SMALL IS BEAUTIFUL: AN EMPIRICAL STUDY OF COMPLEMENTARITIES, SUBSTITUTION AND SPILLOVERS IN THE IT INDUSTRY OF THE OECD COUNTRIES

YenChun Chou
Robert J. Kauffman
Benjamin B. M. Shao

W. P. Carey School of Business, Arizona State University
{yen-chun.chou, rkauffman, ben.shao}@asu.edu

Last revised: December 6, 2009

ABSTRACT

Firms use information technology (IT) to make better use of capital and labor in producing goods or services with the aim to increase productivity and efficiency. Because of the supply-and-demand relationship, the performance of the IT industry is critical to a country's economy. We explore the productivity and efficiency of the IT industry in the context of globalization. We use production function and stochastic frontier analysis methods to examine the impacts of IT goods imports and IT services offshoring on country-level IT industry. Our data cover 2000 to 2006 for fourteen OECD countries. Because our explanatory variables are measured at the country level, we are able to capture cross-industry interactions between the IT-producing industry and IT-using industries. Because of the limitations of our data set, we employ resampling methods from small sample statistics as a means to show the stability and robustness of our empirical results. We report that the import of IT goods has a positive effect on the productivity and efficiency of the IT industry in the OECD countries we studied. We posit that this occurs because international knowledge spillovers have brought technological progress to the IT industry across the OECD. We also have evidence to suggest that IT services offshoring negatively affects the productivity and efficiency of the IT industry. This occurs when the scale of production is reduced due to adverse complementarities that exist between IT services and IT goods. Our findings provide implications for policy-makers on international IT trade and the welfare tradeoffs that occur with the development of IT offshoring practices.

Keywords: Complementarities, economics, empirical research, IT industry, production, statistical resampling, spillovers, stochastic production frontier analysis, substitution.

Acknowledgments. The authors are thankful to Yannis Bakos, Eric Clemons, Lorin Hitt, Raghu Santanam, and other participants in our presentations of this work at Arizona State University, and the 2010 INFORMS Annual Meeting for helpful comments. Discussions with Eric Clemons, Barrie Nault, Andrew Odlyzko, Eric Wang, and Chris Westland were also beneficial to the development of our small sample approach to this research. The authors thank the W. P. Carey School of Business and the Information Systems Department for research funding. Rob Kauffman also acknowledges the Center for Advancing Business through IT, the W. P. Carey Chair in Information Systems, the E-Commerce Research Center at National Sun Yat-Sen University, and the Shidler School of Business, University of Hawaii for generous support.

> "*Any experiment may be regarded as forming an individual of a 'population' of experiments which might be performed under the same conditions. A series of experiments is a sample drawn from this population.*"
>
> William Sealy Gosset, creator of the "Student's *t*-distribution," writing as Student (1908, p. 1)

> *"Essentially, all models are wrong, but some are useful."*
>
> George E. P. Box and Norman R. Draper (1987, p. 74)

1. INTRODUCTION

The information technology (IT) industry is critical to the economies that host them due to the supply-and-demand relationship between IT-producing and IT-using industries. We use the term *IT industry* in this research as the OECD (2002) has defined it: manufacturing of office and computing machinery. The consumption of IT capital contributes to the output of IT-using industries, and helps to increase the efficiency of other factors of production such as capital and labor (Mittal and Nault, 2009).

Global IT trade in 2007 was estimated at US$3.8 billion, with the Organization for Economic Cooperation and Development (OECD) countries accounting for over 52% of the total (*OECD IT Outlook* 2008). On the supply side, the contribution of the IT sector to business sector value-added for 23 OECD countries was 8.9% on average in 2007. This reflects a stable level of sector value-added since 2004, when the share of IT goods to total goods trade was 13.2% (*OECD IT Outlook* 2006). OECD exports and imports of IT goods have continued to expand over the years, driven by growth in the trade of electronics, communication, and audio and video equipment. The continued growth of the IT industries in the OECD economies is critical because of IT's role as an enabler for the production processes of IT-using industries.

The recent *OECD IT Outlook* (2008) also reports that imports of IT goods to OECD countries increased 7% and imports of IT-related services grew 9% annually from 1996 to 2007. This suggests why the OECD countries' IT industries are so exposed to foreign competition (Conway et al. 2006). Over 80% of firms surveyed by industry consultants at Gartner Inc. indicated that the firms were considered shifting U.S. IT jobs overseas (Leung, 2003). In this context, examining the performance of the IT industry relative to the globalization of IT goods and services will be worthwhile. More studies on IT value creation at the macroeconomy level will be useful too, as suggested by Park et al. (2007).

Most previous studies on IT value focused on the empirical regularities of IT-driven productivity and IT-based consumption. Brynjolfsson and Hitt (1996) investigated IT value at the firm level and found significant contributions of IT capital to firm productivity. Barua et al. (1995) reported that IT improves capacity utilization and inventory turnover. Another important perspective on exploring IT value is to examine IT production. Gordon (2000) and Stiroh (2001) confirmed the contribution of the IT-producing sector's growth to the resurgence of U.S. productivity in the 1990s. The rationale is twofold. First, the IT-producing sector has spillover effects on other IT-using industries by enabling technological progress. Second, IT-using industries consume IT capital goods and achieve higher marginal product due to *IT capital deepening* (Bosworth 2004). A significant portion of labor productivity growth in the services industries in the U.S. came from continuous accumulation of IT capital during 1995 to 2001. Little attention has been paid to value creation through IT production though, especially in the global context.

The IT industry in OECD and non-OECD countries has different characteristics, and country-specific IT industry reactions to activities occurring in the global IT markets may vary too. Most previous research has concentrated on international trade and foreign direct investment (FDI) in developing countries, yet the developed countries account for the lion's share of trade and FDI (Iyer et al., 2008). We will study the IT industry in all o f the OECD countries for which data are currently available, to evaluate the impacts of international trade of IT goods and services on their performance for 2000 to 2006.[1] We ask: How does the globalization of IT goods and services impact the performance of the IT industries in OECD countries? What can explain the observed outcomes? How can we provide the strongest evidence, in spite of the small sample of data available to study country-specific heterogeneity in imported IT goods and offshored IT services?

Though there have been many productivity studies, Iyer et al. (2008) point out that few have examined the efficiency of industry performance, and fewer yet have explored the causes of industry-level efficiency variations or the effects of globalization. To address this gap in the literature, we will examine the effects of IT goods imports and IT services offshoring on the productivity and efficiency of country-level IT industry. [2]

We will employ a production function analysis to measure productivity and stochastic frontier analysis to assess efficiency. Production function analysis assesses *total factor productivity* as a means to gauge the portion of outputs not explained by the amount of inputs used in production (Comin, 2008). We will do this using a standard Cobb-Douglas production function, whose technology parameter represents total factor productivity. This lets us capture the effects of imported IT goods and IT services offshoring. We will use stochastic frontier analysis to measure deviations in observed output levels from the best out-

[1] New data will become available sometime in 2010 that will permit us to update our coverage of IT industry performance up to 2008. We do not expect to be able to increase the number of countries on which data will be available, however, since the OECD has not been able to collect it from countries from all of its member countries. Thus, we caution the reader at the outset of this research to recognize the limitations that we faced with the development of this research.

[2] Although our focus is on the performance of an OECD country's IT industry, we should note at the outset that the measurement of our explanatory variables is at the *country level*. This choice was necessary due to the unavailability of more disaggregated data. Country-level measurement enables us to capture cross-industry interactions between the IT industry and other IT-using industries, and offer an unusual and innovative perspective. If we were only to consider IT goods impacts for the IT industry, rather than at the country level, we would be unable to examine the effects of substitution between domestic and imported IT goods. This positive argument also applies to the effects of complementarities that may exist between IT production and IT services.

put levels that are observed (Aigner et al., 1977). With this approach, we can identify inefficiency that occurs due to uncontrollable factors, such as weather conditions, electricity outages, and government regulation changes. Such stochastic shocks are outside the control of managers in the IT industry, and occur mostly at random.

In this research, we found that IT goods imports in the OECD countries have had positive impacts on the productivity and efficiency of IT industries during the study period. IT services offshoring in OECD countries seems to negatively affect the IT industry's performance at the country level. To explain these observations, we will leverage theories on knowledge spillovers, substitution and complementarities to explain the dynamics that are observed. *Knowledge spillovers* stimulate technological improvements by collocated industries or firms through technological innovation that occurs locally. International knowledge transfer through technologies embedded in imported IT goods is well recognized to support knowledge spillovers, for example (Park et al., 2007). *Substitution* occurs when two goods can be consumed or used in place of the other. In the OECD countries context, imported IT goods and domestic IT goods are competing substitutes. *Complementarities* refer to two complementary goods that are used or consumed together to create higher utility. Their cross-price elasticity of demand usually is negative. IT services and IT products are complementary goods.

IT services typically are produced in the presence of IT hardware and software products. As more IT services are offshored to foreign vendors or insourced to overseas branches, the resulting reduction in demand for domestic IT services will lead to a decrease in the domestic consumption of complementary IT goods. One can think of the potential negative impact as *adverse complementarities*. Contrary to conventional thinking on welfare gains from IT offshoring at the national level, they may create unfavorable outcomes for the productivity and efficiency of a country's IT industry.

