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Research Note

Returns to Information Technology Outsourcing

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This study extends existing information technology (IT) productivity research by evaluating the contributions of spending in IT outsourcing using a production function framework and an economywide panel data set from 60 industries in the United States over the period from 1998 to 2006. Our results demonstrate that IT outsourcing has made a positive and economically meaningful contribution to industry output and labor productivity. It has not only helped industries produce more output, but it has also made their labor more productive. Moreover, our analysis of split data samples reveals systematic differences between high and low IT intensity industries in terms of the degree and impact of IT outsourcing. Our results indicate that high IT intensity industries use more IT outsourcing as a percentage of their output, but less as a percentage of their own IT capital, and they achieve higher returns from IT outsourcing. This finding suggests that to gain greater value from IT outsourcing, firms need to develop IT capabilities by intensively investing in IT themselves. By comparing the results from subperiods and analyzing a separate data set for the earlier period of 1987–1999, we conclude that the value of IT outsourcing has been stable from 1998 to 2006 and consistent over the past two decades. The high returns we find for IT outsourcing also suggest that firms may be underinvesting in IT outsourcing.

Key words: economic analysis; industry analysis; information technology; IT impacts; IT intensity; IT outsourcing; output elasticity; production function; production theory; productivity
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1. Introduction

Information technology (IT) outsourcing refers to the use of a third-party vendor to provide IT services that were previously provided internally (Lacity and Hirschheim 1995). The most common areas for IT outsourcing include systems development and integration, software maintenance and support, hardware maintenance and support, and data processing and management. Despite the sluggish economy in the early part of the decade, IT outsourcing has been growing steadily. A report by Gartner (De Souza et al. 2007) indicates that the IT services market is expected to grow from US$674.1 billion in 2006 to US$964.4 billion in 2011. According to a survey by *InformationWeek* (2006), on average, U.S. firms spent 14.7% of their IT budget on IT outsourcing in 2006.

Most prior studies on IT outsourcing have focused on outsourcing practices and decisions. Studies that examined the performance of IT outsourcing have mainly relied on anecdotal evidence or practitioners' perceptions. Although these studies provide insights into the factors affecting firms' outsourcing decisions and outsourcing success, they mostly use cross-sectional data collected at a single point in time. Our industry-level panel data cover a greater proportion of the economy—60 of 61 U.S. industries—and include more degrees of freedom, less multicollinearity, and greater variation, resulting in greater efficiency of the estimators (Hsiao 2003). This gives us greater opportunity to assess the impacts of IT outsourcing on objective performance measures, such as output and productivity.

The purpose of our study is to estimate the value of IT outsourcing using recent U.S. industry-level data as a means of providing insight for decision making on IT spending. Over the past two decades, many IT researchers have studied IT investments at the firm, sector, and country levels, using a production function framework with IT capital treated as an input to production and its value measured in terms of contributions to output and productivity. We build on this literature by separating IT outsourcing expenditures as an input to production, and we estimate the contributions of IT outsourcing to industry output and labor productivity. To understand under what conditions IT outsourcing is likely to create greater value, we also investigate how an industry's IT intensity influences its use of IT outsourcing, as well as the value it captures from IT outsourcing.

Our results indicate that IT outsourcing has made positive and economically meaningful contributions to output and productivity in U.S. industries over the period from 1998 to 2006. We find that IT outsourcing adds substantially greater value to the U.S. economy compared to outsourcing in other areas and is consistent with the prediction that IT outsourcing will increase substantially. The high returns to IT outsourcing we report suggest that firms may be underinvesting in IT outsourcing.

Our results for a split analysis of industries based on their IT intensity reveal systematic differences across industries with respect to benefits from IT outsourcing. We find that high IT intensity industries not only use more IT outsourcing as a percentage of their output but also generate higher returns from IT outsourcing. This is despite using less IT outsourcing as a percentage of own IT capital, indicating that greater use of IT may provide capabilities that can be used to obtain greater value from IT outsourcing. After analyzing a separate data set for the earlier period of 1989–1999, we found that our results extend through the last two decades.

The rest of the paper is organized as follows. Section 2 reviews the related literature. Section 3 presents the production function framework and develops our empirical model. Section 4 describes our data set and the estimation procedure. In §5, we present our empirical findings, conduct additional analyses, and provide theory-based explanations for the results. Finally, §6 discusses our contributions and concludes the paper.

2. Related Literature

2.1. IT Investments and Productivity

Since the mid-1990s, a large number of studies in information systems (IS) and economics have examined the contribution of IT investments to economic performance at the firm (e.g., Brynjolfsson and Hitt 1995, 1996), industry (e.g., Gordon 2000, Oliner and Sichel 2000), and country levels (e.g., Dewan and Kraemer 2000). Most found a positive relationship between IT investments and economic performance.

A common approach used to model the relationship between IT and economic performance is the production function framework. It relates the output of a firm to the inputs consumed. In this approach, IT capital is treated as an input in the production function, along with labor and non-IT capital, and the contribution of IT is measured by the output elasticity of IT capital. Although a production function is a firm-level concept, it has been used for industry-level and country-level studies (e.g., Cheng and Nault 2007, Dewan and Kraemer 2000). Most IT productivity studies have measured returns to IT investments focusing on IT capital, with the exception of Brynjolfsson and Hitt (1995, 1996), who measured the returns to IT labor and the returns to the sum of IT capital and IT labor at the firm level. However, as firms rapidly grow their spending in IT outsourcing, it becomes increasingly important to take IT outsourcing into account when measuring returns to IT investments. Otherwise, the measured returns are to in-house IT capital only, rather than to total IT investments.

2.2. Services Outsourcing

With the growing importance of services outsourcing in today's economy, researchers have begun to examine the related economic impact (e.g., Olsen 2006). Most studies use a production function framework, treat services outsourcing as an intermediate input in a production function, and measure value based on the contribution that outsourcing makes to output or productivity growth. Some studies have found evidence of a significant productivity impact of services outsourcing. For example, Amiti and Wei (2009) found that foreign services outsourcing, but not materials outsourcing, contributed to higher labor productivity in U.S. manufacturing industries. Similarly, ten Raa and Wolff (2001) found that productivity growth in U.S. manufacturing industries was positively related to increased use of services outsourcing. Other studies did not find significant results. For example, Siegel and Griliches (1992) did not find a significant relationship between post-1979 improvement in manufacturing productivity growth and an increase in services outsourcing. Also, Fixler and Siegel (1999) reported that outsourcing actually led to short-run reductions in services sector productivity.

These mixed results indicate that the productivity impact of services outsourcing depends on country, industry, and firm-specific characteristics (Olsen 2006). The mixed results may also occur because these studies analyzed services in the aggregate, so that differences between types of services may disappear in the process of averaging. Abraham and Taylor (1996) found that firms differ in their reasons for outsourcing different types of services. Firms tend to outsource less-skilled services, such as janitorial work, to take advantage of low-wage rates, for example. In contrast, they contract out higher-skilled services, such as engineering or IT services, to benefit from the economies of scale accruing to specialized vendors. Thus, realized value can differ across different types of services (Bartel et al. 2006).

2.3. IT Outsourcing

Prior IT outsourcing studies have focused on the determinants of firms' outsourcing decisions. These studies use two major theories: production economics and transaction cost economics. In production economics, IT outsourcing creates value for firms because of the production cost advantages offered by vendors (e.g., Ang and Straub 1998, Loh and Venkatraman 1992). Vendors can produce IT services at lower costs than firms' internal IT departments because they can achieve economies of scale, economies of scope, and economies of specialization (Clemons et al. 2001). Although IT outsourcing is considered as a way to reduce costs, these cost reductions directly impact output and productivity. This is because when there is a change in the cost structure by substituting IT outsourcing for capital and labor, there is a change in the marginal cost of output from using a different input mix. Consequently, there is also a change in output for the profit-maximizing firm. As such, if IT outsourcing changes the cost structure of the firm, then it also changes output levels and productivity.

