, absolute, &amp; relative )</td>
<td>McGuckin and Stiroh</td>
<td>2001</td>
<td>BEA</td>
<td>J. of Technology Transfer</td>
<td>Regression</td>
</tr>
<tr>
<td>IT Capital Intensity (invest rate)</td>
<td>Stiroh</td>
<td>Dec 2002</td>
<td>BEA</td>
<td>AER</td>
<td>regression</td>
</tr>
<tr>
<td>Herfindahl-Hirschman Index (HHI)</td>
<td>Hirschman</td>
<td>1964</td>
<td>BLS/BEA/COMPSTAT</td>
<td>AER</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Next, we examined existing industry-level economic variables used in industry-level studies. Measurement of industry concentration via the Herfindahl-Hirschman Index (HHI) occurs in numerous studies and is calculated by summing the squared marketshare of the firms in a market.

**Theoretic Development**

*Industrial Organizational Factors*

Industrial concentration measures the number and marketshare of major competitors in a given industry and has been the most widely studied factor in industrial organization literature. Increased concentration has been shown to correlate with both increased profitability and increased cost efficiency (Peltzman, 1971; Azzam, 1997). In line with conventional wisdom, increased profitability is believed to be the result of increased market power leading to super marginal-cost pricing. The increase in concentration results in increased ability to control prices and increased bargaining power with suppliers. Gains in IT efficiency should arise because of two factors, substitution effects coupled and optimal scale economies. Prior research on industrial organization has shown industry concentration to be a function optimal plant sizes (Weiss, 1963; Curry and George, 1983). First, firms can expand to a certain point, after which diminishing returns to scale limit the size of firms in a given industry. Second, IT has been shown to be a substitute for other factors of production (Dewan and Min, 1997). As a result of this substitution the optimal size in a given industry should increase, while the level of IT capital remains the same. Because IT exhibits increasing returns to scale the substitution of IT for other production factors this should lead to increased IT capital efficiency.

While one could argue that firms in a more concentrated industry have greater control over inputs and prices they would be less concerned with efficiency, research on the impacts of increased concentration have consistently shown positive efficiency effects when markets become more concentrated. Given the consistent results from industrial organization literature coupled with the unique nature of the increasing returns to IT capital assets we argue that:

*Hypothesis 1: Increasing industry concentration is positively associated with IT capital efficiency.*

Industrial organization literature has shown that in growing industries it is easier for new firms to enter a given market. New market entrants are more likely to use newer technology, because they are often not subject to switching costs that arise from upgrading technology. Despite the advantages of new market entrants, one could argue that in growing industries firms have greater managerial slack and can be with overly concerned with capital preservation resulting in less than optimal levels of IT investment. Also, one could argue that firms in growing industries are chasing revenue and are often not overly concerned with efficiency.
Despite the potential reasons why growth might lower efficiency, we argue that the advantages to new firms in growth industries outweigh the potentially negative factors. Research on the role of new technology in improving efficiency has also shown growth to be a key factor in explaining whether a technology will result efficiency gains (David, 1990; Akeson and Kehoe, 2007). In growing industries new capacity is often built by new firms using modern technology, but in established slow-growth industries investment is often in inferior technologies where the firms have an existing investment. For example, in a growth industry firms are likely to invest in the latest computing architecture, but in more established industries firms are more likely to make investment in legacy architecture that they already have significant investment in. This leads to the following:

**Hypothesis 2:** Increased industry growth rate is positively associated with IT capital efficiency.

According to Ghemawat and Nalebuff (1984) increased efficiency from increased concentration is related to industry expansion. Gains in efficiency attributable to growth are likely result from newer and smaller firms with a superior technological advantage lowering average cost and thus expanding the overall market. As discussed above there are potential reasons why increases in both growth and concentration could result in lower efficiency. In markets that experience both increases in concentration and increases in growth, the growth is likely result from existing firms, which are often subject to substantial switching costs to change technologies. Also these not are likely to have less concern for efficiency and concentrate on expanding to meet the increased demand. This leads to the following:

**Hypothesis 3:** Increased industry growth rate will negatively moderate the impact of increased industry concentration on IT capital efficiency.