The remainder of this article is organized as follows. §2 describes the impacts of the globalization of IT goods and services on a country's IT industry. §3 presents our models. §4 describes the data and international context for this research. §5 presents our empirical findings, and explores the validity and robustness of our results with small sample econometric methods. §6 discusses the implications of this research, and provides an extended discussion that is intended to demonstrate the high relevance of engaged scholarship, by bridging the gap between the technical aspects of our work, and the interests of the policy-making and industry audiences. §7 concludes with contributions and limitation.

2. THEORY: IT GLOBALIZATION AND THE IT INDUSTRY

What are the impacts of imported IT goods and IT services offshoring on the productivity and efficiency of a country's IT industry? To answer this question, it is necessary to consider the process that underlies the changes in productivity and efficiency in response to technological advances and declining operational scale size. We will offer a number of theoretical perspectives that are helpful for establishing an understanding.

2.1. The Knowledge Spillover and Substitution Impacts of IT Goods Imports

Trade theory suggests that trade in technology promotes international technology transfer (Pugel, 1982). Spulber (2008) showed that an international trade in technology is distinct from trades in other types of goods and services. Trade in technology goods creates additional benefits beyond utility for recipient countries through knowledge transfer, raising the expected value of goods based on the new technologies. Park et al. (2007) examined trade in IT goods and argued that, process-wise, international knowledge transfer actually occurs through that technologies that are embedded in IT goods. Through such imports, firms in the recipient countries gain access to advanced technologies, and should be able to produce outputs more productively and efficiently.

Carmer et al. (1999) examined substitution effects among different types and qualities of rice through international trade. Blonigen (2001) used the *theory of substitution effects* to explain the relationship between imported automobile parts and domestically-made ones. In our study context, domestically-produced IT goods compete with foreign-made ones that have similar or better functionality at lower prices. This may cause domestic IT producers to lose market share to foreign competitors. Thus, their operating scale will be reduced, leading to concomitantly declining efficiency and productivity.

Although we expect that the substitution effects are negative, they should be relatively small in magnitude compared with the countervailing positive ones brought about by technological progress. The influences of knowledge spillovers will be greater because technical change acts as a dominant factor for productivity improvement (Shao and Lin, 2009). Thus, we assert our *knowledge spillovers and substitution hypotheses* in two related parts to cover productivity and efficiency:

- **Hypothesis 1a (The IT Goods Imports and Productivity Hypothesis).** *Due to the net effects of knowledge spillovers and substitution, IT goods imports in OECD countries will be associated with gains in productivity of the IT industry at the country level of analysis.*
- **Hypothesis 1b (The IT Goods Imports and Efficiency Hypothesis).** *Due to the net effects of knowledge spillovers and substitution, IT goods imports in OECD countries will be associated with gain in efficiency of the IT industry at the country level of analysis.*

Next, consider the how IT services offshoring affects the IT industry, and the adverse complementarities that arise, in particular.

2.2. The Adverse Complelementarities Impacts of IT Services Offshoring

IT offshoring refers to the use of IT services provided by external vendors or affiliated partners in foreign countries. The main motive for IT offshoring is cost saving (Shao and Smith-David, 2007), which should be of specific interest to both IT-using industries and the IT industry. According to the input-output tables for OECD countries though, the service sector consists primarily of IT-using industries, which accounted for 52% of total IT offshoring (OECD 2006). In contrast, the IT industry accounted for just 8%. Thus, for the IT industry, cost efficiency gains from its own IT offshoring are likely to be outweighed by the greater reduction in demand for its products from IT-using industries due to the complementarities between IT services and IT production. Since a reduction in demand and operating scale will decrease efficiency and productivity of production, we expect IT services offshoring to negatively affect IT industry efficiency and productivity.

Kim et al. (2000) used a similar kind of complementarities-based explanation to examine consumption interactions among related IT product categories. Harrison et al. (2007) explained the negative impacts of IT offshoring on labor and employment using a substitution-based explanation als. Similar to computer software and hardware, IT services and IT products are *complementary goods*: both are required to get the job done. But as firms offshore their IT services, the decrease in demand for domestic IT services will lead to a concomitant fall in consumption of domestic IT goods. The following two hypotheses represent the ideas in our foregoing discussion:

- **Hypothesis 2a (The IT Offshoring and Productivity Adverse Complementarities Hypothesis).** *IT services offshoring in OECD countries will be associated with a decline in the productivity of the IT industry at the country level of analysis.*
- **Hypothesis 2b (The IT Offshoring and Efficiency Adverse Complementarities Hypothesis).** *IT services offshoring in OECD countries will be associated with a decline in the efficiency of the IT industry at the country level of analysis.*

These *adverse complementarities hypotheses* capture the effects of IT offshoring on the performance of a country's IT industry that we believe will be observed. Table 1 summarizes our hypotheses and lists the variables, primary or countervailing forces and effects, the explanations of what happens in the industry process-wise, and the expected impacts on the performance of the IT industry.

Table 1. Summary of the IT Goods Imports and IT Services Offshoring Hypotheses

<table>
<tr><th>Variable</th><th>Primary or Opposing Forces</th><th>Initial Effect</th><th>Process Explanation</th><th>IT Industry Outcomes</th><th>Overall Effect</th></tr>
<tr><td rowspan="2">IT Goods Imports</td><td>Knowledge spillovers
Substitution</td><td>+
-</td><td rowspan="2">Technical progress is the dominating factor for productivity and efficiency improvement.</td><td>Productivity</td><td>+</td></tr>
<tr><td>Knowledge spillovers
Substitution</td><td>+
-</td><td>Efficiency</td><td>+</td></tr>
<tr><td rowspan="2">IT Services Offshoring</td><td>Complementarities</td><td>-</td><td rowspan="2">Services sector = 50%+ IT offshoring, so adverse complementarities outweigh cost efficiencies.</td><td>Productivity</td><td>-</td></tr>
<tr><td>Complementarities</td><td>-</td><td>Efficiency</td><td>-</td></tr>
</table>

3. MODELS

To explore the impacts of imported IT goods and IT services offshoring, we extend the production framework and apply a two-stage stochastic frontier model by considering country-specific characteristics. We introduce two models and discuss the rationale for using stochastic frontier analysis. We also discuss the model specifications.

3.1. Basic Concepts

The *Cobb-Douglas function* is economic input-output correspondence that can be used to estimate productivity. The Cobb-Douglas function has been extensively applied in the IS literature. In our international context of the IT industry of OECD countries, it can be written as: $Output = G \cdot Capital^{\beta 1} \cdot Labor^{\beta 2}$. *Output* is the output level of a country's IT industry. *G* is a *technological change parameter* that captures the amplifying effects of technology on the input parameters. Technological progress is known to drive efficiency gains. *Capital* and *Labor* are input variables. This kind of model has been used to study IT productivity in the cross-country context, as a means of achieving robust results at the aggregate level of the economy (Dewan and Kraemer, 2000).

Stochastic frontier analysis is based on production theory in microeconomics and its associated methods (Aigner et al., 1977). It is used to measure the difference between the ideal and observed output level of a producer with a given production process employing a given set of inputs. This difference in output levels can be further decomposed into *technical efficiency* and random fluctuations that are out of a producer's control. The fundamental idea is that a deviation in observed output from the ideal output might not be entirely under the control of the producer but due to random factors (Greene, 2008).

In measuring efficiency, it is critical to identify random deviations in efficiency (e.g., due to bad weather, electricity outages, machine breakdowns, etc.) to achieve a better understanding of performance. Figure 1 illustrates a *stochastic production frontier* based of the log form of the multiplicative Cobb-Douglas function. The variables x_i denote the inputs and log outputs for unit of analysis *i*, which can be firms, industries or countries, without loss of generality. Two countries, *A* and *B*, to show the relationship between the *inefficiency effect* – the managerially-controllable difference from the production frontier – and the *noise effect* or random error.

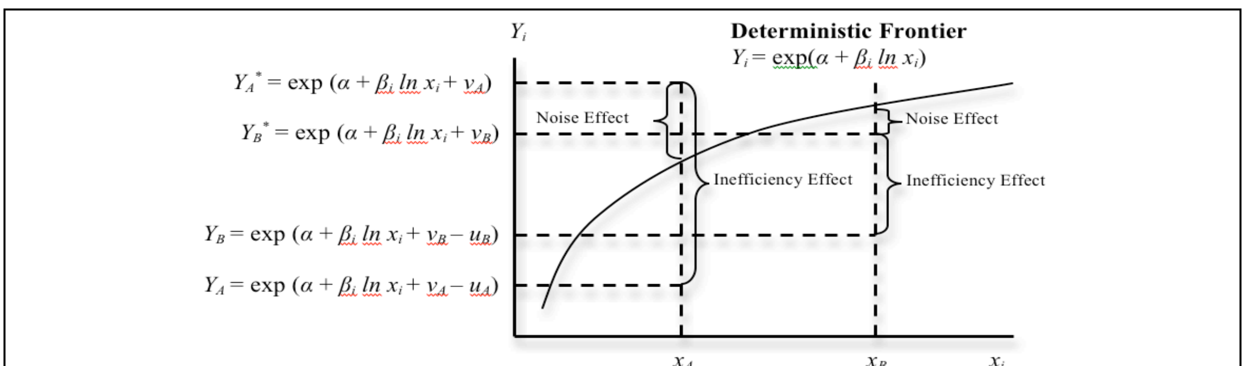

Figure 1. Stochastic Production Frontier Concepts (Coelli et al., 2005)

