JOURNAL
OF EUROPEAN ECONOMY
Vol. 12 (№ 3). September 2013
Publication of Ternopil National Economic University

International Economics

Grace KITE

THE ROLE OF INFORMATION TECHNOLOGY OUTSOURCING ON OUTPUT, PRODUCTIVITY AND TECHNICAL EFFICIENCY: EVIDENCE FROM INDIAN FIRMS

Abstract

Existing econometric studies find that both information technology (IT) and outsourcing of goods and services production increase firms' productivity. Until now, though, there has been no similar evaluation of IT outsourcing. This paper fills that gap using purchasing firms in India as a case study. It finds output elasticity for Software and IT Services (SWIS) outsourcing which implies bigger returns than those available from either general outsourcing or non-outsourced IT. There is also clear evidence that purchasing outsourced SWIS moves firms closer to parity with the most technically efficient firms. The paper concludes that outsourcing is a superior option for firms that wish to invest into IT and that in India it should be encouraged by policy.

Kite Grace, School of Oriental and African Studies, University of London.

With thanks to Simon Commander, Chrisanti Avgerou, Duo Qin and participants at International Conference on Applied Economics 2012 for feedback on earlier drafts of this research.

Key words:

Information Technology, Software, Outsourcing, India.

JEL: O140, O330, O190.

Introduction

Since its emergence in the 1980s, adoption of information technology (IT) in production has expanded rapidly. Firms have undertaken complex projects to transform and improve their processes using the technology, and, in order to save money or to obtain technical advice, many have hired specialist IT outsourcing companies to help. This paper is concerned with the impact of this outsourced IT, and in particular the question of what, if anything, it adds to productivity and technical efficiency.

Existing related literature includes a great deal of research on the impact of in-house (not outsourced) IT, and a smaller but still significant body of work on the returns from outsourcing other goods and services. Together, these two have established a well-accepted body of econometric methods and practices. They have also confirmed that both types of purchase bolster output and productivity. This paper provides the first econometric analysis of the combination of IT and outsourcing; that is, IT outsourcing. It examines software and IT services[1] (SWIS) outsourcing in India and finds that it outperforms outsourcing of other goods and services and offers higher returns than those available from IT bought without help. There is also evidence that IT outsourcing offers an opportunity to catch up with the most technically efficient firms.

In India these findings have an important policy implication. The country is host to a large, successful, and high profile SWIS outsourcing industry, which so far is in receipt of policy incentives to focus on exports. The finding that SWIS outsourcing offers such strong returns implies that the Indian economy would be

[1] The term «Software and IT Services» refers to a full range of IT and software-related business-to-business services. These include custom application development, network consulting and integration, software testing, application management, software deployment and support, hardware deployment and support, IT training, IT consulting, systems integration, managed services, hosting services and support/maintenance, as well as sale and installation of packaged software in client businesses.

much better served if this industry instead focussed on domestic projects. The need for policy reform is urgent. Despite faster economic growth in recent decades, India remains under-developed and opportunities to improve production processes, competitive position and so economic growth must be seized.

The remainder of the paper is laid out as follows. Section 1 provides a brief overview of relevant literature; Section 2 describes the data; Section 3 covers the methods and findings on output; Section 4 the methods and findings on technical efficiency; and Section 5 concludes.

1. Related Literature

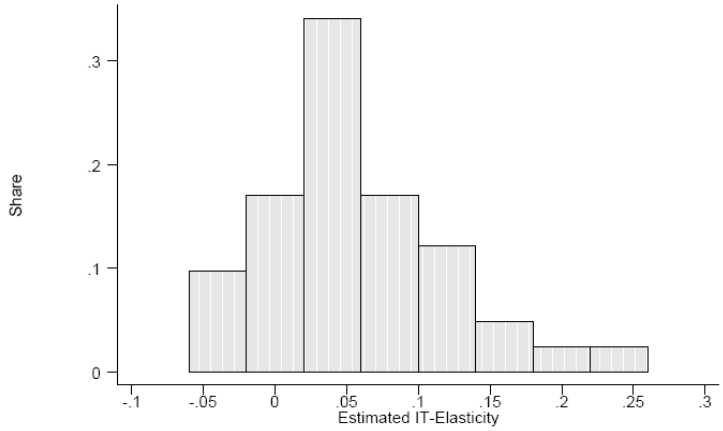
Research on IT use in production finds that when it is used well, IT brings process improvements, cost savings, and ongoing opportunities to learn and adapt. Firms incorporate the technology by gathering information from all departments into one or more pieces of software and then making them available to all relevant staff (Perez, 1985: 9). This increases the amount and quality of information available to workers, enabling decisions to be made independently, without managerial assistance (Bresnahan, Brynjolfsson, and Hitt, 2002: 342; Brynjolfsson and Yang, 1996: 11). It also opens up the possibility of computerised monitoring of performance. Workers, processes and outcomes can be tracked using the new technology, so that there is a further saving on supervisory staff, and so that opportunities for improvement can be identified and acted upon quickly (Perez, 1985: 9, Brynjolffson and Yang, 1996: 30). Alongside an improved ability to compete and expand, this opportunity to successfully improve and adapt brings savings on «processing time», «transaction costs», «inventory costs», and even «material wastage» (Mody and Dahlman, 1992: 1708).

Given this role for the technology, it is not surprising that the literature which evaluates its impact finds significant productivity and output effects. Figures 1, 2 and 3 provide a selected summary of this research. Figure 1 is a meta-analysis of econometric studies using firm or industry level data from a variety of developed countries (Stiroh, 2002). It plots the output elasticity of IT in 40 econometric models from 20 different studies. The median estimate suggests that doubling the stock of IT capital leads to an impressive 5% increase in output. Figures 2 and 3 together illustrate the macroeconomic implications. Figure 2 shows the number of percentage points of GDP growth attributable to IT in the U.S[2]. It shows that IT adoption was responsible for a remarkable acceleration in economic growth in the 1990s, and that by the end of that decade, IT use was contributing almost 1.4 percentage points of GDP growth per annum.

[2] Figure 2 summarizes the results of 8 separate analyses which all use the same methodology but examine different periods. The findings are arranged from left to right by the start date of the period under consideration.