Capital-intensive industries have several characteristics that should lower IT efficiency. First, increased capital intensity raises the barrier to entry for new firms, which in turn results in lower competition and diminished efficiency (Capon, et. al., 1990; Bharadwaj, et. al., 1999). Also, increased capital investment is also likely to take resources away from complementary investments that are necessary with IT investments (Bharadwaj, et. al., 1999). However, because IT has been shown to be a substitute for ordinary capital IT efficiency could be grater in capital intensive industries because there is a greater potential for gain though substitution. Despite the fact that IT has been shown to be a net substitute for ordinary capital in aggregate at the firm level, this does not mean that IT can always substitute for ordinary capital. It could very well be the case that in capital intensive industries, like heavy manufacturing or metal production, that the substitution of IT is quite limited. In capital-intensive industries the capital often takes the form, such as a stamping press and smelters, such that there is likely no suitable substitute. As a result in capital-intensive industries the gains from substitution are likely to be
outweighed by the cost to efficiency of lower competition and underinvestment due to resource demands of ordinary capital. This leads to the following:

**Hypothesis 4: Increasing capital intensity is negatively associated with IT capital efficiency.**

As discussed above, increased capital intensity raises the barrier to entry for new firms (Capon, et. al., 1990; Bharadwaj, et. al., 1999). New firm entry has shown to be a way in which industry efficiency improves and is likely to be even more pronounced for IT efficiency due to switching cost issues. Since increased capital intensity makes it more difficult for new firms to enter the market and that new firm entry is key to efficiency gains resulting from industry growth, this leads to the following:

**Hypothesis 5: Increasing capital intensity will negatively moderate the impact of growth on IT capital efficiency.**

**Transaction Cost Factors**

Buyer/supplier relations are a central subject of research in transaction cost economics (TCE) and have a very long history of both empirical and theoretic work (Shelanski and Klein, 1995). IT has been shown to reduce external coordination costs by improving the monitoring of suppliers (Bakos and Brynjolfsson, 1993). IT has also been shown to reduce agency costs by reducing the cost of monitoring employees, which could result in IT efficiency being greater in industries where a greater share of production is internalized. Prior research has shown that while IT does reduce internal coordination costs, it reduces external coordination costs to a greater degree (Brynjolfsson, et. al., 1994). Consistent with TCE, by reducing external coordination cost through IT, firms are more effectively able to manage suppliers and externalize inefficient internal operations (Malone, Yates, and Benjamin, 1987). Given that prior research has shown that a major benefit of IT is that it increases the ability to externalize, or outsource, inefficient operations leading to increased efficiency, this leads to the following:

**Hypothesis 6: Increasing outsourcing intensity is positively associated with IT capital efficiency.**

**Comparison of Services and Manufacturing**

Finally, we explore differences in IT efficiency between manufacturing and services. Services differ from manufacturing because of the nature of production in a service context is inherently different from production in a manufacturing context. Services exhibit the characteristics of intangibility, inseparability, and heterogeneity. Intangibility refers to the idea that services cannot be inventoried, are not readily measured, and they
do not even consume physical space (Shostack, 1977). Inseparability refers to the idea that the consumption of a service and the production of a service often occur simultaneously (Carmen and Langeard, 1980). Service production is often inseparable from consumption to such a degree that the consumer rises to the level of co-production (Parasuraman, et. al., 1985). Heterogeneity refers to the idea that services often vary from day to day and customer to customer (Parasuraman, et. al., 1985). Services and manufacturing are different in that in a service context the customer supplies key inputs to the production process (Brown, et. al. 2002). Co-production of output that is common in services necessitates a high degree of cooperation between consumer and producer. In service industries the production process is highly contingent upon the specific interactions of consumers and producers, which implies far greater uncertainty a priori in the sequence of events necessary for production of services. As a result high degree of uncertainty results from the co-production found in services (Argote, 1982; Jones, 1987).

The heterogeneity inherent in service processes manifests as variety that can be seen as a sign of the flexibility that is necessary for high quality (Feldman, 2000). In a manufacturing environment, in contrast, variation in the sequence of tasks used in production is seen as indicative of poor quality (Oakland, 1996). Empirical work on task sequencing has observed a high degree of variety in service settings (Pentland, 2003). Previous studies have shown processes to be a potential source of flexibility in organizations (Feldman and Pentland, 2003). Increasingly, information processing involves the use of workflow management systems, which are being used to define work processes in service industries (Fletcher, et. al., 2003). The ability of a service provider to deal with a wide variety of situations is a mark of high customer service (Zeithaml, et. al., 1990; Cronin and Taylor, 1994) and a key factor in retaining customers in service environments (Keaveney, S., 1995). Service workers must be capable of developing novel solutions to the often unique situations they often face. A great deal of uncertainty results from this uniqueness, often requiring a great deal of information processing and a high level of IT capital (Bowen and Ford, 2002).