Recent studies suggest that IT outsourcing can also provide strategic benefits by providing new capabilities and bringing about fundamental transformations in customer organizations (Linder 2004). For example, Levina and Ross (2003) find that a vendor's comparative advantages stem from the set of core competencies and complementarities that it has developed over time. These advantages of IT outsourcing come at the expense of transaction costs (Williamson 1985) associated with outsourcing, which include vendor search and contracting costs, transition costs, and managing costs (Aubert et al. 2004). Most of these are "hidden costs" involved in making contracts and transactions with other organizations, as they may be hard to foresee before firms enter IT outsourcing agreements (Barthelemy 2001).

To date, relatively little attention has been paid to studying the value of IT outsourcing. Studies that have examined performance have mainly employed perceptual measures, such as managers' satisfaction (e.g., Grover et al. 1996, Lee and Kim 1999) and the degree to which the expected objectives have been achieved (e.g., Lacity and Willcocks 1998). Most have found significant impacts of IT outsourcing. For example, Levina and Ross (2003) described a firm that realized estimated cost savings of more than US$1 million in data center processing costs, and Lacity and Willcocks (2000) reported that most of their respondents from the United States and United Kingdom realized the benefits they expected from IT outsourcing. More recently, a few studies have measured the value of IT outsourcing by using stock market returns data (e.g., Agrawal et al. 2006) and found that IT outsourcing announcements are associated with positive abnormal returns.

There are several reasons why IT outsourcing can create value, despite the transaction costs involved. First, with the growth of IT outsourcing, competition is increasing among outsourcing providers. Although vendors' production cost advantages over firms' internal IT departments have become larger as vendors develop new competencies over time (Levina and Ross 2003), some vendors' cost advantages benefit their IT outsourcing clients because of greater competition, although the vendors are unavailable to fully appropriate the returns they are due. Second, firms learn from their own or others' experiences in IT outsourcing. Consequently, this learning helps reduce transaction costs and increase the value they can capture. Firms can reduce the hidden costs by choosing activities that are safe to outsource, carefully researching vendors, and drafting tight contracts (Barthelemy 2001). They also can reduce transaction risks by redesigning work flows and dividing work among multiple vendors (Aron et al. 2005) and by backsourcing some of the outsourced IT activities that can be better performed in-house (Benaroch et al. 2010).

Third, advances in information and communication technologies have made it easier to coordinate with vendors and monitor their performance (Banker et al. 2006), thereby further reducing transaction costs. In sum, these studies indicate that transaction costs are decreasing and that firms are increasingly capturing value from IT outsourcing.

3. Our Productivity Framework for IT Outsourcing

Among the various production function forms, the Cobb-Douglas form has been the most widely used because it is simple, fits production data well, and, in log form, has parameter estimates that are directly interpretable as output elasticities. Cobb-Douglas forms have been used in the IT productivity literature (Brynjolfsson and Hitt 1996, Cheng and Nault 2007, Dewan and Min 1997, Dewan and Kraemer 2000), as well as in the services outsourcing literature (Olsen 2006).

Although a production function is a firm-level concept, it has been applied to the industry, sector, and country levels. Aggregate production functions have been used extensively in economics and have been shown to work well, as long as the input shares are relatively stable over time (Fisher 1971). In particular, the aggregate Cobb-Douglas production function has been shown to be robust to relatively large variations in the input shares (Felipe and Holz 2001).

In our analysis, we treat IT outsourcing as an intermediate input consumed in production. An industry's intermediate inputs are the outputs of other industries used by the industry as inputs and include energy, materials, and services. We measure IT outsourcing as *purchased IT services*: the value of intermediate inputs from industries that provide IT services. To measure the contribution of IT outsourcing to output, we use an extended Cobb-Douglas production function form,

$$Y = AK^{\alpha}L^{\beta}M^{\gamma}Z^{\delta}X^{\omega}.$$

Here, Y is gross output, and K, L, and M are non-IT capital, labor, and non-IT services intermediate inputs, respectively. Z is IT capital, and X is IT services intermediate inputs, which we refer to hereafter as IT outsourcing. A is a technological change parameter capturing multifactor productivity (MFP), and α, β, γ, δ, and ω are output elasticities for non-IT capital, labor, non-IT services intermediate inputs, IT capital, and IT outsourcing, respectively.

In the IT productivity literature, IT outsourcing has been embedded in the intermediate inputs, whether intermediate inputs are measured explicitly (e.g., Cheng and Nault 2007) or implicitly, where output is measured as value added. Separating IT outsourcing from the rest of the intermediate inputs allows us to measure the former's contribution as an input, just as we measure the contribution of IT capital. Because we have intermediate inputs in the production function, we use gross output as output. For our estimation, we take the natural log of our extended Cobb-Douglas form to create an additive form,

$$y = a + \alpha k + \beta l + \gamma m + \delta z + \omega x.$$

Each lowercase variable represents the log of the corresponding uppercase variable. Among the parameters, ω represents the average percentage increase in gross output associated with a 1% increase in spending in IT outsourcing, and similarly for the other parameters and their associated variables. By assuming that firm-level production functions can be represented using our Cobb-Douglas form, we can use this form to estimate industry-level output elasticities as an aggregate of the firms in the industry.

To measure the contribution of IT outsourcing on productivity, we transform the production function into a labor productivity equation by dividing both sides by labor L. Assuming constant returns-to-scale (i.e., $\alpha + \beta + \gamma + \delta + \omega = 1$), we get

$$\frac{Y}{L} = A\left(\frac{K}{L}\right)^{\alpha}\left(\frac{M}{L}\right)^{\gamma}\left(\frac{Z}{L}\right)^{\delta}\left(\frac{X}{L}\right)^{\omega}.$$

The left-hand side variable represents labor productivity in terms of output per labor hour, and each right-hand side variable represents the corresponding input per labor hour. Taking the natural log, we get

$$\hat{y} = a + \alpha\hat{k} + \gamma\hat{m} + \delta\hat{z} + \omega\hat{x}.$$

Each lowercase variable with a hat represents the log of the corresponding uppercase variable divided by labor hours.

4. Data and Methods

4.1. Data and Variables

We used annual data for 60 nonfarm industries in the U.S. private sector provided by the Bureau of Labor Statistics (BLS) and the Bureau of Economic Analysis (BEA) for the period of 1998–2006. The entire private sector of the U.S. economy consists of 61 industries. These industries are based on the 1997 North American Industry Classification System (NAICS) and are at the three-digit level. We excluded the Farm industry (NAICS 111-112) because data on IT outsourcing are not available (see Online Appendix A for a list of sectors and industries[1]). Table 1 provides details of the sources, construction procedure, and deflators used. We used *chain-type quantity indices* as deflators to show the growth of output or other variables over time, holding prices constant. We obtained real values by multiplying nominal values from the year 2000 by the chain-type quantity indices.

For industry *output* and total *intermediate inputs*, we used annual industry account data from the BEA. We constructed our *labor* variable by multiplying the number of full-time equivalent employees by the average work hours of 2,080 hours, provided by the BLS. To calculate IT and non-IT capital stock, we used the BEA's Fixed Assets Tables. For *IT capital*, we aggregated the net stock of private fixed assets in the category of "information processing equipment and software," as defined by the BEA. These assets are computer and peripheral equipment, communications, instruments, photocopy and related equipment, office and accounting equipment, and software.[2] This measure of IT capital is broader and more comprehensive than the measures used in

[1] An electronic companion to this paper is available as part of the online version that can be found at http://isr.journal.informs.org/.