Figure 1

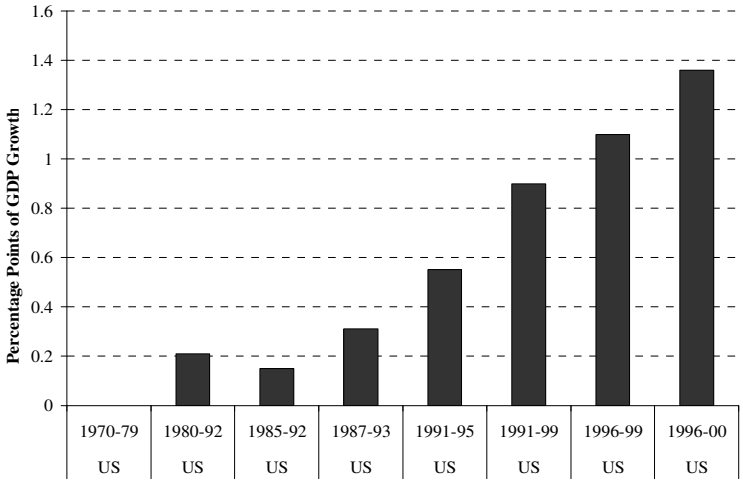
Histogram of Output Elasticities of IT from Firm or Industry-level Econometric Studies



Source: Stiroh (2002: 30).

Figure 2

GDP growth per annum attributed to IT in US



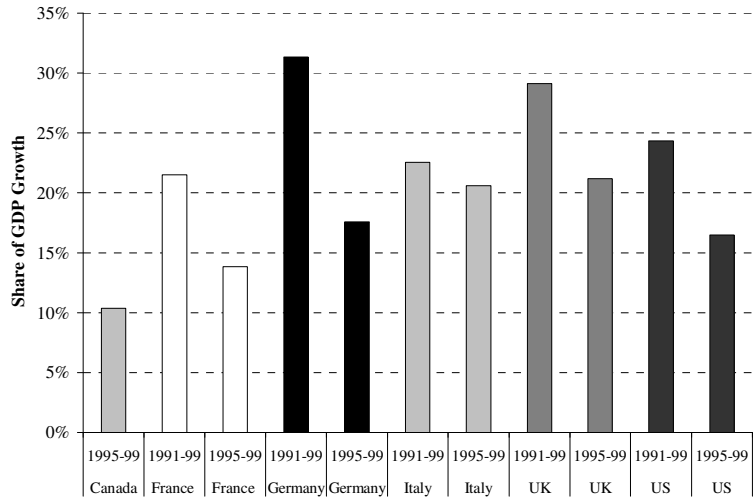
Notes: Adapted from Jorgenson, Ho, and Stiroh (2007:9), International Monetary Fund (2001:106,116), Oliner & Sichel (1994), Jorgensen & Stiroh (1995), Sichel (1997), Jeong, Jeong, and Shin (2002), Crafts (2001), Daveri (2001), Oliner & Sichel (2000)

Figure 3 illustrates the share of GDP growth attributable to IT in a selection of developed countries[3]. It indicates a norm of between 10% and 30% throughout the 1990s.

The contribution of goods and services outsourcing is very different, but the evidence suggests that it too gives a strong boost to productivity in firms that undertake it. Rather than improving the buying company's processes, outsourcing typically means reducing the scope of its activities. The firm relocates the least productive parts of its business, so that instead of producing intermediate goods and services, it simply buys them from the most cost- and quality- effective suppliers, wherever they happened to exist around the world (Nolan, 2001: p. 101; Olsen, 2006: p. 8). This raises productivity in the remaining part of the business simply because of the composition of tasks assigned to each company: The original firm no longer undertakes low productivity tasks, and so its productivity on the remaining, smaller scope of activities increases (Amiti and Wei, 2006: p. 7).

Figure 3

Share of Total GDP Growth Attributed to IT Use in Developed Countries



Notes: Adapted from Colecchia (2001); Daveri (2001); World Development Indicators (2010).

[3] Figure 3 draws on the results of studies which identified percentage points of GDP growth attributable to IT use in production. These results are expressed as a share of total GDP growth in each country to facilitate comparisons between countries.

Figure 4

Estimates of the Elasticity of Productivity to Outsourcing

		What is outsourced?	Who is outsourcing it?	Firm Level Studies: % increase in productivity for 100% more outsourcing	Industry Level Studies: % increase in productivity for 10% more outsourcing intensity
Banga & Goldar (2004)	India	S	M	13%	
Gorzig and Stephan (2002)	Germany	S	M	6.8%	
Criscuolo and Leaver (2005)	UK	S	S	6.8%	
Egger and Egger (2001)	EU	M	M		5.3%
Amiti and Wei (2004)	US	S	M		4.3-5.7%
Girma and Gorg (2003)	UK	Both	M		1.7-4.9%

Note: M = materials/manufacturing, S = services. Adapted from sources cited in the table.

Figure 4 shows estimated elasticities of productivity to outsourcing in the author's preferred specification for 2 groups of comparable studies. Banga and Goldar (2004), Criscuolo and Leaver (2005), and Gorzig and Stephan (2002) conducted firm-level studies where outsourcing is measured directly from firm-level data on expenditures, and Amiti and Wei (2004), Girma and Gorg (2003), and Egger and Egger (2001) conducted industry-level studies where outsourcing is measured by outsourcing intensity[4]. There are currently not enough studies of this sort to support detailed generalisations, but these analyses do have one thing in common. That is, the estimated elasticities are all strong. The firm-level estimates range from 6.8% to 13% for a 100% increase in outsourcing; and the industry-level estimates between 2% and 6% per 10% additional outsourcing intensity.

In the light of these findings it is reasonable to expect that the combination of IT and outsourcing, that is IT outsourcing, should also bring strong productivity effects. The nature of IT outsourcing varies from project to project, but it is almost always pursued either as a route to relocate low productivity IT tasks, or as a way to invest into new IT. At the low productivity end, some firms ask their IT outsourcing partners to provide simple but time consuming services cheaply. This might include producing custom lines of computer code, fixing the year 2000

[4] The proportion of total expenditure on inputs that is outsourced.

bug[5], or converting older programs to work with newer systems (D'Costa, 2004: p. 63). On the other hand, IT outsourcing firms are also often asked to help with new investments into IT. In these projects their role involves designing, custom building, and installing 'IT solutions'. They manage clients' hardware, software, and maintenance needs, and in some cases even redesign a company's processes around the new technology. Not surprisingly given this scope, these projects require considerable technical expertise and experience (NASSCOM, 2006: 10). Typically they are outsourced not to save money, but because the firm does not have the know-how needed to carry them out alone.

In India there is a potential for IT outsourcing to do an important job, but so far there is no quantitative research that can confirm its value. If IT outsourcing aids investment into the technology, it can offer inexperienced Indian firms advice on how best to use it (NASSCOM, 2006: p/ 10). This might lead to successful applications of the technology being brought from the developed countries to India, and so progress towards parity with technology use in world class firms. The country could experience similar improvements in productivity and output as those discussed above, and the economy-wide impact could be considerable. However, it remains unclear whether the type of IT outsourcing bought in India is of this nature, and until now, there are no systematic quantitative analyses of its effects.