Productive effects from IT investment are known to arise as a result of IT capital substituting for labor (Dewan and Min, 1997). Comparisons of manufacturing and services have long observed that substitution of capital for labor is much easier in manufacturing than in services (Baumol, 1967). As an example it takes a nurse today nearly as long to change a bandage as it did a hundred years ago, but the manufacture of most products over this time has required drastically less labor. Prior empirical work has found that manufacturing industries have greater gains in terms of productivity form IT than services (Dewan and Min, 1997). In summary, services differ strongly from manufacturing in terms of intangibility, inseparability, and heterogeneity. These differences have manifested in empirically observable differences in the effect of various input factors, both IT and non-IT, have upon productivity. Due to these substantial differences it is expected that the impact of industry factors on the efficient use of IT will vary from services to manufacturing, which leads to the following proposition:
Proposition 1: The correlation of industry-level factors on IT capital efficiency will vary significantly from manufacturing to services.

Data

The modeling approach used in this paper is a two-stage analysis. First, efficiency scores are generated using DEA analysis and next we explain the differences in efficiency using regression analysis. The explanation of the data follows the flow of the analysis. The Data for this study was collected from several sources. The data is United States industry-level data 3-digit NAICS granularity for the seven years from 1998-2004. The paper includes 43 industries per year, for a total of 301 industry-years. A summary of the data used to develop the efficiency scores is shown in table 4. All dollar denominated measures are in real-dollar terms, year 2000 dollars.

Table 4. Variables and data sources for DEA analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Data source</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITK</td>
<td>IT capital stock. Sum of hardware, software, and communication equipment in dollars.</td>
<td>BEA fixed asset tables</td>
<td>Input</td>
</tr>
<tr>
<td>ITO</td>
<td>IT outsourcing. Sum of industries 5415 “Computer systems design and related services” and 514 “Information and data processing services” in dollars</td>
<td>BEA input-output accounts</td>
<td>Input</td>
</tr>
<tr>
<td>K</td>
<td>All non-IT capital stock in dollars.</td>
<td>BEA fixed asset tables</td>
<td>Input</td>
</tr>
<tr>
<td>L</td>
<td>Labor expenditure in dollars.</td>
<td>BEA input-output accounts</td>
<td>Input</td>
</tr>
<tr>
<td>M</td>
<td>Sum of all non-IT outsourcing in dollar terms.</td>
<td>BEA input-output accounts</td>
<td>Input</td>
</tr>
<tr>
<td>YE</td>
<td>Output per employee. Y/E</td>
<td>BEA input-output accounts, BLS Industry employment tables.</td>
<td>Output</td>
</tr>
<tr>
<td>VAE</td>
<td>Value added per employee VA/E. An industry-level proxy for profitability.</td>
<td>BEA input-output accounts, BLS Industry employment tables.</td>
<td>Output</td>
</tr>
</tbody>
</table>

A description of the covariates to explain the efficiency scores obtained in the DEA step and control variables are shown in tables 5 and 6.

Table 5. Covariates used to explain efficiency scores.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHI</td>
<td>Herfindahl-Hirschman Index. A measure of industry concentration. $HHI_j = \sum_{i=1}^{n} m_{i,j}^2$, where n is the number of firms in the industry and $m_{i,j}$ is the marketshare of the ith firm in the jth industry.</td>
<td>COMPUSTAT</td>
</tr>
</tbody>
</table>
The industry concentration measures were calculated from COMPUSTAT because the more often used industry concentration measures from the US Economic Census are only calculated for manufacturing industries. We calculated the growth rates as one-year estimates for two reasons. First, the NAICS data we used starts in 1997, prior to that the industry data was calculated using the SIC scheme. Second, as discussed in the theory section the entry is key to our argument and this is best studied using contemporaneous growth rates (Hause and Du Rietz, 1984; Bloch, 1981). Consistent with prior literature the outsource intensity measures used are the level of outsourcing in dollar terms relative to the level of gross output (Feenstra and Hanson, 1996). Capital intensity measures are measured in dollar per employee terms (Stiroh, 2002). The control for time is an integer from 0 to 6.
DEA efficiency