[2] Three types of software are treated as investments that comprise IT capital stock: prepackaged software, custom software, and own-account software (Parker and Grimm 1999). *Own-account*

Table 1 **Data Sources and Construction Procedure**

Variable	Source	Construction procedure	Deflator
Output (Y)	BEA Annual Industry Account	Gross output by industry converted to 2000 U.S. dollars.	Chain-type quantity index for output from BEA
IT capital (Z)	BEA Fixed Asset Data	Net stock of information processing equipment and software by industry converted to 2000 U.S. dollars.	Chain-type quantity index for fixed assets by type from BEA
Non-IT capital (K)	BEA Fixed Asset Data	Net stock of private fixed assets, excluding information processing equipment and software by industry converted to 2000 U.S. dollars.	
Labor (L)	BEA Annual Industry Account	Total full-time equivalent employees by industry multiplied by average annual work hours (2,080 hours).	None
IT outsourcing (X)	BEA KLEMS Intermediate Use Estimates	Sum of an industry's intermediate inputs purchased from NAICS 5142 and NAICS 5415. Converted to 2000 U.S. dollars.	Chain-type quantity index for KLEMS intermediate inputs from BEA
Non-IT services Intermediate inputs (M)	BEA Industry Input-Output Account (Use Tables)	An industry's total intermediate inputs from the Use Table, excluding purchased IT services. Converted to 2000 U.S. dollars.	Chain-type quantity index for KLEMS intermediate inputs from BEA

some previous studies. The *non-IT capital* data were obtained by subtracting the IT capital stock from the total net stock of private fixed assets. For our capital measures, we used "productive stocks," which measure the income-producing capacity of the existing stock during a given period, rather than "wealth stocks," which measure the current market value of the assets in use (Oliner and Sichel 2000, Stiroh 2002).

Ideally, we would prefer flow measures of IT and non-IT capital rather than stocks to use with output, intermediate inputs, and labor. However, flow measures do have weaknesses because the process of converting capital stocks into capital service flows involves several assumptions. We usually cannot obtain direct measures of the prices or quantities of capital service flows (Harper 1999). A number of studies have used capital stock measures together with flow variables, such as labor and intermediate inputs (Brynjolfsson and Hitt 1996, Cheng and Nault 2007, Dewan and Min 1997, Mittal and Nault 2009, Oliner and Sichel 2000). Those studies that used both stock and flow variables for IT capital found that the results are similar (e.g., Kudyba and Diwan 2002).

To obtain data on IT outsourcing, we use capital, labor, energy, materials, and purchased services (KLEMS) intermediate use estimates for the period from 1998 to 2006 from the BEA. These estimates show the value of output produced by one industry purchased and used by another industry for each pair of industries in the economy. We measure an industry's *IT outsourcing* as the services the industry purchases from two IT services industries: Data Processing Services (NAICS 5142) and Computer Systems Design and Related Services (NAICS 5415). The intermediate input data include imports from other countries, so our IT outsourcing measure captures both domestic and offshore IT outsourcing. Also, our IT outsourcing measure includes intraindustry purchases of IT services for the two IT services industries: NAICS 5142 and NAICS 5415.[3] We calculate *non-IT services intermediate inputs* by subtracting

software investment includes compensation for in-house computer programmers and systems analysts engaged in the production of software not embedded in equipment that is to be sold or software produced for sale. *Custom software* includes new computer programs, as well as programs incorporating preexisting or standardized modules, developed by third-party organizations/individuals. However, expenditures on repair and maintenance (e.g., Y2K and other emergency fixes, routine debugging and recoding to accommodate changes to input data), and employees' training on software (unless part of a package deal) are treated as intermediate inputs and, hence, are included in IT outsourcing. Purchased software that gets embedded in hardware and then resold is treated as an intermediate input as well. As the expenditures for developing new custom programs are captured by IT capital, our IT outsourcing measure understates industries' spending on IT outsourcing.

[3] *NAICS 5142: Data Processing Services* industry comprises establishments primarily engaged in providing electronic data processing services. These establishments may provide complete processing and preparation of reports from data supplied by customers; specialized services, such as automated data entry services; or may make data processing resources available to clients on an hourly or time-sharing basis (http://www.census.gov).

NAICS 5415: Computer Systems Design and Related Services industry comprises establishments primarily engaged in providing IT expertise through one or more of the following activities: (1) writing, modifying, testing, and supporting software to meet the needs of a particular customer; (2) planning and designing computer systems that integrate computer hardware, software, and communication

Table 2 Summary Statistics: 60 Industries in the United States (1998–2006)

Data series	Mean	Std. dev.	Min.	Max.	Percentage of output
Output (in millions of 2000 U.S. dollars)	274,081.3	292,705.3	24,312.3	1,879,325.0	100.00
IT capital (in millions of 2000 U.S. dollars)	22,864.0	39,110.2	684.0	273,019.5	8.30
Non-IT capital (in millions of 2000 U.S. dollars)	138,753.4	173,401.3	3,546.8	1,076,126.0	50.60
Labor (in millions of work hours)	3,572.1	4,914.0	74.9	28,749.8	NA
IT outsourcing (in millions of 2000 U.S. dollars)	1,749.8	2,080.0	4.4	10,770.9	0.64
Non-IT services Intermediate inputs (in millions of 2000 U.S. dollars)	125,168.5	115,907.6	7,530.1	569,781.1	45.67

IT outsourcing from total intermediate inputs (see Online Appendix B for the correlations and collinearity diagnostics for our data).

Our summary statistics in Table 2 indicate that in base year dollars, on average, a single U.S. industry spent approximately US$1.7 billion per year in IT outsourcing, and there is substantial variation in industries' annual spending in IT outsourcing, ranging from US$4.4 million to US$10.8 billion.

Figure 1 shows the total IT outsourcing that we calculated from the intermediate input data for U.S. industries over the period from 1998 to 2006 in base year dollars. IT outsourcing increased until 2000, reaching approximately US$104 billion. We believe that this increase partially reflects firm spending in making their IS Y2K ready. IT outsourcing dropped in 2001 and 2002, because of the recession following the dot-com crash and the 9/11 terrorist attacks. However, since 2003, spending in IT outsourcing increased, reaching nearly US$125 billion in 2006. In Figure 1, we also show the estimates of IT outsourcing, based on Gartner's IT services revenue forecast for 2001–2004 (De Souza et al. 2003). Their estimates are greater than ours by 12%–14%. Considering that our measure of IT outsourcing does not include government spending while Gartner's estimates do, our estimates closely match those from Gartner.[4] IT outsourcing has grown more rapidly than non-IT services intermediate inputs. The average annual growth rate of IT outsourcing from 1998 to 2006 was about 5.4%, whereas non-IT services intermediate inputs have grown by about 3.5% annually.

4.2. Estimation Procedure

Because we use a cross-sectional time-series data set, there are potential econometric problems of heteroskedasticity across industries and autocorrelation across time. According to the Breusch-Pagan test for heteroskedasticity and the likelihood ratio test for panel-level heteroskedasticity, we can reject the null hypothesis that the errors are homoskedastic ($\chi^2 = 197.69$, $p < 0.001$; $\chi^2 = 855.76$, $p < 0.001$). In addition, the Wooldridge (2002) test for autocorrelation indicates the presence of first-order autocorrelation (AR1) in our panel data set ($F = 98.93$, $p < 0.001$).

In the presence of heteroskedasticity and autocorrelation, pooled ordinary least squares (OLS) regression may be problematic. Although the OLS estimators are unbiased and consistent, they are not efficient, and the standard errors are not correct (Greene 2000). To deal with these issues, we use feasible generalized least squares (FGLS) to effect the appropriate corrections (Wooldridge 2002).