3.2. The Productivity and Efficiency Models

Amiti and Wei (2005) used the technological change parameter of the Cobb-Douglas model, representing total factor productivity, to estimate the impacts of services offshoring on productivity at the industry level. Park et al. (2007) used a similar approach to explore the impacts of domestic and foreign IT stocks on national productivity. We will extend this model to capture the effects of the globalization of IT goods and services. We specify the production frontier for the IT industry in the OECD countries from 2000 to 2006 industry productivity and efficiency performance. We also take into account country and time-specific heterogeneity (Greene 2004), as follows:

Cobb-Douglas Productivity Model:

$$Output_{it} = G(ITImports / GDP_{it}, ITOffshoring / GDP_{it}, FDI / GDP_{it})\ Capital^{\beta 1}\ Labor^{\beta 2}$$

$$lnOutput_{it} = \beta_0 + \beta_1\ ln\ Capital_{it} + \beta_2\ ln\ Labor_{it} + \beta_3\ ITImports / GDP_{it} + \beta_4\ ITOffshoring / GDP_{it} + \beta_5\ FDI / GDP_{it} + \varepsilon_{it}$$

Two-Stage Stochastic Frontier Efficiency Model:

- Stage 1 (measurement of inefficiency u):

$$lnOutput_{it} = \gamma_0 + \gamma_1\ ln\ Capital_{it} + \gamma_2\ ln\ Labor_{it} + v_{it} - u_{it}$$

with $u_{it} \sim |N(\mu_{it}, \sigma_u^2)|$, $v_{it} \sim N(0, \sigma_v^2)$

- Stage 2 (explanation of inefficiency u):

$$u_{it} = \alpha + \gamma_3\ ITImports / GDP_{it} + \gamma_4\ ITOffshoring / GDP_{it} + \gamma_5\ FDI / GDP_{it} + \varphi_{it}$$

Hejazi and Safarian (1999) argued that focusing exclusively on trade or FDI may lead to biased estimation of the growth effects of an international orientation. For example, foreign affiliate sales and trade exports to the same market are both complements and substitutes (Blonigen, 2001). Our representation of IT globalization is that it occurs through data on IT products imports and IT services offshoring. To control for potential bias, we attempted to use IT-specific FDI in our analysis, but the lack of data limited this option. We only had access to overall FDI at the country level. Having only aggregate FDI may restrict the fidelity of our reading on the IT industries, so we included FDI inflows as a *quasi-control variable* rather than an explanatory variable.

Imports of IT goods, IT offshoring, and FDI are all aggregated at the country level. To control for the size of a country's economy, we divided each of the three variables by gross domestic product (*GDP*), that is, *ITImports* / *GDP*, *ITOffshoring* / *GDP*, and *FDI* / *GDP*. If we were to consider imports of IT goods specific to a country's IT industry alone, we would not be able to capture the substitution effects between domestic IT goods and imported IT goods consumed in the country. The same argument applies to IT offshoring: if we only were to use data specific to a country's IT industry, we would overlook the complementarities between IT production and IT services. IT services require the consumption of IT goods that are provided by either domestic IT producers or foreign IT vendors through imports. When domestic IT-using industries acquire less IT services or when they offshore IT services to other countries, the demand for IT goods produced by the domestic IT industry should decline. This complementarity needs to be captured in the international context, and our models and data serve to accomplish this.

4. DATA COLLECTION AND VARIABLES

We collected panel data on IT industry production and IT globalization from fourteen OECD countries during 2000 to 2006.[3] The data sources included the OECD, the World Trade Organization (WTO), the United Nations (UN), and the World Bank. The production data on the IT industry came from OECD's Structural Analysis database (STAN), which defines the IT industry in terms of the category of "Office, Accounting and Computing Machinery" following the International Standard Industrial Classification Revision 3 (ISIC Rev. 3).

Table 2. Data Sources

VARIABLE	DESCRIPTION	SOURCES
Output	IT industry gross output (ISIC Rev. 3 Code 30) (constant 2000 $)	OECD Stan Database
Capital Stock	Estimated net stock of fixed assets via the series of gross fixed capital formation of IT industry and geometric age-price profiles (constant 2000 $)	OECD Stan Database
Labor	IT industry employee compensation (constant 2000 $)	OECD Stan Database
IT Goods Imports	Imports of office and telecom equipment (SITC Codes 75, 76 and 776).	World Trade Org.
IT Offshoring	Computer and information services (EBOPS 262)	UN Service Trade Database
FDI	Net inflows of foreign direct investments	World Bank
GDP	National gross output.	World Bank

Notes. EBOPS 262 = "Extended Balance of Payments Services:" computers (hardware, software, and data processing), news agency (provision of news, photographs, and feature articles to the media), and other information services (database services and web search portals).

Measures of capital stock at the international level are known to be difficult to collect. Only a limited number of national statistical offices in the OECD countries publish capital stock data on a regular basis. Also, there are issues with the international comparability of the national data of the countries that collect it (Schreyer and Webb, 2006). Although the STAN database provides a standard industry classification that mitigates the data comparability issues to some extent, measuring capital stock at the industry level has proven to be an insurmountable hurdle: the STAN database only provides gross capital stock for six out of thirty member countries. This makes the design of an industry-level analysis untenable.

The strength of the STAN database that we can draw upon, however, is that it provides rich information on net capital flows at the country and industry levels. With this data in mind, we implemented an approximation method attributable to Kohli (1982) that was suggested by the OECD (2008) productivity measurement manual. It can be used to estimate initial capital stock in a given year, working forward

[3] The OECD countries included are Austria, Belgium, Czech Republic, Finland, France, Germany, Greece, Italy, Korea, Norway, Poland, Sweden, the United Kingdom and the United States. Some notable exceptions are Canada, Denmark, the Netherlands and Japan, among others.

from the earliest net capital flows that an analyst is able to acquire to the given year. Because this is an approximation though, it is prudent to have a set of initial net capital flows for several years in the past to achieve an estimate of the initial capital stock. This is a means of providing a degree of within-data set validation. In fact, this was the main constraint we had to overcome in constructing our panel data on the OECD countries, since in 1989, there were only 24 members and not every country reported national statistics at the industry level.

Applying this approximation, we estimated the initial capital stock at $t = 0$ for country i as follows: $TotalCapital_{i0} = InvCapitalFlow_{i0} / (GrowthRate_i + DeprecRate_i)$. In this expression, $InvCapitalFlow_{i0}$, is the initial investment capital flow into country i. The growth rate, $GrowthRate_i$, of the investment capital flow was calculated with the earliest ten years of investment data that we had available. We assumed an appropriate depreciation rate, $DeprecRate_i$, of 5%, which was used by Park et al. (2007), in their *Information Systems Research* study of the impact of international IT Transfer on national productivity. Once we obtained the initial capital stock, $TotalCapital_{i0}$, we then computed the subsequent values of the capital stock series using the *perpetual inventory method* via the following relation (with the country subscript suppressed): $TotalCapital_t = TotalCapital_{t\text{-}1} \cdot (1\text{-}\ DeprecRate_i) + InvCapitalFlow_{t\text{-}1.}$

For IT services offshoring and IT goods imports, we used UN data for the imports of "Computer and Information Services," and WTO data for the imports of "Office and Telecom Equipment." For the impacts of IT globalization, we collected the net inflows of GDP and FDI to the various countries from the World Bank. We then included them as control variables in our models to account for the economy size, and a country's external orientation, beyond the level of trade in which it engages.[4] (See Table 3.)

Table 3. Descriptive Statistics

VARIABLES	MEAN	STD. DEV.	MIN	MAX
IT Industry Production (millions of constant 2000 $)				
Output (gross output)	$4,970	$10,590	$7,554	$58,364
Labor (employee compensation)	$ 331	$ 387	$ 372	$ 1,741
Capital (estimated fixed assets)	$5,135	$10,081	$ 0.42	$47,958
IT Globalization Ratio				
ITImports / GDP (inflows of IT hardware equipment divided by GDP)	3.254	1.561	1.122	8.372
ITOffshoring / GDP (IT services offshoring divided by GDP)	0.199	0.152	0.145	0.590
Outward Orientation Ratio				
FDI / GDP (net inflows of foreign direct investments divided by GDP)	3.338	3.282	-0.323	15.732

[4] Kauffman and Kumar (2008) have pointed out that data availability in the international IT impact research normally takes two years for international agencies and governments to assemble, another typical limitation on the construction of data sets for this kind of work.

5. RESULTS

We next present our estimation results for the productivity and efficiency models, and evaluate their implications for the hypotheses that we stated earlier in Section 3. Since we are dealing with a relatively small sample of OECD countries' data, we also will discuss additional robustness evaluations that we carried using statistical re-sampling methods, as a basis for increasing the credibility of our claims for the empirical results.

5.1. Estimation Results

To examine the performance of the IT industry in the context of IT globalization, recall that we used an extended Cobb-Douglas function for productivity assessment and a two-stage stochastic frontier model for efficiency measurement. Table 4 shows the estimated impacts on productivity and efficiency. A positive sign on a coefficient estimate indicates that the variable has a negative impact on efficiency.