2. Data

The main source of data used to evaluate Indian IT outsourcing is the PROWESS database, published by the Centre for Monitoring the Indian Economy (CMIE, 2009). This rich data source covers a large panel of firms who are registered on India's main stock exchanges, as well as many public-sector enterprises. The CMIE (2009) reports that the database includes most organised industries, banking, and services, and as evidence to support this claim, it estimates that the included firms contribute 75% of all corporate taxes and 95% of all sales taxes collected in India. The database includes assets, expenditures, and outputs for these companies and together these cover many of the variables necessary for identifying the impact of IT outsourcing. In total, there are almost 27,000 fully populated observations on nearly 10,100 firms.

The PROWESS data is not perfect, however. Figure 5 shows the breakdown of populated observations by year and sector. It shows that there is sample attrition, particularly after 2006. This does not appear to have significantly affected the sector-wise composition of the sample, with the split for Manufacturing (56%), Services (21%), and Finance (23%) remaining fairly consistent through all

[5] Many early computer systems used only two digits to identify years, after the year 2000 this became a problem because, for example, 85 could mean 1985 or 2085.

four of the years. Despite this, the potential for attrition bias does remain a concern and is the subject of robustness tests discussed below. Another issue is that PROWESS does not report expenditure on SWIS outsourcing separately, but includes it in the composite measure «Expenditure on Software and Other Professional Services». The definition of this latter metric shows that it includes expenditure on outsourced SWIS, but that it also includes all other «expenses reported by a company on external professional services engaged by the company for services other than for audit, consultancy, software development, IT-enabled services, cost audit and legal services» (CMIE 2009). Using this metric as a measure of SWIS outsourcing is justified, because a major portion of what is included in it is SWIS outsourcing. The modelling strategy described below also mitigates for the most likely type of bias which may have arisen from use of this composite variable.

Figure 5

Populated Sample by Sector and Year

	2005	2006	2007	2008	Total
Manufacturing	4,908	4,406	3,640	2,284	15,238 (56%)
Finance	1,932	1,695	1,221	676	5,524 (21%)
Services	2,120	1,862	1,425	817	6,224 (23%)
Total	8,960	7,963	6,286	3,777	26,986

Source: Author calculations based on CMIE (2009).

The data underwent a careful treatment designed to ensure accurate identification of the impact of SWIS outsourcing. Capital variables are net of cumulative depreciation, so as to better capture their productive value rather than their cost at purchase. In addition, all the variables which are measured in money terms have been corrected for inflation using individually appropriate price indexes. For non-services variables these have been sourced from Reserve Bank of India (2011). For services variables, GDP deflators have been constructed from real and nominal output in the appropriate sector, as published in the Indian National Account Statistics published by Ministry of Statistics and Programme Implementation (2011). Software, both in-house and outsourced, is deflated using a recent index of software prices constructed by Prud'homme, Sanga, and Yu, (2005)[6].

[6] This index is for Canada. Its use here is valid on the assumption that software is freely traded so that price movements are similar across countries. It is also consistent with comments from IT professionals in India.

Figure 6 begins a preliminary analysis of the PROWESS data by showing the number of firms that purchased outsourced SWIS. It also shows their share of output and profits during the sample period. Column 4 reports the percentage of the sample in each year that undertakes SWIS outsourcing. This percentage ranges between 62% and 74%, showing that firms in this sample are likely to opt for SWIS outsourcing. It is also increasing year on year, showing that SWIS outsourcing is becoming more prevalent over time. The share of output for firms buying SWIS is much higher than those firms' share of the sample. This illustrates both the large size of the firms which go in for SWIS outsourcing and their importance in terms of their contribution to economic activity. The share of profits is even higher than the share of output, illustrating that firms buying SWIS are more profitable than other firms in the sample.

Figure 6

Presence and Importance of SWIS Outsourcers

	Sample split by SWIS spending:			SWIS outsourcers contribute (in real terms)…	
	SWIS Outsourcers	Others	% SWIS Outsourcers	Output (%)	Profit (%)
2005	5,583	3,377	62%	77%	81%
2006	5,163	2,800	65%	78%	84%
2007	4,304	1,982	68%	80%	84%
2008	2,810	967	74%	80%	86%

Note: Total number of observations is 26,986. Profits shown are net of taxes.

Source: Author's calculations based on CMIE (2009).

Figure 7 shows the extent of SWIS outsourcing by industry. The table ranks industries by their mean annual expenditure on SWIS outsourcing per firm, and it also includes the per cent of firms in each industry that undertake SWIS outsourcing and their total expenditure in Rupees and US dollars. The top ten purchasers of SWIS outsourcing in the table include communications, manufacturing, banking, retail, transport and logistics, and two other categories of services. These industries match very closely with those that have been found to use IT intensively in other developed and less-developed countries, and as such their appearance here is to be expected (Baily and Lawrence 2001: p. 309, Hanna 1994: p. 40). The disaggregated nature of the PROWESS data reveals an interesting fact about manufacturers who undertake SWIS outsourcing. The big-

gest spenders are heavy industries, such as chemicals, machines and computers. As with services like communications, banking, logistics, and services outsourcing, these sectors produce goods which are used as inputs to other sectors. What this means is that the industries which are the biggest spenders on SWIS outsourcing together have many linkages to the rest of the Indian economy, and might even be termed «infrastructure».

Figure 7

SWIS Outsourcing by Sector, SWIS Outsourcers Only

Rank	Sector	SWIS spend per firm (Rs. Crore)	% SWIS outsourcers	SWIS spend by all firms (Rs. Crore)	SWIS spend by all firms (US$m)
1	Communications	Rs. 34.3	88%	Rs. 1,570.6	$348.5
2	Banks	Rs. 7.0	97%	Rs. 674.3	$149.6
3	Transport and Logistics Services	Rs. 3.2	78%	Rs. 306.0	$67.9
4	Housing Finance	Rs. 3.0	81%	Rs. 74.1	$16.4
5	Misc Services	Rs. 2.6	75%	Rs. 805.8	$178.8
6	Retail	Rs. 2.4	84%	Rs. 24.7	$5.5
7	Chemicals Manufacturing	Rs. 2.3	71%	Rs. 1,552.7	$344.5
8	Services Outsourcing	Rs. 1.7	79%	Rs. 41.6	$9.2
9	Computers Manufacturing	Rs. 1.5	71%	Rs. 26.4	$5.9
10	Machines Manufacturing	Rs. 1.5	70%	Rs. 537.9	$119.4
11	Couriers	Rs. 1.4	81%	Rs. 7.7	$1.7
12	Metals Manufacturing	Rs. 1.4	74%	Rs. 466.3	$103.5
13	Transport Manufacturing	Rs. 1.4	68%	Rs. 216.0	$47.9
14	Media and Films	Rs. 1.3	84%	Rs. 107.4	$23.8
15	Hotels	Rs. 1.3	74%	Rs. 104.7	$23.2
16	Financial Brokers	Rs. 1.3	80%	Rs. 65.7	$14.6
17	Tourism	Rs. 1.3	86%	Rs. 9.7	$2.1
18	Financial Institutions	Rs. 1.1	86%	Rs. 26.5	$5.9
19	Healthcare	Rs. 1.1	77%	Rs. 37.0	$8.2
20	Finance - non banks	Rs. 1.0	59%	Rs. 93.6	$20.8
21	Consultants	Rs. 1.0	68%	Rs. 87.6	$19.4
22	Minerals Manufacturing	Rs. 0.7	64%	Rs. 106.7	$23.7
23	Food Manufacturing	Rs. 0.7	60%	Rs. 247.9	$55.0
24	Misc Finance	Rs. 0.7	45%	Rs. 197.1	$43.7
25	Misc. Manufacturing	Rs. 0.6	70%	Rs. 120.1	$26.7
26	Securities Brokers	Rs. 0.5	45%	Rs. 96.6	$21.4
27	Textiles Manufacturing	Rs. 0.5	69%	Rs. 197.1	$43.7
28	Wholesalers	Rs. 0.4	61%	Rs. 127.7	$28.3