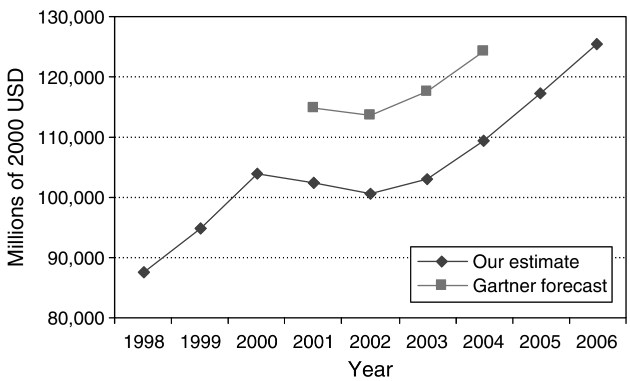
Beck and Katz (1995) suggest that researchers working with cross-sectional time-series data sets should use OLS with panel-corrected standard errors (OLS-PCSE) instead of FGLS, because the standard errors of the estimated coefficients based on FGLS may understate the true sampling variability. Their Monte-Carlo analysis shows that OLS-PCSE performs better than FGLS in estimating the standard

technologies; (3) on-site management and operation of clients' computer systems and/or data processing facilities; and (4) other professional and technical computer-related advice and services (http://www.census.gov).

As we noted earlier, we used the 1997 NAICS for our data set. In the 2002 NAICS, data processing services were included in Data Processing, Hosting, and Related Services (5182).

[4] Because Gartner (see update by De Souza et al. in 2007) provides estimates for the total IT services in North America, we made adjustments with respect to the scope of the services and the size of the U.S. economy relative to Canada. Gartner's IT services definition includes a wide range of services, including business process outsourcing. According to Gartner's definition, IT outsourcing accounts for approximately 40% of the total IT services (Babaie 2002). In 2008, the gross domestic products of the United States and Canada were $12.4 trillion and $1.1 trillion, respectively, which means that the United States accounted for 92% of the North American economy in that year. We multiplied Gartner's original numbers by $0.4 \cdot 0.92$ to obtain the estimates of IT outsourcing spending.

Figure 1 **Trends in IT Outsourcing in U.S. Industries (1998–2006)**



Source. Authors' calculations were based on the BEA's KLEMS intermediate input data and the De Souza et al. (2003) worldwide IT services revenue forecast.

errors. Another advantage of OLS-PCSE is that it can take contemporaneous correlations into account, in addition to heteroskedasticity.

A recent study shows that FGLS is more efficient in estimating standard errors than OLS-PCSE, however (Chen et al. 2005). Thus we report results based on both FGLS and OLS-PCSE. Our OLS-PCSE estimates are corrected for heteroskedasticity, contemporaneous correlation, and autocorrelation, whereas in FGLS estimation, corrections are made for error structure with heteroskedasticity and autocorrelation only. Because the AR1 process may be industry specific (i.e., panel specific), we consider both common AR1 and panel-specific AR1 (PSAR1) processes in our estimations. In the PSAR1 model, we calculate the autocorrelation parameter for each industry by using generalized differencing, which is then used for estimating the variance-covariance matrix. We also include year dummies to control for year-specific effects common across industries and sector dummies at the NAICS two-digit level to control for time-invariant sector-specific effects. The use of sector dummies saves substantial degrees of freedom over industry dummies—46, in fact—and avoids fixed-effects model problems that we will discuss later. This yields the following specification of our empirical model

$$y = a + \alpha k + \beta l + \gamma m + \delta z + \omega x + \sum_t b_t D_t + \sum_j c_j S_j + \varepsilon,$$

where D_t denotes the year dummies, and S_j denotes the sector dummies.

5. Results

5.1. Contributions of IT Outsourcing to Productivity

To examine whether IT outsourcing has contributed to productivity in the U.S. economy, we estimated our extended Cobb-Douglas production function using our full sample of 540 observations, which pools 60 industries in the United States over nine years. Our estimates are shown in Table 3. We found that the estimates for labor, non-IT capital, and IT capital are similar to those in related studies (adjusted for intermediate inputs) that examined pre-2000 time periods (e.g., Brynjolfsson and Hitt 1995, Cheng and Nault 2007, Dewan and Kraemer 2000, Dewan and Min 1997); see Online Appendix C.

Table 3 **FGLS and OLS-PCSE Estimation Results: Extended Cobb-Douglas**

	FGLS		OLS-PCSE	
Parameter	AR1	PSAR1	AR1	PSAR1
Non-IT capital	0.059*** (0.011)	0.051*** (0.007)	0.058*** (0.012)	0.127*** (0.014)
IT capital	0.043*** (0.009)	0.083*** (0.009)	0.029*** (0.011)	0.041*** (0.014)
Labor	0.227*** (0.012)	0.241*** (0.007)	0.212*** (0.010)	0.207*** (0.017)
Non-IT services intermediate inputs	0.631*** (0.014)	0.626*** (0.011)	0.649*** (0.029)	0.620*** (0.019)
IT outsourcing	**0.034***** (**0.010**)	**0.021**** (**0.009**)	**0.042***** (**0.013**)	**0.025**** (**0.012**)
95% confidence interval for IT outsourcing	0.014–0.054	0.003–0.038	0.016–0.068	0.002–0.049

Notes. We used our full sample of 540 observations covering 1998–2006. Standard errors are in parentheses. FGLS estimates are corrected for heteroskedasticity and autocorrelation. OLS-PCSE estimates are corrected for heteroskedasticity contemporaneous correlation and autocorrelation.

$^{***}p < 0.01$; $^{**}p < 0.05$.

Table 4 **GMPs of Factor Inputs**

	FGLS		OLS-PCSE		
Parameter	AR1	PSAR1	AR1	PSAR1	Average GMP
Non-IT capital	0.12	0.10	0.11	0.25	**0.15**
IT capital	0.52	1.00	0.35	0.49	**0.59**
Labor	NA	NA	NA	NA	**NA**
Non-IT services intermediate inputs	1.38	1.37	1.42	1.36	**1.38**
IT outsourcing	**5.31**	**3.28**	**6.56**	**3.91**	**4.77**

Next, we learned that the output elasticity estimate for IT outsourcing is significant and ranges from 0.021 to 0.042. This result indicates that IT outsourcing made positive and significant contributions to output in U.S. industries from 1998 to 2006. For the median industry in terms of output (NAICS 3361-3364: Motor Vehicles, Bodies and Trailers, and Parts), this implies that a \$10.43 million (0.01 · \$1,043.47 million) increase in IT outsourcing is associated with a \$34.72 (0.00021 · \$165,328.3 million) to \$69.44 million (0.00042 · \$165,328.3 million) increase in output.[5]

To compare the contribution of IT outsourcing relative to that of non-IT services intermediate inputs, we examined *gross marginal product* (*GMP*), defined as the output produced by one more unit of a given input, which is calculated by dividing the output elasticity of an input by its input share. As shown in Table 4, the average GMP of IT outsourcing of 4.77 is substantially greater than that of non-IT services intermediate inputs at 1.38. This indicates that IT outsourcing has made substantially greater contributions to output in U.S. industries than non-IT services intermediate inputs. We recognize that the high GMP of IT outsourcing, compared to other intermediate inputs, is partly because of its much smaller factor share (0.64% versus 45.7%), and because of diminishing marginal returns, the GMP of IT outsourcing will decrease as industries invest more in IT outsourcing. In addition, the GMP of IT capital is substantially greater than the GMP of non-IT capital, which is consistent with previous studies.

To evaluate the net contribution of IT outsourcing, we examined the *net marginal product* (*NMP*), which is GMP net of the cost, as in Brynjolfsson and Hitt (1996). It is straightforward to calculate NMP because both IT outsourcing is a flow variable. Because a dollar of IT outsourcing costs \$1, the average GMP of 4.77 implies that the net benefit of IT outsourcing is \$3.77 on average. In comparison, \$1 of non-IT services intermediate inputs has an average NMP of \$0.38. Note that because of the hidden costs, the true cost of a dollar of IT outsourcing may be greater than \$1. However, even if the hidden costs really were \$1, the NMP of IT outsourcing would still be greater than that of non-IT outsourcing.