Our results show that *ITImports /* GDP has a positive impact on productivity, lending empirical support to our IT Goods Imports and Productivity Hypothesis (H1a). Knowledge embedded in the import process for foreign-made IT goods appears to bring about technical progress – the driving force for productivity improvement – for the domestic IT industry among the OECD countries that we studied. In terms of efficiency, knowledge spillovers also appear to outstrip the substitution effects, leading to a positive net impact on efficiency. This finding is in accord with the IT Goods Imports and Efficiency Hypothesis (H1b). *ITOffshoring / GDP* has a negative impact on productivity, according to our estimation results, which supports the IT Offshoring and Productivity Adverse Complementarities Hypothesis (H2a). A reduction in demand for domestic IT services due to IT offshoring diminishes productivity, most likely through a process that leads to a reduction of the scale of domestic IT production. Thus, IT offshoring is associated with adverse complementarities that develop between IT services and IT production. We also find that such adverse complementarities hurt efficiency, a result that is consistent with the IT Offshoring and Efficiency Adverse Complementarities Hypothesis (H2b).

Table 4. Productivity and Efficiency Results for the OECD Countries, 2000-2006

VARIABLE	PRODUCTIVITY		EFFICIENCY	
	COEFF.	STD. ERR.	COEFF.	STD. ERR.
ln Capital	0.481***	0.045	0.536***	0.046
ln Labor	0.454***	0.076	0.494***	0.079
ITImports / GDP	0.177***	0.050	-0.095***	0.030
ITOffshoring / GDP	-1.658***	0.586	0.643**	0.321
FDI / GDP	-0.110***	0.026	0.060***	0.015
Adj.-R^2	91%		25%	

Notes. Models: For productivity estimation, extended Cobb-Douglas function; for efficiency estimation, first-stage stochastic frontier analysis (results marked with lighter gray background), and second-stage regression (results marked with darker gray). Unit of analysis: 14 OECD countries for 7 years, with some missing data; $N = 85$. Signif.: * = $p < 0.10$; ** = $p < 0.05$; *** = $p < 0.01$. Interpretation: Positive signs on coefficients indicate a negative impact on efficiency.

5.2. Statistical Re-Sampling for Ensuring Small Sample Robustness

Since our data consist of only fourteen OECD countries, one can raise the question about the robustness of the parameter estimates and results that we have established based on such a small sample. To enhance the validity of our results and our confidence in the conclusions we have drawn, we also performed a *small sample statistical re-sampling technique* called *jackknifing* to estimate the precision of our sample statistics, especially the standard errors and confidence intervals of the estimate of a variable's coefficient in a regression (Miller 1964).

The jackknifing procedure was originally proposed by Quenouille (1949) to estimate the bias of a one-sample estimator. Tukey (1958) later found that jackknifing can also be used to construct variance estimators. Similar to *bootstrapping*, which permits random re-sampling with replacement, jackknifing allows an analyst to compare the coefficient estimates based on an entire data set with a new estimates obtained by iteratively calibrating the model with a subset of observations that are left out (Miller 1964). This provides a basis for estimating the bias and standard error of an estimator (Miller 1968), through the assessment of *pseudo-values*, which are sub-sample estimates of the parameter of interest. The variant of the jackknifing method that we will apply is systematically re-computing the estimator of interest by leaving out one observation at a time from the sample data set (Schechtman and Wang, 2004). Jackknifing-generated parameter pseudovalue estimates support the assessment of the variability of a statistic in a full sample versus in comparison with its sub-samples, rather than via some more restrictive parametric assumptions. Jackknifing is applicable to complex sampling schemes, such as multi-stage sampling with varying sampling weights as well (Shao and Tu, 1995).

Advances in the application of jackknifing in the 1970s and 1980s support the broad application of the method to a range of problem settings where there is an interest establish a reading on the true value of some parameter θ based on the parameter pseovalues than can be obtained via a function of the regression $\theta = f(\beta)$, for the range of supported linear and non-linear models (Miller 1974a, 1974b). Jackknifing leads to the elimination of observation i (a country in our application), with the resulting sub-sample parameter of $\hat{\beta}_{-1}$, the least squares estimate of $\hat{\theta}_{-i} = f(\hat{\beta}_{-i})$. The related jackknife estimate of the function $\theta = f(\beta)$ for n observations then is given by $\tilde{\theta} = n\hat{\theta} - (n-1)(\sum \hat{\theta}_{-1} / n)$, with the standard error of the pseudo-values as $\tilde{\theta}_{-i} = n\hat{\theta} - (n-1)\hat{\theta}_{-1}$, which is also a consistent estimate of the asymptotic standard deviation of $\hat{\theta}$. See Miller (1974a) for more details.

The Productivity Re-Sampling Results. We next consider the jackknife re-sampling results for the iterative estimation of the Cobb-Douglas production model. We depict the variation of the coefficient estimates for the *ITImports / GDP* and *ITOffshoring / GDP* in the productivity model estimations in

Figure 2. (See Appendix Table A1 for the details of the jackknife estimation results in comparison to the estimates produced from the full sample in the Full Sample column.)

***ITImports / GDP* Pseudo-Values in the Productivity Estimation (H1a)**	***ITOffshoring / GDP* Pseudo-Values in the Productivity Estimation (H1b)**

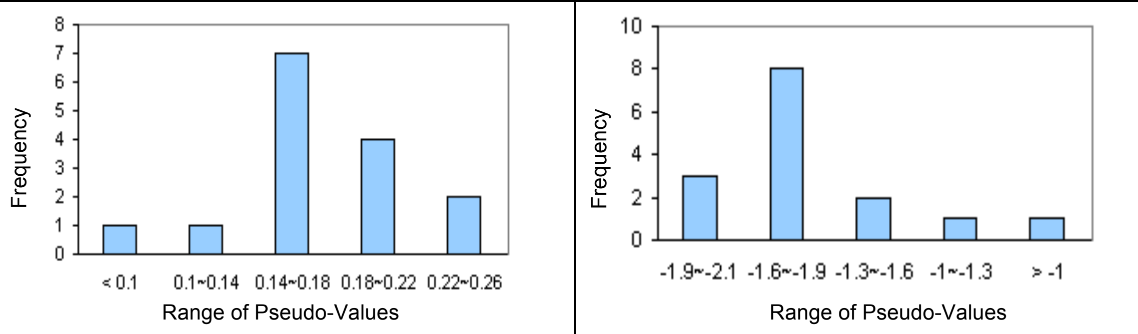

Figure 2. Jackknife: Knowledge Spillovers and Substitution Hypotheses Results

The main observation that should be made here is that the re-sampling-based productivity results exhibit some variation of the relevant coefficients, reflecing the distribution of jackknife pseudo-values. (See Figure 3.) They nevertheless appear to be similar to the full sample results. (See Table 4 and Appendix Table A1.) An exception is the estimate for the IT goods imports variable when the Czech Republic is dropped. In addition, the coefficient estimates for IT services offshoring are similar for all of the estimations that were run with individual countries iteratively dropped out, except for when Belgium was dropped. (See Figure 3 again.) The coefficient estimates for the exceptions have the same signs; it is just that they became insignificant.

Thus, the jackknifing results for the effects of IT goods imports and IT services offshoring relative to the productivity of the IT industry at the country level among the OECD countries provide additional evidence of the robustness of our conclusions regarding the knowledge spillovers and substitution hypotheses (H1a and H2a). IT good imports have a positive impact and IT outsourcing has a negative impact on the productivity of the IT industry.

The Efficiency Re-Sampling Results. We next consider the iterative re-sampling estimation results for efficiency in the stochastic frontier analysis. We applied the jackknife procedure to the second stage of our two-stage stochastic frontier model only. We did not need to do this for the first stage, since it only measures technical efficiency. This should be determined based on the whole data set. In contrast, the second stage attempts to explain efficiency variations across the OECD countries IT industry. The results of this second analysis are shown next. (See Figure 3.)