Notes: Annual averages amongst those firms that purchase outsourced SWIS. Monetary values are in constant 2005 rupees or dollars. Total number of observations is 26,986.

Source: Author calculations based on CMIE (2009) and RBI (2009).

One other fact stands out from Figure 7. That is, at Rs. 33.4 crore per company per year on average, the communications firms in the sample spend almost 5 times as much as firms in the second biggest spending industry, banking. During the sample time period, mobile telecommunications were experiencing very rapid growth in India and this may be part of the reason for such a large expenditure. To ensure that results on SWIS outsourcing are not being driven solely or mainly by this high spending industry, it is excluded in robustness tests reported below.

Figure 8

Summary Statistics for SWIS Outsourcers vs. Others, Rs. Crore

	All firms	SWIS outsourcers	Others	Standard Deviation
Real output	Rs. 338.4	Rs. 403.3	Rs. 211.6	*3,460.9*
Real capital	Rs. 120.1	Rs. 146.5	Rs. 68.5	*1,248.8*
Real labour (wages)	Rs. 17.4	Rs. 22.3	Rs. 7.8	*155.0*
Real intermediate inputs	Rs. 114.0	Rs. 123.9	Rs. 94.8	*1,339.1*
Real IT capital	Rs. 0.8	Rs. 1.0	Rs. 0.3	*8.6*
Real 'other' outsourcing	Rs. 0.2	Rs. 0.3	Rs. 0.1	*2.3*
Real SWIS outsourcing	Rs. 1.2	Rs. 1.8	Rs. 0.0	*13.5*

Notes: All figures are in constant 2005 rupees crore. Figures are unweighted averages over the whole sample period. Standard deviation given is for all firms. Total number of observations in all calculations is 26,986. Intermediate inputs is calculated as materials + power + outsourced goods and services.

Source: Author calculations based on CMIE (2009) and RBI (2009).

Figure 8 completes the description of the PROWESS data by reporting summary statistics for the dependent and main explanatory variables used in the econometric models. The figures included indicate that SWIS-buying firms produce more real gross output than other firms. However, they also use more materials and capital and purchase more, or more expensive, labour. What is also clear is that they use much higher levels of IT capital in-house and they outsource more of their other intermediate goods and services production. In other words, the firms that buy SWIS are bigger, and have production processes that are more intensive in IT, outsourcing, and IT outsourcing. The challenge which is taken up in the next section is to understand how each of these differences contributes to their higher output.

3. The Impact of IT Outsourcing on Output and Productivity

3.1. Methods

The approach used here combines methods from the empirical literature on the impact of IT and from the literature on more general outsourcing. This combination of approaches is necessary because, on the one hand, outsourced SWIS is similar to other outsourcing, in that it occurs outside the firm. On the other hand, though, outsourced SWIS also has the potential to either complement or substitute for IT used in-house by firms. This means that any evaluation of outsourced SWIS must include an evaluation of in-house IT or risk misattribution of output or productivity effects.

The literature on the impact of IT uses a production function modified to include IT assets, such as equation (1).

$$Y = AF(K,IT,L,M) \quad (1)$$

Here *Y* refers to gross output; *K* to stocks of capital; IT to stocks of in-house hardware and software; *L* to labour; M to intermediate inputs (including materials, energy, and any other purchased inputs to production) and *F*(.) to the function which determines the amount of output produced from a given quantity of inputs. A refers to total factor productivity (TFP) and measures the efficiency with which all inputs are converted into output.

The literature on outsourcing postulates that firms who outsource experience improvements in TFP, because outsourcing is expected to facilitate the relocation of the least productive parts of a company's business, leaving better productivity in the remainder (Olsen, 2006). This leads to equation (2) in which OS refers to outsourcing of services and/or manufactures. *Y, K, L, M* and *F*(.) are defined as before.

$$Y = A(OS)F(K,L,M) \quad (2)$$

Combining these two approaches with a focus on IT outsourcing, denoted OSIT, gives equation (3). Assuming a Cobb-Douglas functional form for *F*(.) and taking logs of the resulting expression leads to equation (4). In equation (4), ln (.) is the natural logarithm, the γ's are the elasticities of output to different kinds of outsourcing, and the α's are the elasticities of output to the other inputs. All other elements of the equations are defined as before.

$$Y = A(OS)F(K,L,M) \tag{3}$$

$$\ln(Y) = \gamma_{IT}\ln(OSIT) + \gamma_{SM}\ln(OS) + \\ + \alpha_K\ln(K) + \alpha_{IT}\ln(IT) + \alpha_L\ln(L) + \alpha_M\ln(M) \tag{4}$$

3.2. Findings

Figure 9 shows the results of estimating equation (4) using the populated sample from the PROWESS data. Column 1 shows a benchmark estimate of the production function without SWIS outsourcing, and with in-house IT, and goods and services outsourcing, combined with capital, and intermediate inputs respectively. Column 2 splits intermediate inputs to show goods and services outsourcing separately, and column 3 splits in-house IT from ordinary capital. Column 4 includes both types of outsourcing (goods and services, and SWIS) and in-house IT. Then column 5 removes insignificant variables from this model to give the preferred specification. In both column 4 and column 5, SWIS outsourcing is highly significant and its coefficient indicates that doubling expenditure on SWIS outsourcing leads to a 9% increase in real gross output. This figure is higher than the estimated elasticity of output to in-house IT in the preferred specification, at 6%, and the elasticity for other outsourcing, which is not significantly larger than zero. The estimate for SWIS is also significantly higher than the median estimate for in-house IT in similar studies in developed countries, which Stiroh (2002) found to be 5%.