The first step in our analysis was to obtain efficiency scores for each industry-year using data envelopment analysis (DEA). DEA measures offer several advantages. First, DEA measures are inherently prescriptive, as opposed to the descriptive nature of central-tendency measures such as ordinary least squares regression. Second, DEA allows for the combination of multiple inputs and multiple outputs into a single virtual input and a single virtual output. DEA has become an increasingly important means to investigate efficiency due to the flexibility it provides. DEA provides a means to include multiple output measures and requires no statistical assumptions be made about the data. We calculated the efficiency scores over 61 industries for each of the seven years available on a year-by-year basis in order to make comparisons across years and to control for changes attributable to differences in macroeconomic conditions. The DEA efficiency scores were calculated using the Banker/Charnes/Cooper (BCC) formulation (Banker, et. al., 1984). The DEA analysis used was a convex hull, output-oriented, variable returns to scale (VRS) formulation. We chose to use a VRS implementation in order to account for the scale differences between industries. Resulting from the DEA is a set of slacks for each input term. The resulting slacks are used to obtain an efficiency score, in percentage terms, for the IT-related input factor of IT capital.

Covariate analysis

We performed the covariate analysis using OLS regression. Recent research has shown OLS applied in the second stage of a DEA efficiency analysis to be a superior approach to either a parametric approach, such as stochastic frontier, or a Tobit regression on the second stage of a DEA score for analysis of the impact of exogenous covariates on efficiency (Banker and Natarajan, 2007). The approach this paper takes has been successfully applied to efficiency analysis in other contexts (Ray, 1991). After obtaining efficiency scores for all industry/years, the service and manufacturing industries were separated from the whole data set for analysis. We compared manufacturing industries, those with NAICS codes in the 300s, to pure service firms. Although transportation and wholesale/retail trade is sometimes considered a service, they were not included because they do not meet the classic criteria of a service. Transportation and retail/wholesale trade involve inventory, thus do not meet the intangibility criteria of a service. Also, they typically involve a low degree of heterogeneity in production relative to pure services such as consulting or food service. As a result, the study defines services as NAICS codes 511 through 81. Three regressions were used. The first model consists of the IT capital efficiency score regressed against the market concentration ratio, industry growth rate, an interaction between industry growth and industry concentration, outsource-intensity, and capital intensity. The second model is same as the first, but also contains a binary indicator for service industries. The third model is an exploratory model used to develop separate estimates of effects of each of the factors in the main model of manufacturing and services. Endogeneity was controlled for using IT capital intensity and time was controlled for using an integer representing the year. The equations are used are as follows:
The purpose of this study is to investigate why efficiency in the use of IT resources varies across industries. Due to the cross-sectional nature of the data we checked for heteroskedasticity using the White Heteroskedasticity Test with cross-terms on all regressions and corrected for it using White Heteroskedasticity-Consistent Standard Errors (WHCSE) where indicated. Finally the IT efficiency scores were highly left-skewed, which was corrected using an inverse-log transformation. All regressions were performed in STATA. Regression results are shown in table 7.