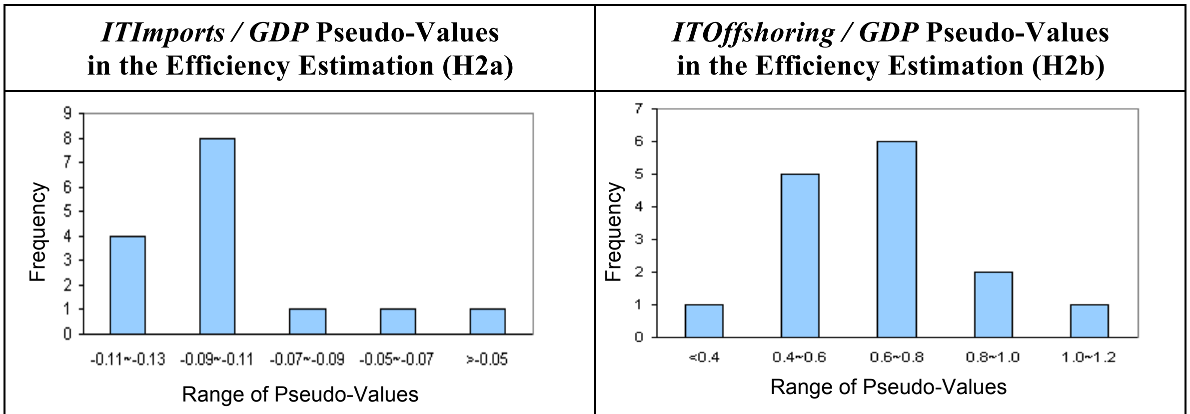

Figure 3. Jackknife: Adverse Complementarities Hypotheses Results

Figure 3 shows the distribution of pseudo-values for the *ITImports / GDP* and *ITOffshoring / GDP* in the context of the efficiency estimation. We can use these results to assess whether greater or lesser confidence should be accorded to our adverse complementarities hypotheses. The relatively tight distribution of coefficients' pseudo-values around the estimated values of the coefficient in the full sample offers further encouragement on the robustness of our primary findings. The efficiency results based on the jackknife method are very consistent for IT goods imports, and relatively (if not perfectly) consistent for IT services offshoring also. The coefficient pseudovalue estimates for IT goods imports are all significant and negative, except when the Czech Republic is left out of the jackknife data set. The coefficient pseudovalue estimates for IT services offshoring also are significant and positive for all but five of the fourteen countries. (See Appendix Table A2 for the details of the results that are summarized in Figure 3.) Where there are findings that did not match our expectations for some of the countries, the pseodovalues all have the same signs; they were not significant though. From this additional analysis, we feel stronger in asserting our conclusion related to the adverse complementary hypotheses: IT goods imports have a positive impact and IT services offshoring has a negative impact on the efficiency of the IT industry among the OECD nations that we studied.

5.3. Results for a Control Variable: Foreign Direct Investments

Although foreign direct investments (FDI) is not a variable of our main interest and its measurement is at the country level, we noticed that its estimated impacts on both productivity and efficiency of the IT industry were significant and negative. (See Table 4, and Appendix Tables A1 and A2.) To probe this result further, we estimated one-year and two-year lagged models for FDI, and the results were consistent: they still indicated negative impacts for FDI on productivity and efficiency. (For brevity of exposition, we omit the results here, since there is no new information that the reader will take away from them.) These results appear somewhat surprising. However, the empirical research on the spillover effects of FDI have been mixed in the literature (Lipsey 2002; Smeets 2008; Zhu and Liu, 2007). Moreover, some researchers have argued that positive impacts of FDI may only exist through backward linkages or vertical FDI (Harris 2009; Smarzynska 2002).

Vertical FDI occurs when multinational companies transfer knowledge to their local suppliers to maintain or improve product quality, while taking advantage of the lower cost of local suppliers (Markusen and Venables, 2005). This results from efficiency or resource-seeking incentives for investors. Horizontal FDI due to increased market competition may bring negative knowledge spillovers, however (Javorcik, 2004; Javorcik et al., 2004). *Horizontal FDI* occurs when multinational companies have incentives to prevent such competitive position-compromising information leakages (Markusen, 1995). Competition from foreign investors puts pressure on domestic firms' market shares (Aitken and Harrison, 1999). Domestic IT goods producers, as a result, will lose market share to foreign competition, and suffer from decreases in productivity and efficiency. Since our data covered mostly developed OECD countries that have mature markets, these countries probably mostly have horizontal FDI, which is mainly driven by market access opportunities, and not cost advantages. FDI in the OECD countries, thus, is likely to bring about negative impacts.

We have seen this with the mobile phone market in the U.S. LG Corporation's (www.lg.com) CDMA mobile phones were the bestsellers in the U.S. in the 2002 to 2005 period (LG Press Release, 2005). LG is based in Seoul, South Korea. It manufacturers its mobile phones in China, which makes it hard for most U.S. domestic producers to compete – even when they do global sourcing. Another example is microcomputers and PCs. The U.S.'s second largest producer of PCs, Dell Inc., saw its market share of PC sales decline rise by just 0.1 percentage point to nearly 15% in the U.S. in 2008. Meanwhile, Taiwan's Acer (www.acer-group.com), the third largest seller of PCs in the world, achieved a three percentage point increase to 10.9% share during the same period (Vance, 2009). Acer purchased the American PC producer-retailer Gateway Inc. in August 2007. Both companies represent cases of horizontal FDI. Still, our analysis is based on national-level FDI. It would be more informative if we had been able to gain access to FDI data that were specific to the IT industry in the OECD countries, but these simply were not available.

6. DISCUSSION

We next offer some final observations about the methods innovations we have leveraged, and why research in the IS discipline should not shy away from small sample empirical research. As Box and Draper (1987, p. 74) have reminded us, "[e]ssentially all models are wrong, but some are useful," including those we parameterize with model-based statistical estimates. We also comment on the nature of the rich insights that this research has to offer to theory-building and policy-making efforts on IT offshoring.

6.1. "Small Is Beautiful:" Valuing Empirical Research with Hardly Any Data At All

In this research, we have employed a couple of innovations that we would like to point out to others so they will be encouraged to study settings in which it is hard to do meaningful empirical research. In this case, our primary challenge was with finding data to take this work – and the resulting contributions to new knowledge – beyond the level of individual case study or cross-case analysis. Indeed, there were some OECD countries that had data available for all the variables that were important to us in this research. But if we had not taken a more aggressive approach to the construction of our data set – with multiple agency data sources, multiple methods for building "good enough" measures, and advance thought given to validating the crucial IT capital measures that we use at the country level – we would not have been able to accomplish much.

Perhaps one of the strongest methods-related messages that we can leave with the reader is that having access to a lot of data sometimes can misdirect the investigator away from important problems and the necessity for thinking through what it will take to achieve useful insights in theory and business policy terms. For example, we are reminded of the seminal work in software engineering economics by Chris Kemerer of the University of Pittsburgh, who published one of the early empirical validations of the alternate software cost estimation models in the 1980s (Kemerer 1987). He studied function point analysis, a method which offered a lower cost means to collect proxy measures for gauging software output size that was shown to perform well relative to the less robust measurement of source lines of code across different development environments. The author, pointing to the well-known work of two other leading software engineering economists, Barry Boehm at the University of South California and Allan Albrecht of IBM White Plains (now IBM T. J. Watson Research Center), commented:

> *"... 15 projects qualified for inclusion in the study. The researcher or practitioner interested in large business applications is likely to find this data set to be a useful contribution for two reasons: First, in terms of sheer number of projects, it compares favorably with a number of other published studies ... Second, and more important than the number of projects alone, is the content of the database. This database contains large business applications, 12 of which were written entirely in Cobol, the most widely used business data-processing language. By contrast, Boehm's 63-project database contains only 7 business applications, of which only 4 were written in Cobol. Albrecht's 1983 database contains 18 Cobol projects, but with an average size of only 66* [*thousand source lines of code*]. *The average size of Cobol applications in the ABC database is 221* [*thousand source lines of code*]." Kemerer (1987, p. 419)

Most researchers – doctoral students and faculty alike – are likely to view an empirical study with only fifteen software projects (like Kemerer's) or fourteen countries (like ours) as a poor candidate for being able to make a meaningful contribution to theory and practice in a well-developed sub-field of knowledge in an academic discipline. They might even view it with derision, and believe that others who are conducting the research might be wasting their time for the want of "better" problems that offer the investigator access to much richer data sets.

Nothing could be farther from the truth though. This perspective fails to recognize that the "right" perspectives, tools and expectations can be brought to bear on the problem, in order to generate new knowledge. Kemerer's work is an exemplar in this respect. It contains innovative data analysis and modeling, and rich comparisons across different approaches to software size estimation within the limited project data. More importantly, he offers a set of extraordinary revelations about how much new knowledge can be extracted from such a "small slice" of the world of software development project management in large organizations. This is a valuable lesson for IS researchers to learn – even those of us who are used to large data sets, high-powered panel data econometrics, and the ample degrees of freedom for model specification that go along with these. This lesson is suggestive of the high frontier of new knowledge that awaits our discovery, so long as we have the courage to innovate a bit to tap into it.

Another interesting and recent example of "empiricism in the small" has nothing to do with IS research, but it nevertheless is instructive to drive home our key methods message in this research: empirical research with small data sets can be quite powerful. The relevant work is by economists, Bentley Coffey of Clemson University and Patrick McLaughlin of the United States Federal Railroad Administration (Coffey and McLaughlin 2009). They studied the extent to which women with "nominally more masculine names" were more likely to become judges in South Carolina. They used state voting records for the elections of officials to fill state judiciary position. In spite of starting with 2.25 million voters, ultimately their sample included only 156 male and 52 female judges. Further, among the female judges, relatively few had names that were very masculine. Nevertheless, the authors sought to validate the *Portia hypothesis*: the idea that women with more masculine names might be more electable to judicial positions that were traditionally held by men. [5] Their innovation – beyond the act of asking such an interesting research question in the first place – was to figure out how to create metrics to score "nominal masculinity," and then work with the statistical re-sampling method of 10,000- iteration random bootstrapping. Their results showed that female judges are five time more likely to achieve an elected state judgeship if they have nominally more masculine names. Coffey and McLaughlin (2009)'s article, in spite of its recent vintage and the limited data it employs on female judges with masculine names, is a work that is likely to reach "seminal paper" status in a relatively short time.

The reader surely will understand the point we are trying to make now: what matters most in research is the quality of the problem that is being studied, and not the availability or the amount of data that the investigator uses to study it. In contributing this research article to the newly-established *Pacific Asia Journal of the Association for Information Systems*, we hope that this message will come through – in addition to our theory and policy-related findings.