The coefficients on labor, capital and intermediate inputs from column 1 are reasonably robust to the inclusion of IT outsourcing. Their output elasticities in columns 4 and 5 are within 95% confidence intervals for the same elasticity in the models without outsourcing. This suggests that the majority of the impact of SWIS outsourcing comes through increases in TFP, not through changes in firms' use of, or return from, the traditional inputs. The coefficient on in-house IT capital, on the other hand, does not remain stable between column 3, and columns 4 and 5. When SWIS outsourcing is included, the elasticity for in-house IT falls by 25%, from 8% to 6%. This shows that estimating the impact of in-house IT without controlling for IT outsourcing, as is common in the existing literature on IT, leads to misleading results. There is a similar issue with estimating the impact of other types of outsourcing. In column 2, which replicates methods common in the literature on goods and services outsourcing, these purchases have a positive and significant impact on productivity. However, once SWIS outsourcing and in-house IT are included, the variable loses significance, and the conclusion that general outsourcing is important to these firms is overturned.

Figure 9

Econometric Estimates of Equation 4

Dependent Variable is log of real output					
	1	2	3	4	5
Log real capital	0.2020*** *(0.0119)*	0.1924*** *(0.0119)*	0.1868*** *(0.0116)*	0.1762*** *(0.0117)*	0.1767*** *(0.0117)*
Log real labour	0.5175*** *(0.0174)*	0.5172*** *(0.0176)*	0.5051*** *(0.0185)*	0.4802*** *(0.0186)*	0.4844*** *(0.0186)*
Log real intermediate inputs	0.3306*** *(0.0128)*	0.3291*** *(0.013)*	0.3364*** *(0.0131)*	0.3424*** *(0.0131)*	0.3434*** *(0.0131)*
Log real 'other' outsourcing		0.0671* *(0.0331)*		0.0412 *(0.0322)*	
Log real in-house IT capital			0.0810*** *(0.0195)*	0.0589** *(0.0201)*	0.0607** *(0.0198)*
Log real SWIS outsourcing				0.0868*** *(0.0182)*	0.0888*** *(0.018)*
Constant	Yes	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes	Yes
Sector Dummies	Yes	Yes	Yes	Yes	Yes
Dummies for Foreign Trade	Yes	Yes	Yes	Yes	Yes
N	26,986	26,986	26,986	26,986	26,986
R-squared	86.8%	86.7%	86.8%	86.9%	86.9%
Returns to Scale	1.05	1.04	1.11	1.05	1.065
P- value from test of H0: SWIS=in-house IT					0.32

Key: ***means significant at the 0.1% level, **means significant at the 1% level, * means significant at the 5% level

Notes: Estimated using weighted OLS with cluster robust standard errors to account for panel data. All equations are weighted using log of real spending on wages. Robust standard errors are given in parentheses and italics. All variables are in 2005 rupees crore, with 1 crore equivalent to US$221,900 in 2005. Returns to scale is the sum of coefficients for all non-outsourced inputs and should equal 1 under neo-classical assumptions. Where outsourcing, or in-house IT are reported separately they are excluded from intermediate inputs and from capital, respectively.

Source: Author calculations based on CMIE (2009).

Figure 10 takes the results in column 5 of Table 2 and subjects them to a first set of robustness tests. Column 2 performs the first of these, which was necessary because of panel attrition in the PROWESS data. To test for any bias arising from loss of firms over time from the database, the model is re-estimated

using only observations in earlier years of the sample, before any significant attrition took place. The estimated coefficients on all variables are similar to the baseline estimates in column 1. This suggests that attrition bias is not driving any of the results. Column 3 performs a second test. It shows the results of re-estimating the equation excluding the communications firms which were found above to be very big spenders on SWIS. Again, the coefficients are similar to the baseline estimates in column 1. This shows that communications firms are not solely or mainly responsible for the positive findings on SWIS outsourcing.

Figure 10

Robustness Tests

Dependent Variable is log of real output	1 Base	2 2005 and 2006 only	3 Excludes Comms	4 Manufacturing	5 Services
Log real capital	0.1767***	0.1760***	0.1803***	0.0766***	0.2168***
	(0.0117)	*(0.0124)*	*(0.012)*	*(0.0144)*	*(0.0182)*
Log real labour	0.4844***	0.4803***	0.4843***	0.3007***	0.7456***
	(0.0186)	*(0.0198)*	*(0.0186)*	*(0.0139)*	*(0.0292)*
Log real intermediate inputs	0.3434***	0.3533***	0.3403***	0.6364***	0.0870***
	(0.0131)	*(0.0132)*	*(0.0134)*	*(0.015)*	*(0.0237)*
Log real in-house IT capital	0.0607**	0.0651**	0.0757***	0.0609***	0.0521*
	(0.0198)	*(0.0239)*	*(0.0197)*	*(0.0165)*	*(0.0294)*
Log real SWIS outsourcing	0.0888***	0.0935***	0.0982***	0.0634***	0.1082*
	(0.018)	*(0.022)*	*(0.0187)*	*(0.0148)*	*(0.0337)*
Constant	Yes	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes	No
Sector Dummies	Yes	Yes	Yes	Yes	Yes
Dummies for Foreign Trade	Yes	Yes	Yes	Yes	Yes
N	26,986	16,923	26,779	15,238	11,748
R-Squared	86.9%	86.2%	86.7%	94.3%	84.8%

Key: ***means significant at the 0.1% level, **means significant at the 1% level, * means significant at the 5% level

Notes: Estimated using weighted OLS with cluster robust standard errors to account for panel data. Weighted using log of real spending on wages. Robust standard errors in parentheses and italics. All variables are in 2005 rupees crore, with 1 crore equivalent to US$221,900 in 2005.

Source: Author calculations based on CMIE (2009).

Columns 4 and 5 show the results of estimating the model separately for manufacturers and services firms. Many of the coefficients in these specifications are different from one another in ways that are expected. For example, services firms' output is more elastic to labour inputs and less elastic to increases in materials than that of manufacturers. This is expected because manufacturing is more materials intensive and less labour intensive than many services industries. In both column 4 and column 5, the coefficient on SWIS outsourcing is positive and significant. In services firms, the models imply that a 100% increase in SWIS outsourcing leads to 11% more output, whilst in manufacturers the same proportional increase in spending leads to only 6% more output. These estimates suggest that the services industries in the sample get greater benefit from IT outsourcing than the manufacturing industries. This could be because services production is simply more amenable to automation using outsourced SWIS (Stiroh, 2002: p. 6). It might also reflect manufacturers experiencing diminishing returns to outsourcing, as on a worldwide basis, manufacturers adopted outsourcing before services firms (Olsen, 2006: p. 24).