Next, we examine how much IT outsourcing has contributed to labor productivity. As shown in Table 5, the estimates are similar to those from the production function estimation. The estimates for IT outsourcing indicate that, on average, a 1% increase in spending on IT outsourcing per labor hour was associated with a 0.024%–0.04% increase in labor productivity.[6]

5.2. IT Intensity Split Analysis

To test whether industries are different with respect to the ways they use and benefit from IT outsourcing, we split the industries based on IT intensity. This split sample analysis is similar to Dewan and Min (1997) and Mittal and Nault (2009), who used IT intensity for grouping industries. *IT intensity* is measured by the ratio of IT capital to industry size. Because industry size can be measured by either the value of output or the number of employees, we use two measures of IT intensity. The first measure of IT intensity is the *ratio of IT capital to output*, as in Cheng and Nault (2007). The second measure of IT intensity is the *ratio of IT capital to labor*, consistent with Dumagan et al. (2003). We rank ordered the industries based on their mean IT intensity over the period from 1998 to 2006 and split them into two groups of 30 industries.[7] The

[5] We estimated our model with dummy variables for the IT vendor industries (NAICS 334: Computer and Electronic Products; NAICS 514: Information and Data Processing Services; and NAICS 5415: Computer Systems Design and Related Services) and obtained similar results (see Online Appendix D). One noticeable difference was that the coefficients on IT capital and IT outsourcing were smaller, because of obvious correlations of the dummy with IT capital and IT outsourcing: IT vendor industries make intensive IT investments and heavily use IT outsourcing.

[6] In the labor productivity equation, we divided both sides of the production function by labor hours. Thus, even though IT outsourcing replaces part of the labor, the reduction in labor will increase not only output per labor hour (i.e., labor productivity) but also IT outsourcing per labor hour. If the IT outsourcing/labor substitution were severe, then our regular production function would have had additional variance in those two variables, thereby affecting the estimation results. Finding basically the same results from the production function and the labor productivity equation shows that our results were not driven by severe substitution. In addition, given that IT labor is only a small fraction of total labor—less than 1% in terms of costs according to Brynjolfsson and Hitt (1996), we believe that the overall results are not affected by the substitution between IT outsourcing and IT labor. Finally, if monitoring and coordination tasks associated with outsourcing take away workers' time, which could have been invested in producing output otherwise, it will be reflected in the output elasticity of IT outsourcing. The significant output elasticities of IT outsourcing we obtained suggest that overall IT outsourcing makes a significant contribution to output and labor productivity.

[7] An alternative way to split the industries is to visually inspect the plots to find a natural split (analogous to a scree plot in factor analysis). This method resulted in 20 and 22 high IT intensity industries and 40 and 38 low IT intensity industries under the two measures of IT intensity. The results were similar in magnitudes and signs,

Table 5 FGLS and OLS-PCSE Estimation Results: Labor Productivity Equation

	FGLS		OLS-PCSE	
Parameter	AR1	PSAR1	AR1	PSAR1
Non-IT capital	0.062***	0.044***	0.061***	0.127***
	(0.011)	(0.007)	(0.013)	(0.016)
IT capital	0.044***	0.076***	0.028***	0.044***
	(0.009)	(0.008)	(0.011)	(0.014)
Non-IT services intermediate inputs	0.631***	0.637***	0.654***	0.605***
	(0.014)	(0.010)	(0.026)	(0.021)
IT outsourcing	**0.032*****	**0.024*****	**0.040*****	**0.026*****
	(**0.010**)	(**0.009**)	(**0.014**)	(**0.012**)
95% confidence interval for IT outsourcing	0.013–0.050	0.007–0.042	0.012–0.067	0.002–0.049

Notes. We used our full sample of 540 observations covering 1998 to 2006. Standard errors are in parentheses. FGLS estimates are corrected for heteroskedasticity and autocorrelation. OLS-PCSE estimates are corrected for heteroskedasticity contemporaneous correlation and autocorrelation.
$^{***}p < 0.01$; $^{**}p < 0.05$.

high IT intensity group has significantly higher average IT intensity (14.3% under both measures) than the low IT intensity group (2.3% and 2.8% under the two measures). Both a t-test for comparing two samples and the Mann-Whitney U-test concluded that the difference is statistically significant at $p = 0.001$ under both measures. Tables 6 and 7 show the summary statistics for the high and low IT intensity groups under the two IT intensity measures.

We compared the ratio of IT outsourcing to industry output and found that high IT intensity industries use significantly more IT outsourcing (0.92% and 0.87% of output) compared with low IT intensity industries (0.33% and 0.41% of output), which is consistent with the findings of Loh and Venkatraman (1992). Interestingly, in high IT intensity industries, IT outsourcing is a smaller percentage of own IT capital (6.4% and 6.1%), as compared to low IT intensity industries (14.7% and 14.8%).

To examine whether the two industry groups differ in their returns to IT outsourcing, we estimated separate production functions and labor productivity equations for the high and low IT intensity industry groups.[8] According to the results of the relevant likelihood ratio tests, we reject the null hypothesis that the coefficients are equal between the subsamples at $p = 0.001$ under both measures of IT intensity.

As we show in Tables 8 and 9, the coefficient estimates for IT outsourcing are greater in high IT intensity industries, in both the production function and labor productivity equation when we measure IT intensity as the ratio of IT capital to output. We used a z-test to evaluate the equality of regression coefficients between the two samples (Clogg et al. 1995) and got $z = 1.37$ ($p < 0.1$) for the production function results and $z = 1.08$ ($p > 0.1$) for the labor productivity equation results. Our null hypothesis is that the two coefficients are equal between the two samples. The difference, it turns out, is more pronounced when we measure IT intensity as IT capital divided by labor, where IT outsourcing is not significant in low IT intensity industries.

5.3. Analysis of Three-Digit SIC Manufacturing Industries for 1987–1999

Our continuous sample period is constrained to 1998–2006 because data in pre-1998 years are based on the Standard Industry Classification (SIC), whereas our current data are based on NAICS. Using a separate data set based on SIC for an earlier period, we examined whether the results are robust to earlier years by estimating the same models (the production function and labor productivity equation models). We used a data set constructed from the MFP data for three-digit SIC manufacturing industries and the input-output tables for 1987–1999 provided by the BLS. This data set was used in a study by Cheng and Nault (2007), who provide a detailed description. These SIC data are disaggregated one level more than our NAICS data.

Data on output, total intermediate inputs, and labor hours are directly available from the MFP data. IT capital and non-IT capital have been constructed by aggregating productive stock of relevant assets. All of the variables, except for labor, are converted to 1987 U.S. dollars using appropriate deflators provided by the BLS. To measure IT outsourcing, we used the value of the intermediate

although the output elasticities of non-IT capital and IT outsourcing in the high IT intensity group were insignificant, because of the large standard errors resulting from the smaller sample sizes.

[8] Alternatively, one can estimate the coefficient of the interaction term between the IT intensity dummy and IT outsourcing using the full sample. We found a positive and significant coefficient under both measures of IT intensity: 0.023 ($p < 0.10$) and 0.042 ($p < 0.001$), corroborating our split-sample results (see Online Appendix E).