---

[5] Shakespeare's character, Portia, dressed as a man to impersonate a lawyer, so she could plead against the court's judgment of her lover, Antonio, the Merchant of Venice, having to pay off his creditor with a "pound of flesh."

6.2. Theory and Policy Implications

Lou Dobbs, a leading American journalist and for nearly 25 years at American news giant CNN, and its top economics correspondent and business anchor in North America, has railed against the "evils of outsourcing," including lost jobs, depressed wages, declining corporate control of business processes, and new vulnerabilities for the theft and exploitation of sensitive, private data. Although some concerns can be raised about the substitution of imported IT goods for domestic ones, others have suggested a much more positive set of outcomes from IT offshoring. For example, the Information Technology Association of America commissioned Global Insight (www.globalinsight.com) (2004) to do a study on IT offshoring and its impacts on the American economy. From 2004 to 2008, the study predicted, 317,000 new jobs would be created from incremental new economic activity that was made possible by offshoring, along with further expansion in non-IT offshoring services and US$124.2 billion in GDP that would not materialize in the absence of IT offshoring. Global Insight also reported that outsourcing will lead to higher productivity, though the mechanism for this that was proposed was not identified.

The knowledge spillovers that result from IT goods imports can also lead to improvements in productivity and efficiency. After accounting for these two forces and their interaction, our research has found that IT goods imports have a positive net impact on the productivity and efficiency of IT industries in the OECD countries. In comparison with prior research on the impacts of technological change on labor productivity, Eaton and Kortum (1996, p. 251) have commented that "(w)here technological change originates and how it spreads across countries is less well understood." They further pointed out that the majority of OECD countries obtain over 90% of their productivity growth from ideas that originated abroad. Previous studies also confirmed that international technology diffusion occurs through R&D activities and licensing agreements in the PC industry (e.g., Anand and Khanna, 2000; Mendi, 2007). Consequently, our results complement the research stream by exploring the diffusion of international IT capabilities through the international trade of IT goods.

Though welfare gains at the economy level from IT offshoring have been recognized in the literature, we found that IT offshoring has negative impacts on the performance of the OECD countries' IT industry in terms of productivity and efficiency. This is analogous to the dilemma we have seen arise elsewhere in electronic commerce. An example is person-to-person (P2P) file sharing, which has had negative impacts on the creative artists who compose music (due to loss of ability to enforce copyright) and the music industry as a whole (through reduced song and album sales in the face of piracy), but positive impacts on social welfare in general.

McLaren (2000) has argued that globalization provides firms in countries that are suppliers and buyers in international trade with more options to pursue in their procurement strategies, mitigating the potential hold-up problem (Voeth and Herbst 2006, Williamson 1995). Broda and Weinstein (2006) have shown that globalization increases the product variety that firms can offer, which in turn has the potential to improve a country's national social welfare. Due to the adverse complementarities between IT production and IT services though, IT offshoring – based on our results – has demonstrated negative impacts on the productivity and efficiency of the OECD countries' IT industry. Policy-makers and government officials need to be cognizant about this trade-off. Though benefits from IT offshoring are being achieved at the national level, they also need to be aware of the possible negative impacts on the domestic IT industry's performance.

Since most outsourced IT activities tend to involve low skill requirements, most IT equipment that is needed to perform these IT activities being outsourced is obtained as price-sensitive commodity-type technology product*s* (e.g., PCs and printers). Kramer and Dedrick (1998) found that price competition in commodity IT hardware markets is fierce, and Asian producers have cost advantages over those in the U.S. and other OECD countries. Additionally, in commodity markets for PCs, brands yield little differentiation power (Bresnahan et al., 1997). Thus, foreign outsourcing IT services vendors should favor less expensive IT equipment produced by low-cost IT manufacturers either locally or in developing countries, instead of brand name IT products from companies in the outsourcers' own developed countries.

Yet, the IT producers in the OECD countries have competitive advantage in high-end product lines. For example, Red Hat (www.redhat.com) recently announced that its open source cloud computing solution is available on HP's (www.hp.com) high-end BladeSystem Matrix (HP Press Release, 2009). In the markets for high-end IT products, functionality and quality are more important than prices. As a result, there will be more attractive profit margins and higher value to be appropriated than in the intensely competitive markets for commodity IT products. Thus, in response to the demand reduction for IT products brought by IT offshoring, the IT industry in the OECD countries should focus more on the production of high-end products that can yield more value-added. As we know from observed firms such as Intel, HP, IBM and Sun Microsystems, it is necessary to pursue a strategy of continuously technology investment and R&D. This is consistent with Aspray et al.'s (2006) argument on IT offshoring that as firms get their IT routines wired from abroad, IT workers previously in non-core functions will be reassigned to core business processes or activities that require intensive quality control and staff involvement.

Thus we see that this research offers methods, theory, and policy insights for the specific context that we studied, as well as more broadly, for international settings involving trade in IT goods, IT offshoring, and FDI. Although we will not claim that our research design is "first-best" for the setting we have explored – the data simply did not permit that – nevertheless, the policy-making ideas and industry-related perspectives that we have been able to develop from it suggest the high relevance of this form of engaged scholarship for international business and government.

7. CONCLUSION

The performance of the IT industry in OECD nations is critical to their national economies. This is true based on the supply-and-demand relationship between IT-producing and IT-using industries in these countries. Although previous research has shown that the IT industry facilitates a country's economic performance (Oliner and Sichel, 2000), we have probed the issues more deeply. Our goal has been to understand the extent to which the performance of the IT industry in OECD countries is affected by increasing globalization of industry production, through IT goods imports and IT services offshoring. To produce new knowledge in this domain of study, we applied two associated methods from production economics: an extended Cobb-Douglas production model and a two-stage stochastic frontier approach. These two methods enabled us to examine how the productivity and efficiency of the IT industry in fourteen OECD countries has been affected during the past decade. We have done this work with confidence in the value of small sample statistics methods, and a sense that important research can be done with hardly any data at all, if the analyst brings the "right" theory, models and methods to the work.

Since the IT industry is one of the drivers of economic growth in most developed countries, our analysis is useful for the implications it offers to policy-makers. Our results are suggestive of the consequences of increasing IT trade and IT offshoring. Our research contributes by offering three distinct explanatory and predictive perspectives – the theories of knowledge spillovers, substitution and complementarities theory – to explain the changing dynamics of IT globalization. Our research has considered all three and the interactions among them simultaneously. Our findings suggest that the knowledge spillovers and substitution effects theories compete with one another, so that establishing an explanation of the phenomena that we observed in the selected OECD countries requires an analyst to determine which of the theories is likely to be consistent with the dominant effects that are observed. Our assessment of the relationships between IT production and IT offshoring suggested that a theory of adverse complementarities may be appropriate to explain what is happening with the underlying cross-industry processes.

Although this research represents one of the first attempts to examine the productivity and efficiency of IT industry in the presence of the globalization of IT goods and services, it has several limitations that are worthwhile to point out to the reader. First, we stated early on in this article that a data set comprised of only fourteen OECD countries presented some challenges for us to establish the robustness of the conclusions we have attempted to draw about our two groups of hypotheses. Our use of the small sample statistics technique of jackknifing reflects our effort to do the best we can with the limited data at hand, by providing a fuller reading on what the data can tell us, and especially the extent to which such a small amount of data might bias our conclusions.

Second, we also have pointed out to the reader that it was difficult for us to acquire data on exactly those variables that we wished to study. Capital stock data for IT were not directly available at the industry level for all the OECD countries that we hoped to target. Our approach – and one that we hope the reader will believe offers an inventive solution to the data availability problem that we faced – was to apply a capital stock estimation method suggested by the Statistics Department of OECD, that has been used for different purposes in other macroeconomic analysis contexts. This method may be useful for other researchers who are constrained by the unavailability of capital stock data, and where its imputation can be accomplished for various analysis settings.

A third limitation is due to the choice we made to model IT goods imports, IT services offshoring and FDI – all of which are at the aggregate country level – as opposed to the disaggregated industry level. This choice enabled us to estimate and explain some of the behavioral richness of the interactions between the IT industry and other IT-using industries. Nevertheless, it would have been even better for us to have been able to obtain data on the specific amount of IT goods imports that were consumed by each industry across the years of the study. But such data are not accessible to anyone now.

This was due to the lack of disaggregated data that the various international agencies make available. The national economic statistics organizations of the OECD countries do not share the same practices with data collection, nor do they always choose to make it available to the OECD. The reader may note that Japan, an important OECD member nation, and one of the largest economies in the world in terms of its international trade, is not represented in our data. Data on IT imports, capital and offshoring have not been made available by the Japanese Ministry of Economy, Trade and Industry (METI, www.meti.go.jp), or the Japan External Trade Organization (JETRO, www.jetro.go.jp), though these organizations are among the most sophisticated collectors of data on trade, economy and technology. Additionally, because our data were collected from multiple sources, it may also be the case that inconsistent measurement methods and quality controls effected by the different agencies might lead to potential measurement errors and bias the results we have reported and the conclusions we have drawn. Fortunately, our research is no more subject to problems with validity from this source than any other related work that has been undertaken to date in the OECD countries and international trade domain.