Figure 11 reports a set of re-estimations of equation (4) that control for unobserved firm specific heterogeneity and for simultaneity in the production function. Correcting for firm specific heterogeneity is important because the nature of individual firms might affect both dependent and explanatory variables in ways not fully captured by the models. Two issues in point are the effect of different organisational and managerial set ups, and different skill profiles in the workforce. Because IT decentralises decision making, flatter organisational hierarchies, accompanied by fewer managers, and more highly skilled workers, are complementary to IT investments (Commander, Harrison, and Menezes-Filho, 2011). In developed countries it has also been established that these innovations are productivity-enhancing in their own right so that wherever they are not modelled separately, their presence brings an upward bias in estimates of the effect of IT (Bresnahan, Brynjolfsson, and Hitt, 2002). This uncertainty over coefficients is compounded by a well known issue which affects all production function analysis. The problem is that inputs to production are not truly independent variables, but are chosen by firms, and possibly in response to unobserved variables, or output and productivity shocks (Griliches and Mairesse, 1998). In other words, there is some reverse causality or simultaneity between inputs and outputs which raises doubts over the accuracy and interpretation of coefficients.

The models in Figure 11 also correct for the most likely type of bias arising from the use of a composite variable to measure IT outsourcing. This bias arises if some sub-groups of firms – perhaps multinationals or larger firms – have both higher productivity and a higher proportion of the expenditures measured by the composite variable for SWIS outsourcing. Assuming IT outsourcing is more important for output and productivity than the other miscellaneous expenditures included in the measure, this situation would tend to bias the estimated elasticity for IT outsourcing upwards. However, as long as the mix of IT outsourcing versus

other types of expenditures included in the composite variable depends predominantly on the nature of each firm's business it will mostly vary across firms, and will change rarely, or slowly, over time. In this scenario any bias arising from the mix of what is in the composite variable will be largely corrected in any model which corrects for unobserved firm specific heterogeneity.

Figure 11

Firm Specific Heterogeneity and Simultaneity

Dependent Variable is log of real output	1 Base	2 Fixed Effects	3 First Differences	4 Blundell Bond
Log real capital	0.1767*** *(0.0117)*	0.0324*** *(0.0057)*	0.0649** *(0.0244)*	0.0947*** *(0.0271)*
Log real labour	0.4844*** *(0.0186)*	0.5910*** *(0.0094)*	0.7082*** *(0.0417)*	0.1006 *(0.109)*
Log real intermediate inputs	0.3434*** *(0.0131)*	0.3022*** *(0.0057)*	0.3320*** *(0.0316)*	0.002 *(0.0374)*
Log real in-house IT capital	0.0607** *(0.0198)*	0.0212*** *(0.0063)*	0.024 *(0.0141)*	0.0348*** *(0.0104)*
Log real SWIS outsourcing	0.0888*** *(0.018)*	0.0469*** *(0.0065)*	0.0366* *(0.0186)*	0.0421*** *(0.0119)*
Year dummies	Yes	Yes	Yes	Yes
Sector and trade dummies	Yes	No	No	No
Lagged dependent variable	No	No	No	Yes
N	26,986	26,986	17086	17086
R-Squared	86.9%	99.0%	55.9%	
P-value from Hansen test of overidentifying restrictions				0.342

Key: ***means significant at the 0.1% level, **means significant at the 1% level, * means significant at the 5% level

Notes: Column 1 is estimated using OLS and cluster robust standard errors; column 2 is estimated using fixed effects; column 3 is estimated using OLS on first differenced data; column 4 is estimated using general method of moments and uses both lags of the variables and lags of first differences of the variables as instruments for first differences and levels of the variables (as suggested by Blundell and Bond, 1998).

Source: Author calculations based on CMIE (2009)

Columns 2 and 3 in Figure 11 control for unobserved firm level heterogeneity. In both of these two models the variable for SWIS outsourcing remains positive and highly significant. However, the magnitude of the effect falls from 9% per 100% increase in expenditure to 4.7% for the fixed effects model and 3.7% for the model in first differences. This shows that, as expected, there are unobserved firm level characteristics which are related to the use of outsourced SWIS or its measurement, and which also have a positive effect on output. Column 4 develops the first differences model of column 3 further by using instrumental variables to correct for production function simultaneity. In this model the traditional inputs, labour and intermediate inputs, are found to be statistically insignificant, suggesting that the instruments used are weak. Despite this, SWIS outsourcing remains positive and significant with a coefficient that implies 4.2% more output from 100% more expenditure.

Figure 12

In Sample Effects of SWIS Outsourcing

	SWIS Outsourcing	In-House IT
Gross marginal product (Rs.)	11	6
Growth in output per firm from IT investment (%)	18%	7%
Growth in output per firm from IT investment (Rs. Crore)	23	9
Share of total growth in output per firm from IT investment	10%	4%

Notes: Gross marginal products are calculated at the mean amongst those firms which have some spending on the IT type in question. All growth figures refer to growth between 2005 and 2008 in real terms. Monetary values are in 2005 rupees crore. Rs. 1 crore was equivalent to US$221,900 in 2005.

Source: Author calculations based on CMIE (2009)

Figure 12 uses the fixed effects elasticity estimates to illustrate the effect of SWIS outsourcing and in-house IT on output in the firms in the PROWESS sample. The first row in the table gives the gross marginal products arising from the elasticity estimates. These are substantially larger than 1 indicating that both types of investment into IT offer excess returns[7]. However, when the gross marginal product of SWIS outsourcing is compared to that of in house IT capital it is

[7] This is a typical finding in the literature on IT and may arise simply because IT does offer super normal returns. However it may also arise because IT has a large service price or user cost because it ages and becomes obsolete very rapidly. See Stiroh, 2002: p. 10 for a discussion of these and related issues.

clear that on average an additional Rs. 1 would be better spent on outsourcing. The other rows in the table are concerned with how much output growth in the sample firms can be attributed to investment into IT. Between 2005 and 2008 real SWIS outsourcing per firm in the sample increased from an average of Rs. 0.56 crore (US$125,000) to an average of Rs. 2.7 crore (US$600,000), giving a percentage growth rate of 380%. Applying the fixed effects elasticity to this growth rate gives an increase in output per firm attributable to IT outsourcing of 18%. This amounts to an output increase per firm from Rs. 230 crore to Rs. 270 crore, or 10% of all growth in output per firm over the period.

4. The Impact of IT Outsourcing on Technical Efficiency

4.1. Methods

This section investigates how IT outsourcing impacts the technology component of firms' TFP, that is, their technical efficiency[8]. It uses stochastic frontier modelling, a type of econometric analysis which measures and analyses firms technology position relative to their most efficient peers (Battese & Coelli 1992, 1995). The technique involves estimating the parameters of a production function which applies to the most technically efficient firms, and for each firm, a «distance» away from this ideal. The distance, or inefficiency, metric measures the difference in output between what each firm would produce if it was as efficient as the high performers and what it actually produces. This gives equation (5) below, where the starred α's denote elasticities for the most efficient firms and -ln(E) is the measure of inefficiency.

$$\ln(Y) = \alpha_K \ln(K) + \alpha_{IT} \ln(IT) + \alpha_L \ln(L) + \alpha_M \ln(M) - \ln(E) \qquad (5)$$

To test the hypothesis that IT outsourcing is a significant driver of progress towards technological parity with the most efficient firms, the firm level inefficiencies, -ln(*E*), are used to create the dependent variable in a second regression[9]. This is shown as equation (6) below:

[8] A technically efficient firm uses the most efficient technology for converting inputs into output. This means it cannot raise output without increasing one or more inputs. It also cannot produce the same output with less of one or more inputs, unless it increases the amount of other inputs used.