**Table 7. Regression Results**

<table>
<thead>
<tr>
<th></th>
<th>I: Base Model</th>
<th>II: Model with Services</th>
<th>III: Model with Separate Coefficients for Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry Concentration</td>
<td>0.17 (.11)***</td>
<td>0.17 (0.11)***</td>
<td>-0.33 (0.31)**</td>
</tr>
<tr>
<td>Industry Growth Rate</td>
<td>0.10 (3178.03)*</td>
<td>0.10 (3171.3)*</td>
<td>-0.34 (7547.04)**</td>
</tr>
<tr>
<td>Growth/Concentration Interaction</td>
<td>-0.13 (1.24)**</td>
<td>-0.13 (1.25)**</td>
<td>0.49 (4.16)**</td>
</tr>
<tr>
<td>Capital Intensity</td>
<td>-0.18 (20.69)**</td>
<td>-0.18 (20.67)**</td>
<td>0.98 (36.04)***</td>
</tr>
<tr>
<td>Growth/Capital Interaction</td>
<td>-0.10 (197.51)*</td>
<td>-0.10 (197.85)*</td>
<td>0 (281.37)</td>
</tr>
<tr>
<td>Outsourcing Intensity</td>
<td>.15 (1938.47)**</td>
<td>0.16 (2073.24)**</td>
<td>-0.47 (4550.01)***</td>
</tr>
<tr>
<td>Services Binary</td>
<td>N/A</td>
<td>0.01 (536.38)</td>
<td>-1.71 (2879.35)***</td>
</tr>
<tr>
<td>Industry Concentration in Serv.</td>
<td>N/A</td>
<td>N/A</td>
<td>0.48 (0.33)***</td>
</tr>
<tr>
<td>Industry Growth Rate in Serv.</td>
<td>N/A</td>
<td>N/A</td>
<td>0.46 (8096.67)***</td>
</tr>
<tr>
<td>G/HHI Interaction in Serv.</td>
<td>N/A</td>
<td>N/A</td>
<td>-0.6 (4.25)***</td>
</tr>
<tr>
<td>Capital Intensity in Serv.</td>
<td>N/A</td>
<td>N/A</td>
<td>-1.22 (38.27)***</td>
</tr>
<tr>
<td>G/K Interaction in Serv.</td>
<td>N/A</td>
<td>N/A</td>
<td>-0.01 (350.91)***</td>
</tr>
<tr>
<td>Outsourcing Intensity in Serv.</td>
<td>N/A</td>
<td>N/A</td>
<td>1.14 (5037.99)***</td>
</tr>
<tr>
<td>IT Capital Intensity</td>
<td>-0.10 (43.52)</td>
<td>-0.10 (44.81)</td>
<td>-7.63 (494.41)***</td>
</tr>
<tr>
<td>IT Capital Intensity in Serv.</td>
<td>N/A</td>
<td>N/A</td>
<td>7.8 (496.41)***</td>
</tr>
<tr>
<td>Year</td>
<td>.01 (122.36)</td>
<td>0.02 (122.79)</td>
<td>-0.04 (104.63)</td>
</tr>
</tbody>
</table>

F = 5.41  4.82  42.62
Prob > F = 0.00  0.00  0.00
R-squared = 0.12  0.12  0.39
Root MSE = 4113.80  4120.80  3462.40

Note: + in model 3 these represent the values in manufacturing.
*,**,*** indicate significance at p=.10, .05, .01 respectively

The results from the base model indicate increased industry concentration and outsourcing intensity are positively correlated with increased IT efficiency. Industry
growth rate was not a significant covariate, but was positively correlated with IT capital efficiency. The interaction between industry concentration and industry growth rate was significant and negatively correlated. Results from base model also indicate that neither of the control factors, IT capital intensity and time, did not have significant effects. Overall model fit was good. Model two results with a binary variable for service industries do not indicate significant differences in IT capital efficiency between services and manufacturing and findings were consistent with the base model. The summary of findings is shown in table 8 and 9.

Table 8. Summary of findings for main models I & II

<table>
<thead>
<tr>
<th>Covariate</th>
<th>Findings</th>
<th>Support?</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1: Increasing industry concentration is positively associated with IT capital efficiency.</td>
<td>Significant at 1%</td>
<td>Yes</td>
</tr>
<tr>
<td>H2: Increasing industry growth is positively associated with IT capital efficiency.</td>
<td>Significant at 10%</td>
<td>Partial</td>
</tr>
<tr>
<td>H3: Increased industry growth rate will negatively moderate the impact of increased industry concentration on IT capital efficiency.</td>
<td>Significant at 5%</td>
<td>Yes</td>
</tr>
<tr>
<td>H4: Increasing capital intensity is negatively associated with IT capital efficiency.</td>
<td>Significant at 5%</td>
<td>Yes</td>
</tr>
<tr>
<td>H5: Increasing capital intensity will negatively moderate the impact of growth on IT capital efficiency.</td>
<td>Significant at 10%</td>
<td>Partial</td>
</tr>
<tr>
<td>H6: Increasing outsourcing intensity is positively associated with IT capital efficiency.</td>
<td>Significant at 5%</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 9. Summary of findings for proposition 1/model 3