Fourth, the IT industry, as defined by the OECD in the context of its macroeconomic analysis operations, only includes IT hardware products. It does not yet consider telecommunications and software. The OECD statisticians have another category called “Radio, TV and Communication Equipment” (ISIC 3832). This category contains radio and television products that typically are not considered to be part of the IT domain. Another interesting observation is that the OECD – to date anyway – does not report data on software expenditures. This is a curious anomaly, and one that is likely to be addressed in the coming years, since software costs have persistently increased over the last two decades. Yet little concrete progress has been made to define the measures, track the data and interpret the cost trends for software development and maintenance at the country level for OECD nations. Consequently, the examination of the performance patterns of the software sector in the OECD context offers a promising, but even more data-constrained avenue for follow-up research.

Finally, the so-called *newly-industrialized economies* (NIE) may have some features that are different from those of the OECD countries, and this may further limit the generalizability of the conclusions that we have drawn for application in other settings. The NIE countries are key suppliers in the global supply chain of IT products – much more so than they are consumers of IT goods imports from other countries, or users of other countries' IT services capabilities. Some examples of NIEs in the Asian context include China, Indonesia, Malaysia, Taiwan and Thailand. They are famous for their use of the *original equipment manufacturer* (OEM) and *original design manufacturer* (ODM) business models in chipset and motherboard, modem and router, and PC and flat panel display production and manufacturing. Future research should examine how the IT industries in these countries have reacted to the globalization of IT goods and services, and how the relationships between the NIE and OECD countries – as producers and consumers – has influenced the globalization of business.

REFERENCES

Aigner, D., Lovell, K., and Schmidt, P. (1977) "Formulation and Estimation of Stochastic Frontier Production Function Models," Journal of Econometrics, 6(1), pp. 21-37.

Aitken, B. J., and Harrison, A. E. (1999) "Do Domestic Firms Benefit from Direct Foreign Investment? Evidence from Venezuela," American Economic Review, 89(3), pp. 605-618.

Alvarez A., Amsler, C., Orea, L., and Schmidt, P. (2006) "Interpreting and Testing the Scaling Property in Models Where Inefficiency Depends on Firm Characteristics," Journal of Productivity Analysis, 25(3), pp. 201-212.

Anand, A., and Khanna, T. (2000) "The Structure of Licensing Contracts," Journal of Industrial Economics, 48(1), pp. 103-135.

Aspray, W., Mayadas, F. and Vardi, M. Y. (eds.) Globalization and Offshoring of Software: A Report of the ACM Job Migration Task Force, New York, NY: ACM Press, 2006.

Blonigen, B. A. (2001) "In Search of Substitution between Foreign Production and Exports," Journal of International Economics, 53(1), pp. 81-104.

Bresnahan, T. F., Stern, S., and Trajtenberg, M. (1997) "Market Segmentation and the Sources of Rents from Innovation: Personal Computers in the Late 1980s," Rand Journal of Economics 28, pp. S17-S44.

Brynjolfsson, E. and Hitt, L. (1996) "Paradox Lost? Firm-Level Evidence on the Returns to Information Systems Spending," Management Science, 42(4), pp. 541-558.

Broda, C., and Weinstein, D. E. (2006) "Globalization and Gains from Variety," Quarterly Journal of Economics, 121(2), pp. 541-585.

Coffey, B., and McLaughlin, P. A. (2009) "Do Masculine Names Help Female Lawyers Become Judges? Evidence from South Carolina," American Law and Economics Review, 11, 1, pp. 112-133.

Comin, D. (2008) "Total Factor Productivity," In S. N. Durlauf and L. E. Blume (eds.), The New Palgrave Dictionary of Economics, New York, NY: Palgrave MacMillan.

Cramer, G. L., Wailes, E. J. and Shui, S. (1999) "Impacts of Liberalizing Trade in the World Rice Market," American Journal of Agricultural Economics, 81(5), pp. 1149-1156.

Dewan, S. and Kraemer, K. L. (1997) "Information Technology and Productivity: Evidence from Country-level Data," Management Science, 46(4), pp. 548-562.

Eaton, J. and Kortum, S. (1996) "Trade in Ideas: Patenting and Productivity in the OECD," Journal of International Economics, 40(3-4), pp. 251-278

Gordon, R. J. (2000) "Does the 'New Economy' Measure Up to the Great Inventions of the Past?" Journal of Economic Perspectives, 14(4), pp. 49-74.

Greene, W. H. (2004) "Distinguishing between Heterogeneity and Inefficiency: Stochastic Frontier Analysis of the World Health Organization's Panel Data on National Health Care Systems," Health Economics, 13(10), pp. 959-980.

Greene, W. H. (2008) "The Econometric Approach to Efficiency Analysis: The Measurement of Productive Efficiency and Productivity Change," Oxford Scholarship Online Monograph, Oxford, UK, pp. 92-251.

Hejazi, W., and Safarian, E. (1999) "Trade, Foreign Direct Investment and R&D Spillovers," Journal of International Business Studies, 13(3), pp. 491-511.

Harris, R. (2009) "Spillover and Backward Linkage Effects of FDI: Empirical Evidence from the UK," Working Paper, Spatial Economics Research Centre, London School of Economics, London, UK, March. Retrieved from www.spatialeconomics.ac.uk/ textonly/serc/publications/download/sercdp0016.pdf on December 1, 2009.

Harrison, A. E., McMillan, M. S., and Null, C. (2007) "U.S. Multinational Activity Abroad and U.S. Jobs Substitutes or Complements?" Industrial Relations 46(2), pp. 347-365.

Hewlett-Packard. (2009) "Red Hat and HP Optimize Red Hat Enterprise Virtualization for HP BladeSystem Matrix," Press Release, Palo Alto, CA, September 3. Retrieved from http://www.hp.com/hpinfo/newsroom/press/2009/090903a.html on December 1, 2009.

Global Insight USA Inc. (2004) "Executive Summary: The Comprehensive Impact of Offshore IT Software and Services Outsourcing on the U.S. Economy and the IT Industry," White Paper, Lexington, MA, March. Sponsored by the Information Technology Association of America. Retrieved from www.itaa.org/itserv/docs/execsumm.pdf on December 1, 2009.

InfoWorld. (2007) "Acer to Acquire Gateway for $710 million," August 21. Retrieved from www.infoworld.com/t/hardware/acer-acquire-gateway-710-million-931 on December 1, 2009.

Iyer, K. G., Rambaldi, A. N., and Tang, K. K. (2008) "Efficiency Externalities of Trade and Alternative Forms of Foreign Investment in OECD Countries," Journal of Applied Econometrics, 23(6), pp. 749-766.

Javorcik, B. S. (2004) "Does Foreign Investment Increase the Productivity of Domestic Firms? In Search of Spillovers through Backward Linkages," American Economic Review, 94(3), pp. 605-627.

Javorcik, B. S., Saggi, K., and Spatareanu, M. (2004) "Does Local Participation Matter Where You Come From? Vertical Spillovers from Foreign Direct Investment and the Nationality of Investors," Policy Research Working Paper, World Bank, Washington, DC.

Kauffman, R. J., and Kumar, A. (2008) "Impacts of ICT on Country Development: Accounting for Area Interrelationships," International Journal of Electronic Commerce," 13(1), pp. 11-58.

Kemerer, C. F. (1987) "An Empirical Validation of Software Cost Estimation Models," *Communications of the ACM*, 30(5), pp. 416-429.

Kim N., Chang, D. R. and Schoker, A. D. (2000) "Modeling Inter-Category and Generational Dynamics for a Growing Information Technology Industry," Management Science, 46(4), pp. 496-512.

Kohil, U. (1982) "Production Theory, Technological Change, and the Demand for Imports: Switzerland, 1948-1974," European Economic Review, 18(2), pp. 369-386.

LG. (2005) "LG Electronics Mobiles Takes Number Two Spot across All Mobile Phones Technologies in the U.S.," Press release, San Diego, CA, November 21. Retrieved from http://mobilephones.us.lge.com/press.aspx?id=7698 on December 1, 2009.

Lipsey, R. E. (2002) "Home and Host Country Effects on FDI," Working Paper No. 9323, National Bureau of Economic Research, Cambridge, MA, October.

Markusen, J. R. (1995) "The Boundaries of Multinational Enterprises and the Theory of International Trade." Journal of Economic Perspectives, 9(2), pp. 169-189.

Markusen, J. R., and Venables, A. J. (2005) "A Multi-Country Approach to Factor-Proportions Trade and Trade Costs," Working papers No. 11051, National Bureau of Economic Research, Cambridge, MA.

McLaren, J. (2000) "Globalization and Vertical Structure," American Economic Review, 90(5), pp. 1239-1254.

Mendi, P. (2007) "Trade in Disembodied Technology and Total Factor Productivity in OECD." Research Policy, 36(1), pp. 121-133.

Miller, R. G. (1964) "A Trustworthy Jackknife," Annals of Mathematical Statistics, 35(1), pp. 1594-1605.

Miller, R. G. (1968) "Jackknifing Variances," Annals of Mathematical Statistics, 39(2), pp. 567-582.

Miller, R. G. (1974a) "The Jackknife: A Review," Biometrika, 61(1), pp. 1-15.

Miller, R. G. (1974b) "An Unbalanced Jackknife," Annals of Statistics, 2(5), pp. 880-891.