[9] Kumbhakar and Lovell (2000: p. 262–265) provide a clear technical explanation of the two step process which has been followed to reach the results here.

$$\ln(\hat{E}) = \beta_{SWIS}\ln(\text{OSIT}) + \sum \beta_j \ln(z_j) \quad (6)$$

In it, the dependent variable is a positive measure of efficiency estimated using equation 5 and the β's measure the elasticity of technical efficiency to outsourced IT and to other controls denoted by z.

4.2. Findings

Figure 13 shows the results of estimating equation (5) using the PROWESS data. Figure 14 then goes on to report the findings from using the resulting inefficiency estimates to investigate how IT outsourcing impacts technical efficiency. Column 1 in Figure 14 shows a regression of technical efficiency on SWIS outsourcing and column 2 modifies this regression by including a range of other relevant control variables. Both sets of estimates show that technical efficiency is significantly higher for firms which purchase outsourced SWIS. This adds another important result to the findings above. It demonstrates that SWIS outsourcing genuinely does improve the production technology that firms use. It moves firms closer to a situation where they cannot improve their output without increasing one or more of their inputs, and in doing so it allows them to catch up with the most efficient firms.

5. Conclusion

This paper has, for the first time, investigated the impact of IT outsourcing. Using Indian firms as its case study, it has estimated the returns to outsourcing in terms of output and productivity, and technical efficiency. The estimated elasticity of output to IT outsourcing is significantly higher than that found for either in-house IT capital, or outsourcing of other goods and services. It is also much bigger than the median estimate for in-house IT capital in a large number of existing studies on developed countries (Stiroh, 2002). This suggests that IT outsourcing offers more than just the relocation of low productivity tasks. It offers an opportunity to purchase more successful applications of the technology than are normally found in firms which keep their IT in house. The findings on technical efficiency are also suggestive of a superior role for IT outsourcing. The paper found that it moves firms closer to the technological frontier, or in other words, that it helps firms to catch up with the technical capabilities of the most efficient firms.

Figure 13

Stochastic Frontier Model

Dependent Variable is log of real output	Coefficient	Standard Error	z-value
Log real capital	0.183***	0.010	17.63
Log real labour	0.657***	0.014	45.84
Log real intermediate inputs	0.391***	0.009	43.76
Log real in-house IT capital	0.159***	0.025	6.39
Constant	Yes		
Year Dummies	Yes		
Sector Dummies	Yes		
Dummies for Foreign Trade	Yes		
N	26,986		

Key: ***means significant at the 0.1% level
Notes: Stochastic frontier model of equation (5).
Source: Author calculations based on CMIE (2009)

Figure 14

The Impact of Outsourced SWIS on Technical Efficiency

Dependent Variable is technical efficiency	1	2
Log real outsourced SWIS	1.44E-07*** *(4.09)*	7.37E-08* *(2.21)*
Age		-9.46E-09*** *(-4.39)*
Age squared		4.98E-11* *(2.26)*
Dummy for importers		4.38E-07*** *(15.67)*
Dummy for 2006		4.9E-08*** *(4.27)*
Dummy for 2007		6.67E-08*** *(4.10)*
Dummy for 2008		1.42E-07*** *(6.04)*
Sector dummies	No	Yes
N	26,986	26,986

Key: ***means significant at the 0.1% level, **means significant at the 1% level, * means significant at the 5% level
Notes: Tobit models. Robust t-values are in parentheses. The dependent variable is ln(*E*) as detailed in the methods section above, and estimated using the model in Figure 13.
Source: Author calculations based on CMIE (2009)

A likely explanation for these strong findings is that IT outsourcing firms offer advice to their clients which enables better returns from IT spending. If this advice is built on knowledge accumulated during previous work in developed countries, there is a precious opportunity for India. The literature on IT adoption in developed countries, reviewed above, found strong impacts at the macroeconomic level, with contributions to economic growth in the range 10–30% the norm. IT enabled acceleration on this scale in India would be very welcome. The country remains under-developed and, in many regions and industries, technically backward. Fast technical progress in infrastructure sectors with many linkages could be an important step towards changing that. With all this in mind, the policy implications are clear. Existing incentives for India's indigenous SWIS outsourcing sector to focus on exports must be removed and replaced with new policies which target domestic projects.

The work included here contributes in several ways to the literature reviewed above. Perhaps the most important of these is the finding that IT is important in India. So far, there are very few quantitative studies in developing countries, and as a result there remains some debate about whether IT is suitable for them (Mody and Dahlman, 1992). To these debates, this paper adds new evidence which supports the recent finding by Commander, Harrison, and Menezes-Filho (2011) that the impact of IT in Indian firms is substantial. This paper also suggests a methodological improvement to authors interested in either the impact of IT, or the impact of outsourcing. It shows that estimating their effects using firm level econometrics may give misleading results if IT outsourcing is important, but not included separately. In future, and particularly in countries with large IT outsourcing markets, it will be important to control for IT outsourcing whenever the role of IT or outsourcing is investigated.

In highlighting the importance of IT outsourcing in developing countries this paper opens a rich vein for new research. An investigation into the role of IT outsourcing in Brazil and China, which both have significant IT outsourcing industries, is an important next step.