Table 6 Summary Statistics for High IT Intensity Industries (30 Industries)

	IT intensity measure 1: IT capital/output		IT intensity measure 2: IT capital/labor	
Data series	Overall mean	Percentage of output	Overall mean	Percentage of output
Output (in millions of 2000 U.S. dollars)	280,635.5	100.00	271,188.1	100.00
IT capital (in millions of 2000 U.S. dollars)	40,056.5	14.30	38,681.6	14.30
Non-IT capital (in millions of 2000 U.S. dollars)	168,041.9	59.90	161,637.2	59.60
Labor (in millions of work hours)	3,449.4	NA	3,449.4	NA
IT outsourcing (in millions of 2000 U.S. dollars)	2,572.2	0.92	2,365.9	0.87
Non-IT services intermediate inputs (in millions of 2000 U.S. dollars)	120,320.0	42.90	122,360.7	45.10

Table 7 Summary Statistics for Low IT Intensity Industries (30 Industries)

	IT intensity measure 1: IT capital/output		IT intensity measure 2: IT capital/labor	
Data series	Overall mean	Percentage of output	Overall mean	Percentage of output
Output (in millions of 2000 U.S. dollars)	269,795.7	100.00	279,243.0	100.00
IT capital (in millions of 2000 U.S. dollars)	6,306.5	2.30	7,681.4	2.80
Non-IT capital (in millions of 2000 U.S. dollars)	103,753.0	36.90	110,157.7	39.40
Labor (in millions of work hours)	3,765.6	NA	4,441.7	NA
IT outsourcing (in millions of 2000 U.S. dollars)	927.5	0.33	1,133.8	0.41
Non-IT services intermediate inputs (in millions of 2000 U.S. dollars)	130,017.0	46.30	127,976.3	45.80

input that each industry purchased from industry SIC 737: Computer Programming, Data Processing, and Other Computer Related Services.[9] Table 10 shows the summary statistics for the variables. The average input share of output for IT outsourcing, 0.29%, is less than half that from 1998 to 2006, 0.64%, implying that firms in the United States have substantially increased spending on IT outsourcing over the past two decades.

The results of estimating the production function and labor productivity equation are presented in Table 11 and suggest that IT outsourcing made significant contributions to output and productivity from 1987 to 1999 in U.S. manufacturing industries. The estimate for IT outsourcing is 0.058, which is greater than the estimates from 1998 to 2006. Although we cannot make a direct comparison because of the differences in the industry composition between the two data sets (i.e., manufacturing industries versus nonfarm private industries), we believe that two factors contribute to this difference. First, the IT outsourcing measure for 1987–1999 is broader and may overstate the amount of IT outsourcing. The measure includes Prepackaged Software, which accounted for 27% of our IT outsourcing measure for 1987–1999, according to the 1997 U.S. Census data, whereas all software expenditures are capitalized and thus are included in IT capital for 1998–2006. Second, spending on IT outsourcing is smaller in our 1987–1999 data set, which indicates more severe underinvestment in IT outsourcing than in the later period. We believe that marginal returns to IT outsourcing have diminished as spending on IT outsourcing has increased.

We split the industries based on IT intensity, measured by the ratio of IT capital to output. The results show the same pattern as the data for 1998–2006. The estimates for IT outsourcing are significantly greater in high IT intensity industries ($z = 2.41$, $p < 0.01$ for the production function; $z = 3.05$, $p < 0.01$ for the labor productivity equation). Using the ratio of IT capital to labor yields similar results. These results reinforce our earlier findings by showing that the economically meaningful contributions of IT outsourcing and the greater returns from IT outsourcing in the

[9] SIC 737 includes Computer Programming Services, Prepackaged Software, Computer Integrated Systems Design, Computer Processing and Data Preparation and Processing Services, Information Retrieval Services, Computer Facilities Management Services, Computer Rental and Leasing, and Computer Maintenance and Repair. Although most of the industries are relevant to IT outsourcing, such subindustries as Prepackaged Software, Information Retrieval, and Computer Rental and Leasing are not directly related to IT outsourcing. Because input-output tables are available only at the SIC three-digit level, we cannot exclude these unrelated industries. As a result, the current measure is likely to overestimate the amount of IT outsourcing. According to the 1997 U.S. Census data, these three industries account for approximately 30% of SIC 737 in terms of the value of receipts.

Table 8 Results of Estimating Production Function: IT Intensity Split (FGLS-AR1)

	IT intensity measure 1: IT capital/output		IT intensity measure 2: IT capital/labor	
Parameter	High IT	Low IT	High IT	Low IT
Non-IT capital	0.028* (0.017)	0.191*** (0.025)	0.053*** (0.017)	0.075*** (0.021)
IT capital	0.117*** (0.021)	0.059*** (0.020)	0.083*** (0.017)	0.066*** (0.019)
Labor	0.267*** (0.023)	0.173*** (0.020)	0.186*** (0.020)	0.175*** (0.019)
Non-IT services intermediate inputs	0.493*** (0.032)	0.548*** (0.021)	0.591*** (0.027)	0.559*** (0.023)
IT outsourcing	**0.066***** (**0.018**)	**0.032***** (**0.017**)	**0.041***** (**0.015**)	**0.002** (**0.021**)

Notes. The high IT intensity group and the low IT intensity group each have 30 industries (270 observations). Standard errors are in parentheses. Results are based on FGLS with heteroskedasticity and AR1 autocorrelation corrections. Results based on FGLS with PSAR1, OLS-PCSE with AR1, and OLS-PCSE with PSAR1 are qualitatively similar (see Online Appendix F).
$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$.

Table 9 Results of Estimating Labor Productivity Equation: IT Intensity Split (FGLS-AR1)

	IT intensity measure 1: IT capital/output		IT intensity measure 2: IT capital/labor	
Parameter	High IT	Low IT	High IT	Low IT
Non-IT capital	0.043** (0.020)	0.197*** (0.023)	0.068*** (0.017)	0.116*** (0.022)
IT capital	0.115*** (0.023)	0.055*** (0.019)	0.068*** (0.017)	0.057*** (0.021)
Non-IT services intermediate inputs	0.488*** (0.035)	0.538*** (0.021)	0.615*** (0.024)	0.570*** (0.021)
IT outsourcing	**0.056***** (**0.020**)	**0.029**** (**0.015**)	**0.034**** (**0.015**)	−**0.017** (**0.019**)

Notes. The high IT intensity group and low IT intensity group each have 30 industries (270 observations). Standard errors are in parentheses. Results are based on FGLS with heteroskedasticity and AR1 autocorrelation corrections.
$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$.

Table 10 Summary Statistics: 92 Three-Digit SIC Manufacturing Industries (1987–1999)

Data series	Mean	Std. dev.	Min.	Max.	Percentage of output
Output (in millions of 1987 U.S. dollars)	29,502.1	44,947.1	557.60	738,130.8	100.0
IT capital (in millions of 1987 U.S. dollars)	1,780.9	3,102.1	30.30	27,661.1	6.0
Non-IT capital (in millions of 1987 U.S. dollars)	20,090.9	22,628.9	461.80	135,540.6	68.1
Labor (in millions of work hours)	410.6	358.1	12.20	2,350.9	NA
IT outsourcing (in millions of 1987 U.S. dollars)	84.3	111.1	0.04	931.9	0.3
Non-IT services intermediate inputs (in millions of 1987 U.S. dollars)	16,457.1	20,580.1	313.20	202,082.5	55.8

high versus low IT intensity industries extend back to 1987–1999.