Mittal, N. and Nault, B. R. (2009) "Investments in Information Technology: Indirect Effects and Information Technology Intensity," Information Systems Research, 20(1), pp. 140-154.

OECD. (2002 and 2006) "OECD Information Technology Outlook," Committee for Information, Computer, and Communication Policy, Geneva, Switzerland.

OECD. (2006) "Measuring Industrial Performance," Directorate for Science, Technology and Industry, Paris, France.

OECD. (2008). "OECD Manual Measuring Capital," Committee on Statistics, Geneva, Switzerland.

Oliner, S. D., and Sichel, D. E. (2000) "The Resurgence of Growth in the Late 1990s: Is Information Technology the Story," Journal of Economic Perspective, 14(4), pp. 3-22.

Park, J., Shin, S. K., and Sanders, G. L. (2007) "Impact of International Information Technology Transfer on National Productivity," Information Systems Research, 18(1), pp. 86-102.

Pugel, T. A. (1982) "Endogenous Technological Change and International Technology Transfer in a Ricardian Trade Model," Journal of International Economics, 13(3-4), pp. 321-335.

Quenouille, M.H. (1949) "Approximate Tests of Correlation in Time-Series," Journal of the Royal Statistical Society, Series B, 11, pp. 68–84.

Schechtman, E., and Wang, S. (2004) "Jackknifing Two-Sample Statistics," Journal of Statistical Planning and Inference, 119(2), pp. 329-340.

Schreyer, P., and Webb, C. (2006) "Capital Stock at the OECD: Status and Outlook," OECD, Geneva, Switzerland.

Shao, B. B. M., and Smith-David, J. (2007) "The Impact of Offshore Outsourcing on IT Workers in Developed Countries," Communications of the ACM, 50(2), pp. 89-94.

Shao, B. B. M., and Lin, W.T. (2009) "Evaluating Information Technology Industry Performance: A Stochastic Production Frontier Approach. In R. J. Kauffman and P. P. Tallon (eds.), Economics, Information Systems and Electronic Commerce Research: Empirical Advances, New York, NY: M.E. Sharpe, pp. 113-134.

Shao, J., and Tu, D. (1995) The Jackknife and Bootstrap. New York, NY: Springer-Verlag.

Smarzynska, B. K. (2002) "Spillovers from Foreign Direct Investment through Backward Linkages: Does Technology Gap Matter?" Working Paper, World Bank, Washington, DC. Retrieved from info.worldbank.org/etools/docs/voddocs/216/415/spillovers_ draft.pdf on December 1, 2009.

Smeets, R. (2008) "Collecting the Pieces of the FDI Knowledge Spillovers Puzzle," World Bank Research Observer, 23(2), pp. 107-138.

Spulber, D. F. (2008) "Innovation and International Trade in Technology," Journal of Economic Theory, 138(1), pp. 1-20.

Student. (1908) "The Probable Error of a Mean," *Biometrika*, 6(1), 1908, 1-25.

Stiroh, K. J. (2001) "What Drives Productivity Growth? Federal Reserve Bank of New York," Economic Policy Review, 7(1), pp. 37-59.

Triplett, J. E., and Bosworth, B. P. (2004) Productivity in the U.S. Service Sector. Washington, DC: Brookings Institute Press.

Tukey, J. W. (1958) "Bias and Confidence in Not Quite Large Samples," Annals of Mathematical Statistics, 29(2), pp. 614-623.

Vance, A. (2009) "Acer Is Everywhere: How Did That Happen?" New York Times, June 27. Retrieved from http://www.nytimes.com/2009/06/28/technology/companies/ 28acer.html on December 1, 2009.

Voeth, M., and Herbst, U. (2006) "Supply Chain Pricing: A New Perspective on Pricing in Industrial Markets," Industrial Marketing Management, 35, 1, pp. 83-90.

Wang, H. J., and Schmidt, P. (2002) "One-Step and Two-Step Estimation of the Effects of Exogenous Variables on Technical Efficiency Levels," Journal of Productivity Analysis, 18(2), pp. 129-144.

Wang, H. J. (2002). "Heteroscedasticity and Non-Monotonic Efficiency Effects of a Stochastic Frontier Model." Journal of Productivity Analysis, 18(3), pp. 241-253.

Williamson, O. E. (1985). The Economic Institutions of Capitalism. New York, NY: Free Press.

Zhu, X. C., and Liu, Z. Y. (2007) "Research on the Spillover Effect of Foreign Direct Investment," China-USA Business Review, 6, 1, 34, pp. 21-25.

APPENDIX. JACKKNIFE STATISTICAL RE-SAMPLING RESULTS

Table A1. Productivity Results of the Jackknife Procedure

VARIABLE	FULL SAMPLE	U.S. OUT	U.K. OUT	SWEDEN OUT
ln Capital	0.481***	0.403***	0.498***	0.476***
ln Labor	0.454***	0.510***	0.407***	0.460***
ITImports / GDP	0.177***	0.232***	0.177***	0.178***
ITOffshoring / GDP	-1.658***	-1.157**	-1.650***	-1.742***
FDI / GDP	-0.110***	-0.113***	-0.113***	-0.113***
Adj.-R^2	91%	91%	91%	91%
Sub-sample size	85	79	81	79

VARIABLE	POLAND OUT	NORWAY OUT	S. KOREA OUT	ITALY OUT
Ln Capital	0.442***	0.464***	0.487***	0.481***
Ln Labor	0.510***	0.566***	0.453***	0.453***
ITImports / GDP	0.157***	0.219***	0.241***	0.185***
ITOffshoring / GDP	-1.803***	-1.686***	-1.976***	-1.600**
FDI / GDP	0.157***	-0.103***	-0.127***	-0.110***
Adj.- R^2	91%	91%	90%	91%
Sub-sample size	79	78	78	78

VARIABLE	GREECE OUT	GERMANY OUT	FRANCE OUT	FINLAND OUT
Ln Capital	0.444***	0.483***	0.574***	0.496***
Ln Labor	0.483***	0.400***	0.376***	0.405***
ITImports / GDP	0.166***	0.192***	0.105**	0.186***
ITOffshoring / GDP	-1.836***	-2.072***	-2.188***	-1.596***
FDI / GDP	-0.109***	-0.112***	-0.088***	-0.114***
Adj. R^2	89%	91%	94%	90%
Sub-sample size	82	78	78	79

VARIABLE	CZECH OUT	BELGIUM OUT	AUSTRIA OUT
Ln Capital	0.488***	0.469***	0.485***
Ln Labor	0.470***	0.507***	0.453***
ITImports / GDP	0.073	0.156***	0.173***
ITOffshoring / GDP	-1.364**	-0.750	-1.604**
FDI / GDP	-0.128***	-0.076**	-0.109***
Adj.-R^2	92%	91%	91%
Sub-sample size	78	80	78

Note: To produce the results related to productivity in this table, we iteratively ran the extended Cobb-Douglas model to obtain the jackknife pseudo-values for all of the model's parameters. We used these pseudo-values to construct Figure 2, as a basis for our evaluation of model robustness. We present the full sample results first, followed by the fourteen selected OECD countries in reverse alphabetical order.

Table A2. Efficiency Results of the Jackknife Procedure

VARIABLE	FULL SAMPLE	U.S. OUT	U.K. OUT	SWEDEN OUT
ITImports / GDP	-0.095***	-0.118***	-0.094***	-0.094***
ITOffshoring / GDP	0.643**	0.288	0.605**	0.494
FDI / GDP	0.060***	0.064***	0.061***	0.063***
Adj.-R^2	25%	27%	25%	23%
Sub-sample size	85	79	81	79

VARIABLE	POLAND OUT	NORWAY OUT	S. KOREA OUT	ITALY OUT
ITImports / GDP	-0.085***	-0.129***	-0.126***	-0.097***
ITOffshoring / GDP	0.731**	0.982***	0.814**	0.628*
FDI / GDP	0.055***	0.051***	0.068***	0.060***
Adj.-R^2	25%	34%	24%	25%
Sub-sample size	79	78	78	78

VARIABLE	GREECE OUT	GERMANY OUT	FRANCE OUT	FINLAND OUT
ITImports / GDP	-0.099***	-0.101***	-0.059**	-0.100***
ITOffshoring / GDP	0.633*	0.533	1.099***	0.486
FDI / GDP	0.059***	0.070***	0.045***	0.064***
Adj.-R^2	24%	27%	35%	23%
Sub-sample size	78	78	78	79

VARIABLE	CZECH OUT	BELGIUM OUT	AUSTRIA OUT
ITImports / GDP	-0.026	-0.096***	-0.090***
ITOffshoring / GDP	0.567*	0.510	0.612*
FDI / GDP	0.066***	0.059***	0.058***
Adj.-R^2	28%	13%	23%
Sub-sample size	78	80	78

Note: To produce the results related to the estimation of efficiency in this table, we iteratively ran the second-stage regression model in the stochastic frontier analysis to obtain the jackknife pseudo-values for two key variables that relate to our hypotheses, *ITImports / GDP* and *ITOffshoring / GDP*, and the control variable *FDI / GDP*. We used these pseudo-values to construct Figure 3, as a basis for our evaluation of model robustness. We present the full sample results first, followed by the fourteen selected OECD countries in reverse alphabetical order.