Bibliography

1. Amiti, M., Wei, S. (2004). Services outsourcing, production and employment: Evidence from the US. IMF Working Paper (forthcoming).
2. Amiti, M., Wei, S. (2006). Service offshoring and productivity: Evidence from the United States. NBER Working Paper No. 11926.
3. Baily, N., Lawrence, R. (2001). Do we have a new E-conomy? *The American Economic Review,* [Papers and Proceedings of the Hundred Thirteenth Annual Meeting of the American Economic Association], 91, 2, 308–312.
4. Banga, R., Goldar, B. (2004). *Contribution of services to output growth and productivity in Indian manufacturing: Pre and post reforms.* Indian Council for Research on International Economic Relations, New-Delhi.
5. Battese, G. E., Coelli, T. J. (1992). Frontier production functions, technical efficiency and panel data: With application to paddy farmers in India. *Journal of Productivity Analysis*, 3, 153–169.
6. Battese, G. E., Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics*, 20, 325–332.
7. Blundell, R., Bond, S. (1998). GMM estimation with persistent panel data: An application to production functions. Institute of Fiscal Studies, Working Paper No. W99/4.
8. Bresnahan, T., Brynjolfsson, E., Hitt, L. (2002). Information technology, workplace organization, and the demand for skilled labor: Firm-level evidence. *Quarterly Journal of Economics*, 117, 1, 339–376.
9. Brynjolfsson, E., Yang, S. (1996). Information technology and productivity: A review of the literature, advances in computers. *Academic Press*, 43, 179–214.
10. CMIE PROWESS database (November 2009). [Online]. Retrieved from http://www.cmie.com/.
11. Colecchia, A. (2001). The impact of information and communications technologies on output growth: Issues and preliminary findings. OECD Directorate for Science, Technology, and Industry Working Paper No. 11. Paris: Organization for Economic Cooperation and Development.
12. Commander, S., Harrison, R., Menezes-Filho, N. (May 2011). ICT and productivity in developing countries: New firm-level evidence from Brazil and India. *The Review of Economics and Statistics,* 93(2), 528–541.

13. Crafts, N. (2001). The Solow Productivity Paradox in Historical Perspective. Long-term trends in the world economy. [Conference Proceedings]. University of Copenhagen.

14. Criscuolo, C., Leaver, M. (2005). Offshore outsourcing and productivity. mimeo.

15. D'Costa, A. (2003). Uneven and combined development: Understanding India's software exports. *World Development*, 31, 1, 211–226.

16. D'Costa, A. (2004). Export growth and path dependence: The locking-in of innovations in the software industry. In: D'Costa and Sridharan, E. (2004) (Eds.). *India in the global software industry, innovation firm strategies and development* (Chapter 3). Palgrave Macmillan.

17. Daveri, F. (2001). Information technology and growth in Europe. [unpublished]. Parma: University of Parma.

18. Egger, H. and P. Egger (2001). Cross-border sourcing and outward processing in EU manufacturing. *The North American Journal of Economics and Finance*.

19. Girma, S., H. Görg (2003). Outsourcing, foreign ownership, and productivity: Evidence from UK establishment-level data. *Review of International Economics*, 12 (15).

20. Gorzig, B, Stephan, A. (2002). Outsourcing and firm-level performance. DIW Berlin, Discussion Papers, No. 309. German Institute for Economic Research.

21. Griliches, Z., Mairesse, J. (1998). Production functions: The search for identification. In: Storm, S. (Ed.) *Econometrics and economic theory in the 20th century.* Cambridge: Cambridge University Press.

22. Hanna, N. (1994). Exploring information technology for development: A case study of India. World Bank Discussion Paper No.246, Washington DC: The World Bank.

23. Heeks, R. (1996). *India's software industry: State policy, liberalisation and industrial development.* New Delhi: Sage Publications.

24. International Monetary Fund (2001). World Economic Outlook: The Information Technology Revolution, [Online], Available: http://www.imf.org/ external/pubs /ft/weo/2001/02/pdf/chapter3.pdf, Chapter 3, pp.103–142.

25. Jeong, K., Jeong, H., Shin, I. (2002). The economic impact of information and communication technology in Korea. In: Pohjola, M. (ed.). *Information technology, productivity, and economic growth: International evidence and implications for economic development.* UNU/WIDER Studies in Development Economics, Oxford University Press.

26. Jorgensen, D., Ho, M., Stiroh, K. (2007). A retrospective look at the U.S. productivity growth resurgence. Federal Reserve Bank of New York Staff Reports, no. 277.

27. Jorgenson, D. and Stiroh, K. (1995). Computers and Growth. *Economics of Innovation and New Technology*, 3 (3 & 4), 295–316.

28. Kite, G. (2012). The impact of information technology outsourcing on productivity and output: New evidence from India. [Procedia Economics and Finance]. The International Conference on Applied Economics (ICOAE), Uppsala, Sweden, 1, 239–248.

29. Kumar, N., Joseph, K. (2005). Export of software and business process outsourcing from developing countries: Lessons from the Indian experience. *Asia-Pacific Trade and Investment Review*, 1, 1, 91–110.

30. Kumbhakar, S., Lovell, K. (2000). *Stochastic frontier analysis*. Cambridge University Press.

31. Ministry of Statistics and Programme Implementation (2011), Ministry of Statistics, National Accounts Statistics, [Online], Available: http://mospi.nic.in/GDP50_08_R_curr_9.9.09.pdf [4 May 2011].

32. Mody, A. Dahlman, C. (1992). Performance and potential of information technology: An international perspective. *World Development*, 20, 12, 1703–1719.

33. NASSCOM (2006). Study on domestic services market opportunity. Retrieved from www.nasscom.in on 11/4/2008.

34. NASSCOM (2008). Strategic review executive summary. [Online]. Retrieved from http://www.nasscom.in on 9 April 2008.

35. NASSCOM (2009). The IT-BPO sector in India – Strategic Review. [Online]. Retrieved from: http://www.nasscom.in/ on 3 March 2009.

36. Nolan, P. (2001). *China and the global economy, national champions, industrial policy and the big business revolution.* Palgrave.

37. Oliner, S.D., Sichel, D.E. (1994). Computers and output growth revisited: How big is the puzzle? Brookings Papers on Economic Activity, 1994(2), 273–334.

38. Oliner, S.D., Sichel, D.E. (2000). The resurgence of growth in the late 1990s: Is information technology the story? *Journal of Economic Perspectives*, 14, 3–22.

39. Olley, G., Paikes, A. (1996). The dynamics of productivity in the telecommunications equipment industry. *Econometrica*, 64, 6. November, 1263–1297.

40. Olsen, K. (2006). Productivity impacts of offshoring and outsourcing: A review. STI Working Paper, OECD Directorate for Science, Technology and Industry (STI), vol. 2006/1.

41. Perez, C. (1985). Microelectronics, long waves and world structural change: New perspectives for developing countries. *World Development*, 13, 3, 441–463.

42. Prud'homme, M., Sanga, D., Yu, K. (2005). A computer software price index using scanner data. *The Canadian Journal of Economics / Revue canadienne d'Economique*, 38, 3 (August), 999–1017.

43. Reserve Bank of India (2009). *Handbook of Statistics on Indian Economy* [Online]. Retrieved from http://www.rbi.org.in/ [21 December 2009].

44. Reserve Bank of India (2011). *Handbook of Statistics on Indian Economy.* [Online]. Retrieved from http://www.rbi.org.in/ [21 December 2009].

45. Sichel, D. (1997). Computers and aggregate economic growth. *Business Economics*, 34, 2, 18–24.

46. Stiroh, K. (2002). Reassessing the role of IT in the production function: A meta analysis. Federal Reserve Bank of New York, mimeo.

47. World Development Indicators (2010). Washington, DC: World Bank.

The article was received on June 26, 2013.