5.4. Additional Considerations and Robustness Checks

One potential issue in our estimations is the presence of time-invariant *industry-level heterogeneity*. This can bias the estimation results if industry-level heterogeneity is included in the error term and is correlated with independent variables, resulting in a simultaneity problem (Levinsohn and Petrin 2003). We have handled industry-level heterogeneity as follows. First, in our FGLS and PCSE estimations, we control for sector-level fixed effects at the two-digit NAICS level by including 13 sector dummies. We believe that our

Table 11 Results for Three-Digit SIC Manufacturing Industries (1987–1999) (FGLS–AR1)

	Production function			Labor productivity equation		
		IT intensity split			IT intensity split	
Factor input	Full sample	High	Low	Full sample	High	Low
Non-IT capital	0.037** (0.018)	0.012 (0.024)	0.056*** (0.016)	0.039** (0.017)	−0.0002 (0.032)	0.039*** (0.018)
IT capital	0.079*** (0.007)	0.114*** (0.014)	0.050*** (0.009)	0.079*** (0.009)	0.150*** (0.020)	0.045*** (0.008)
Labor	0.204*** (0.016)	0.199*** (0.023)	0.208*** (0.013)	—	—	—
Intermediate inputs less IT outsourcing	0.621*** (0.015)	0.607*** (0.023)	0.642*** (0.015)	0.619*** (0.015)	0.558*** (0.026)	0.677*** (0.018)
IT outsourcing	**0.058***** (**0.007**)	**0.077***** (**0.009**)	**0.048***** (**0.008**)	**0.058***** (**0.007**)	**0.087***** (**0.012**)	**0.043***** (**0.008**)

Notes. We used 1,196 observations from 92 manufacturing industries covering 1987–1999. Standard errors are in parentheses. Results are based on FGLS with heteroskedasticity and AR1 adjustments. Year and sector dummies are not shown.
$^{***}p < 0.01$; $^{**}p < 0.05$.

sector-level fixed effects capture a significant portion of industry-level heterogeneity. Second, our results with adjustments for common AR1 and panel-specific AR1 (PSAR1) are similar. Because an AR1 coefficient is estimated for each panel (industry) in PSAR1-based models, part of the industry-level heterogeneity is captured by the AR1 coefficients.

Third, to verify that our results are not driven by the correlation between the error term and the independent variables and the resulting simultaneity problem, we inspected scatter plots between the residuals and both IT capital and IT outsourcing. We could not identify any systematic correlations based on visual inspection of the plots. Moreover, the correlations were very small and insignificant: only 0.08 between the residuals and IT outsourcing and 0.01 between the residuals and IT capital.

We estimated our models, including the industry dummies in FGLS estimation, and then we used the *xtregar* procedure with the fixed-effects option in Stata 10 to control for autocorrelation. As shown in the first two columns of Table 12, both IT capital and IT outsourcing are insignificant. However, for most of the variables, including IT outsourcing and IT capital, the standard errors are more than three times greater in the models with industry fixed effects, compared to our FGLS and OLS-PCSE models with sector dummies (see Table 3). This is likely because of multicollinearity and the loss of degrees of freedom (Yaffee 2003).

Moreover, fixed-effects models use only *within variation*, although *between variation* can be important for obtaining precise estimates (Levinsohn and Petrin 2003). This problem can be more severe in relatively short panels, such as ours. To compare within and between variation, we calculated *coefficients of variation* (CVs) for our IT variables. These show the dispersion of the variables for the whole sample and

Table 12 Results of Estimating the Production Function Based on Alternative Specifications

Factor input	FGLS with industry dummies	Fixed effects with AR1	OLS with robust SE	Random effects with AR1
Non-IT capital	0.096** (0.038)	0.139 (0.099)	0.036* (0.014)	0.076*** (0.023)
IT capital	−0.002 (0.016)	−0.0004 (0.035)	0.003 (0.014)	0.062*** (0.018)
Labor	0.202*** (0.025)	0.215*** (0.05)	0.186*** (0.015)	0.239*** (0.021)
Non-IT services intermediate inputs	0.533*** (0.029)	0.456*** (0.038)	0.722*** (0.024)	0.527*** (0.026)
IT outsourcing	**−0.033** (**0.022**)	**0.002** (**0.030**)	**0.064***** (**0.011**)	**0.027** (**0.020**)

Notes. The OLS model includes year and sector dummies. The fixed-effects and random-effects models include year dummies and are not adjusted for heteroskedasticity. Standard errors are in parentheses.
$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.10$.

for each industry. We found that the *within-industry CVs* were substantially smaller than the *full sample CVs.* When there is little within variation, the fixed-effects models result in inefficient estimates because they ignore important information (Plumper and Troeger 2007). For IT outsourcing, the full sample CV was 21.9%, whereas the average within-industry CV was 2.1%, less than one-tenth of the full sample CV. In the case of IT capital, the full sample CV was 14.9%, and the average within-industry CV was 2.2%. This implies that these variables do not vary much over time within an industry, and so they should be highly correlated with industry fixed effects. Further, this should result in insignificant coefficients for IT capital and IT outsourcing because industry fixed effects remove variation that would have been captured by IT variables without the fixed effects. Thus we conclude that our estimation results are not subject to bias because of industry-level heterogeneity.

We also estimated our models using OLS and random-effects procedures (see Table 12). Under OLS, IT outsourcing was significant, while IT capital was not. This may be because OLS cannot control for autocorrelation, which is present in our data. The random-effects results that we obtained were similar to our FGLS results, although IT outsourcing was insignificant because of a large standard error. Again, this is probably because of the loss of degrees of freedom. Another potential reason is that the random-effects procedure does not control for panel-level heteroskedasticity, which is present in our data.

Our pooled analysis assumes a constant slope across industries, despite potential cross-industry heterogeneity. To examine this potential heterogeneity, we employed *quantile regression* (Koenker and Hallock 2001), which estimates models for conditional quantile functions, based on a bootstrap procedure. We used three quantiles (0.25, 0.50, and 0.75) and discovered that although the output elasticities of IT and non-IT capital change from one quantile to another, the estimates of output elasticity of IT outsourcing are similar across quantiles (see Online Appendix G). This suggests that there is no significant difference in the impact of IT outsourcing among industries with different levels of output.

To examine whether the contribution of IT outsourcing was affected by economic events (e.g., the dot-com crash, the 9/11 terrorist attacks, and the ensuing recession), we conducted a time-based split analysis. The events took place prior to 2002, and the trend in spending in IT outsourcing changed in that year, so we ran regressions for the two periods before and after 2002 (see Online Appendix H). Although the estimate for IT outsourcing post-2002 is greater than that of the pre-2002 period, a likelihood ratio test indicated that we cannot reject the null hypothesis that the estimates are equal between time periods ($p < 0.01$).

As an additional robustness check, we examined the possibility of the endogeneity of IT capital and IT outsourcing inputs. Our results are based on an assumption that IT capital and IT outsourcing are determined by exogenous factors and are not correlated with the error term. However, it is possible that IT capital and IT outsourcing are simultaneously determined with output. For example, firms may have reduced output and simultaneously reduced their spending on IT capital and IT outsourcing when the recession started in 2001. In this case, IT capital or IT outsourcing could be correlated with the error term, and the coefficient estimates would be biased. Using one- and two-year lagged values of our independent variables as instruments, we further checked for the endogeneity of IT capital and IT outsourcing variables, based on the Durbin-Wu-Hausman test for endogeneity and the C-statistic test and Hansen's J-test for exogeneity (Baum et al. 2003). We ran these tests for our two IT variables, both independently and jointly. All of the tests indicated that we cannot reject the null hypothesis that IT capital and IT outsourcing are exogenous. These tests also confirm that we do not have a bias resulting from omitted variables that would result in our IT variables being correlated with the error term. (The test results are provided in Online Appendix I.)

6. Discussion and Conclusions

6.1. Discussion of the Results: Possible Theoretical Implications

Returns to IT Outsourcing. We found that, on average, U.S. industries earned greater GMP from IT outsourcing than they did from non-IT services outsourcing. These high returns to IT outsourcing imply that the impacts of purchased IT services may be systematically different from the impacts of other intermediate inputs, which may be because of rapid advances in IT that have enhanced the quality of IT services while simultaneously reducing the costs of IT services. Our analysis shows that the average annual growth rate of IT capital in the two IT service industries that we have studied (i.e., NAICS 514 and 5415) over the period from 1998 to 2006 was 23%, which is twice as high as the growth rate of IT capital in the rest of the economy, 11.5%. This implies that firms that are vendors in IT service industries have invested in IT more heavily than firms in other industries. The high returns to IT outsourcing may also indicate that firms in U.S. industries underinvest in IT outsourcing. We expect to observe diminishing marginal returns as spending in IT outsourcing increases, although there is some evidence that IT is an increasing returns technology—at least over some ranges of operational size (Kudyba and Diwan 2002).