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Manufacturing</th>
<th>Services</th>
<th>Support?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry Concentration (HHI)</td>
<td>Negative, significant at 5%</td>
<td>Positive, significant at 1%</td>
<td>Yes</td>
</tr>
<tr>
<td>Industry Growth (GROW)</td>
<td>Negative, significant at 5%</td>
<td>Positive, significant at 1%</td>
<td>Yes</td>
</tr>
<tr>
<td>Growth interaction with Concentration (GROWHHI)</td>
<td>Positive, significant at 5%</td>
<td>Negative, significant at 1%</td>
<td>Yes</td>
</tr>
<tr>
<td>Capital Intensity (KINT)</td>
<td>Positive, significant at 1%</td>
<td>Negative, significant at 1%</td>
<td>Yes</td>
</tr>
<tr>
<td>Capital Concentration interaction with Growth (GROWKINT)</td>
<td>Effect not significant</td>
<td>Effect not significant</td>
<td>No</td>
</tr>
<tr>
<td>Outsource Intensity (OINT)</td>
<td>Negative, significant at 1%</td>
<td>Positive, significant at 1%</td>
<td>Yes</td>
</tr>
<tr>
<td>IT Capital Intensity (ITKINT)</td>
<td>Negative, significant at 1%</td>
<td>Positive, significant at 1%</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Limitations

This study is not without limitations. There are four primary limitations to this study. The first limitation is that since the study included service industries the industry concentration was induced from COMPUSTAT, rather than from the Economic Census. Secondly, this study is of a rather limited time frame. While IT assets data is available through the industry accounts back until the 1960s, two factors make use of this data inappropriate. The industry accounts were redefined from SIC to NAICS in 1997, which can bias comparisons between time periods. Prior to 1998 the make-use industry-level accounts were not available, thus important factors such as IT and non-IT related outsourcing could not be included in the study. Thirdly, this study looks at IT capital, but does not provide a more detailed breakdown of IT assets. Finally, the study does not partial out effects from IT labor separate from overall labor expenditure.

Implications for Research

Our research has provided researchers with a better understanding of what industry-level factors impact the efficient use of IT. The research filled an important literature gaps in several ways. First, this study examined using a frontier lens rather than a central-tendency lens. The frontier-based lens is useful in that it is both prescriptive and can accommodate situations where multiple objectives are feasible. Second, this study looked at IT use from an industry-level. Despite the much literature to suggests that firms often base IT investment decisions upon within-industry benchmarking and that industry factors play a critical role in how IT is used, little was know about what these industry-level factors were. Finally, this study provided empirical evidence that services and manufacturing vary considerable in how industry-factors relate to the effective use of IT.

Implications for Managers

Recent evidence from practice suggest that companies often benchmark IT practices using within-industry comparisons and that cross-industry comparisons are much more useful (Cullen, 2007). This study outlined industry-level forces that impact how effectively IT is used in a given industry and that can help managers understand how IT use varies across industries due to these factors. This study has four main findings for managers. First, industry concentration, industry growth, the outsourcing-intensity of the industry, and the capital intensity of the industry all critically impact how effectively IT is used in a given industry. Second, industry growth and industry concentration have important interactions that also impact how effectively IT is used in a given industry. Third, the capital intensity of an industry reduces the benefits of higher industry growth. Finally, manufacturing and services are influenced in radically different ways by these industry forces.

Future Research

Areas of future research include performing efficiency analysis at a more granular level such as firm-level, performing a more longitudinal analysis such as a Malmquist, and
using the disaggregated measures of IT capital provided in the BEA industry accounts to discover differential effects from different types of IT capital. Also, further investigation in terms of both theory and empirical analysis is needed to explain as to why manufacturing and services seem to vary so drastically in terms of effects from IT.

Conclusion
This research explored several under investigated aspects of the impacts of information technology spending. First, this paper examined the efficient use of IT, most prior studies use central-tendency measure to examine the impacts of IT on average. Second, this paper identified several industry-level factors that impact the efficient of IT. Finally, this paper disaggregated industries and showed that industry concentration has different effects on services compared with manufacturing. The paper represents a significant step forward on those fronts. The paper performs two analyses. First, the paper identifies key industry-level factors the impact the efficient use of IT. Second, using a exploratory approach the paper demonstrates how these factors are have very different effects in manufacturing industries compared with service industries. The findings of this note are: 1) industry concentration, growth, outsourcing intensity, and capital intensity impact industry-level IT efficiency, 2) industry growth rate moderates the impact of industry concentration, 3) capital intensity moderates the impact of growth and 4) the impact of these factors vary significantly between manufacturing and services.
Works Cited


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