An additional explanation for the high marginal product for IT outsourcing is that transaction costs are greater in IT outsourcing, as compared with non-IT service outsourcing. A recent survey by Deloitte Consulting found that almost half of the surveyed companies identified "hidden costs" as the most common problem when managing IT outsourcing projects (McDougall 2006). These include the costs of transitioning, managing contracts, and monitoring performance (Aubert et al. 2004). The costs of transitioning may be higher in IT outsourcing because it often involves the transfer of hardware and software, which are technology intensive (Matlus and Andersen 2003). For example, in a data center outsourcing agreement, transition costs can be as high as 15% of the annual cost. Managing IT outsourcing contracts involves such costly tasks as tracking specifications, compiling an audit trail of what was communicated to whom, and measuring performance against hundreds of pages of contracts. However, even if the hidden costs match the price of IT outsourcing, our results of the higher marginal product of IT outsourcing, compared to other types of outsourcing, still hold.

Differences Between High and Low IT Intensity Industries. Our split-sample analysis reveals that high IT intensity industries use significantly more IT outsourcing as a percentage of their output, compared with low IT intensity industries. We believe that this happens for the following reasons. First, IT outsourcing requires substantial coordination and communication with vendors, and implementation of interorganizational systems can help reduce coordination and communication costs by integrating processes and facilitating monitoring of the outsourced work (Malone et al. 1987). By using data from the U.S. manufacturing industry for 1992 and 1997, Bartel et al. (2006) found that an industry's IT intensity is positively associated with its use of communications and software outsourcing. Second, IT outsourcing involves activities (e.g., data processing and management, systems design and development) that have high information intensity, and firms' IT deployment can promote outsourcing of these activities by helping them to be codified, standardized, and modularized (Mithas and Whitaker 2007). Finally, firms in more IT-intensive industries tend to have higher IT expenditures, which can motivate them to use more IT outsourcing for cost savings (Loh and Venkatraman 1992).

The difference between high and low IT intensity industries extends to returns to IT outsourcing. We argue that high IT intensity industries enjoy higher returns to IT outsourcing because of their superior IT capability—the ability to combine IT resources in ways that promote superior performance (Bharadwaj et al. 1999). Prior research suggests that physical IT assets, which form the core of a firm's overall IT infrastructure, are an important part of IT capabilities. By investing heavily in various ITs, firms in IT-intensive industries can develop greater IT capabilities, including technical and managerial IT knowledge (Bharadwaj 2000), which can enable firms to better manage IT outsourcing. The difficulty of managing outsourced IT projects is illustrated in a survey reported by Toolbox.com (2004), which shows that managing and communication are the biggest challenges in IT outsourcing. Thus, superior IT knowledge can help firms effectively manage IT outsourcing to capture its value.

This observation is closely linked to the concept of *absorptive capacity*, which Cohen and Levinthal (1990) use to refer to an organization's ability to evaluate and use external knowledge. They argue that an organization's prior related knowledge is an important source of its absorptive capacity. In the context of IT outsourcing, prior IT knowledge accumulated by a firm can help develop its IT-related absorptive capacity. Boynton et al. (1994) found that managerial IT knowledge leads to high levels of IT use by facilitating information exchanges and joint problem solving among managers. Similarly, Bartel et al. (2006) argue that IT-intensive firms can achieve technological compatibility between customer firms and vendors, which allows them to better use vendors' technologies.

6.2. Concluding Remarks

Estimating the returns to IT outsourcing by using the production function framework, treating IT outsourcing as an input in production, and using an economy-wide panel data set from 60 industries, we found that IT outsourcing has made substantial contributions to output and labor productivity in the U.S. economy. In addition, we discovered that returns from IT outsourcing have been substantially greater than those from the outsourcing of non-IT services.

Our study makes three main contributions. First, by treating IT outsourcing as an input in production, we introduced a novel method for measuring IT outsourcing and its economic impacts at the aggregate level. As firms increasingly purchase IT services from external vendors, investments in IT outsourcing must be taken into account to correctly measure returns to total IT investments. Second, we showed that the impacts of IT outsourcing are not only substantial in terms of the contributions to output and labor productivity, but also are stable and consistent over time. Our time split analysis indicates that the value of IT outsourcing has been stable during our sample period. Also, by using a separate data set for an earlier period, we found that our results on IT outsourcing have been consistent over the past two decades.

Third, our results have shown that there are systematic differences in the ways IT outsourcing is used by industries, depending on their IT intensity. High IT intensity industries not only use more IT outsourcing but also get more out of it. We believe that firms' IT investments facilitate IT outsourcing and that firms investing heavily in IT can better manage and exploit IT outsourcing with their superior IT-related knowledge and capabilities.

Our analysis uses industry-level data, and some argue that firm-level data are better because they are closer to where investment decisions are made. Also, the data are less subject to aggregation error. However, for multidivisional or multiproduct firms—firms from which most studies obtain data—both benefits of firm-level data are compromised, and there are aggregation errors built up from individual workers with individual kinds of capital. As Fisher (1969, p. 554), who analyzed this problem, put it, "[Aggregation problems] also arise at the firm level with production actually carried on in individual establishments or, more fundamentally, by individual workers using individual kinds of capital. The principal difference between such cases is often merely in how closely conditions for aggregation are likely to be satisfied in practice." The benefit of our industry-level analysis is that we examine a broad segment of the economy, thus making our results more generalizable. Moreover, our results are consistent across two different data sets at different levels of aggregation. They also cover different segments of the economy, which strongly suggest that we do not have systematic aggregation errors.

Our study provides implications for policymakers and managers. First, our results can assist them in gauging the aggregate impacts in the economy from IT outsourcing. Second, the high returns to IT outsourcing we report suggests that firms in U.S. industries may be underinvesting in IT outsourcing. Therefore, policymakers should encourage firms to invest more in IT outsourcing. Finally, our results from the IT intensity split analysis suggest that to receive higher returns from IT outsourcing, firms should accumulate IT-related knowledge and capabilities by investing heavily in their IT capital. This implies that firms' own IT investments and IT outsourcing have a complementary relationship. So firms that resort to IT outsourcing simply because they do not have enough IT competence may not be able to reap the full benefits from IT outsourcing.

This study is not without limitations. First, although we explained our IT intensity-based split results based on an IT capabilities argument, there can be alternative explanations. For example, IT-intensive industries may be relatively more amenable to automation and other benefits. To the extent that the use of internal IT and outsourced IT creates benefits in a similar manner, the benefits from IT outsourcing would be greater in more IT-intensive industries. However, our results are not fully consistent with this interpretation. This is because the output elasticity of IT capital in high IT intensity industries is not significantly greater than that in low IT intensity industries when we use the ratio of IT capital to labor hours as the IT intensity measure (see Tables 8 and 9). Second, our data do not distinguish between IT and non-IT labor. Given that IT labor can make a significantly greater contribution to productivity than non-IT labor (Prasad and Harker 1997) and that firms often lay off part of their IT staff or transfer them to vendors when they engage in IT outsourcing, examining the relationship between IT outsourcing and IT labor, as well as their impact on productivity, is an interesting avenue for future research.

Third, although our measure of IT outsourcing is accurate at the aggregate level, measuring IT outsourcing at the firm level would enable us to identify firm-specific factors that moderate the impact of IT outsourcing. Firm-level data are difficult to collect, however, and firms are reluctant to disclose data such as their spending in IT outsourcing. Fourth, although our Cobb-Douglas form is widely used because of its simplicity and other ideal properties for estimation and evaluation, it is not a fully flexible functional form and requires certain constraining assumptions. Finally, our data do not allow us to separate domestic from offshore IT outsourcing. It would be interesting to compare the value impacts of these two types of IT outsourcing.

7. Electronic Companion

An electronic companion to this paper is available as part of the online version that can be found at http://isr.journal.informs.org/.

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