Information Technology and Productivity
Evidence from India's Manufacturing Sector

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Abstract

While India's remarkable performance in IT software and service exports may be inspirational for other Indian industries and more so for other countries in the south, the moot question is how has India fared in terms of harnessing this technology for enhancing manufacturing productivity. This paper is an attempt at addressing this issue by analyzing an unpublished data set on the investment in computers and software at the industry level made available by the CSO. The study finds that low level of IT investment intensity in the manufacturing sector notwithstanding; IT investment does have a positive and significant impact on both partial and total factor productivity. The findings of the paper suggest that in a context wherein the policy makers are concerned with low levels of growth in manufacturing output and productivity, policy measures and institutional interventions towards promoting IT diffusion in the manufacturing sector is likely to give rich dividends.

Key words: India, Information Technology, Productivity, Manufacturing Sector

JEL Classification No: L6, D24, O14

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Introduction

Given the wider applicability, innovational complementarities and productivity enhancing effects in numerous downstream industries, Information Technology (IT) is generally perceived as the General Purpose Technology (Helpman 1998) of the new millennium. Analytically, the contribution of IT to an economy could be viewed at two different but interrelated levels - on account of IT growth and on account of IT diffusion. The former refers to the contribution in output, employment and export earning arising from the production of IT related goods and services (Kraemer and Dedrick 2001) and the latter refers to IT induced development through enhanced productivity, competitiveness, growth and human welfare on account of its diffusion into different sectors of the economy and sections of the society.

Among the developing countries, India is widely known for its success in profiting from the production and export of IT software and services (Schware 1987, Heeks 1996, Kumar 2001, Arora et.al 2001, Joseph and Harilal 2001, Siddharthan and Nollen 2004) that has been facilitated by the innovation system evolved over the years (Balakrishnan 2006, Joseph 2002, 2006, Kumar and Joseph 2007, Parthasarathi and Joseph 2002). The value of output of India's IT software and service sector increased by 43 fold from $0.83 billion in 1994-95 to $ 36.3 billion in 2005-06 accounting for about 4.8 per cent of the GDP (NASSCOM 2006). The export of software and IT enabled service exports during the last two decades has been doubling in almost every alternative year with a recorded annual compound growth rate of over 50 per cent up to late 1990s and 38 per cent since 1997-98. As a result by 2005-06 the IT software and service exports accounts for over 20 per cent of India's exports and even higher than the traditionally leading item in India's export basket viz. textile and textile products (Chandrasekhar et al 2006). What is more, despite the limited R&D orientation by the Indian firms (Parthasarathi and Joseph 2002), and focus on low end of the value chain during the initial years (D'Costa 2002 and Arora et al. 2001) the recent evidence indicates that IT firms are moving up in terms of their technological competence (Joseph and Abraham 2005) and diversifying into more technology intensive areas (Parthasarathy and Aoyoma 2006). These achievements in reaping the direct benefits become all the more striking when considered against the fact that it has been almost entirely at the instance of domestic rather than foreign firms (Arora and Athreya 2002).

However, as per the commonly used indicators diffusion of IT in India remains at very low levels. To illustrate, while the world average PCs per 100 inhabitants in 2005 was 9.71 (Sweden at the top with 76.1) it was only 1.54 in India. Similarly, the Internet penetration (number of internet users per 100 inhabitants) in India for the year 2005 is found to be only 5.44 as compared to 15.27 at the global level with Iceland recording the highest level of 87.76 (ITU, 2007)[1]. Yet, it is by now known that the IT provides developing economies like India, with a great opportunity to "catch up" with the developed economies. Moreover, the benefits of IT using countries/sectors tend to benefit more than the IT producing countries/ sectors owing to the deteriorating terms of trade for IT producers (IMF, 2001)[2].

Despite low IT diffusion in general, IT use has been more promising within the organized manufacturing sector of India. The Annual Survey of Industries (ASI) for the year 1998-99 reported that nearly 35 percent of the firms that came under its purview were using IT for managerial and accounting work. While the use of computers by the ASI firms in networking, Internet and computer aided production had been very low in general, in some technology intensive sectors such as non-conventional energy, motion picture and, electric machinery & equipment it had been relatively high. The average IT investment intensity in the manufacturing sector during 1998-01 has been estimated at 9.6 percent. This however compared poorly with developed countries implying a time lag of over 20 years (Abraham and Joseph, 2007)

[1] http://www.itu.int/ITU-D/ITeye/Indicators/Indicators.aspx#

[2] The estimates of consumer surplus of IT users using panel data for a sample of 41 countries over the years 1992-99 have shown that the increase in consumer surplus for the users has been quite large accounting to several percentage points of GDP. The countries with largest gain in consumer surplus (greater than 3.5 per cent of GDP) are found to be United States United Kingdom, Singapore, Australia and New Zealand (IMF 2001).

Given the remarkable performance in production and export of IT along with indications of enhanced IT capability and its diffusion in the manufacturing sector, it may be of relevance for policy making to explore the contribution of IT in India's manufacturing sector. Such an enquiry becomes all the more important in a context wherein our understanding on the issue at hand at best remains rudimentary and unexplored not only for India but also for many other developing countries. Remainder of this paper is organized as follows. The second section presents the analytical background of the study and makes a stock taking of our understanding on the issue under discussion. The data set used in the study and the method of analysis is the focus of section 3. While the penultimate section presents the empirical findings, the concluding observations and policy implications are presented in the last section.

2. Analytical Background

General Purpose Technologies (GPTs) can be defined as technologies that initially have much scope for improvement and eventually comes to be widely used and to have many Hicksian and technological complementarities (Lipsey et al., 1998). What characterize GPTs could be summarized as follows: First, these technologies perform some generic tasks crucial for the functioning of many production systems. Secondly as Rossenberg (1969) observed, change in one component of an interdependent system creating a stimulus elsewhere has been a highly fruitful source of technological change. Thus viewed, GPTs act as major inducement mechanisms for technological dynamism. Continuous innovational efforts increase the efficiency with which the generic functions are preformed over time, benefiting existing users, and inducing others to adopt new innovations. Thirdly, GPTs exhibit "innovational complementarities" with the application sectors, since technological advances in GPTs make it more profitable for its users across a broad spectrum of sectors to innovate and improve their own technologies. In turn, improvements in those sectors increase the demand for investment in improving GPTs themselves. There are positive loops caused by GPTs that may result in faster and sustained growth for the economy at large (Rosenberg and Trajtenberg, 2001: 6). Thus, as the economy is a system consisting of interrelated subsystems, technical change takes place when relationships among subsystems change or when new interfaces are established. GPTs open up more possibilities for change than specific technologies. The more generally applicable the technologies are, the greater the economic growth potential (Carlsson, 2004).

Carlsson (2004) carried out an extensive study on impacts of the IT, especially the digitization of information and the Internet, as a GPT. He argues that there are four categories of impacts; productivity enhancement in traditional industries; restructuring of economic activities within industries; the creation of more efficient markets; and the creation of new combinations, which give rise to new products and industries.

One of the early hypotheses on the contribution of IT to the economy related to its productivity enhancing properties. Initial studies, however, highlighted the "productivity paradox" – indicating hardly any such impact of IT on productivity [Berndt, Morrison and Rosenblum (1992) Oliner and Sichel (1994)]. However, at the firm level most of the studies reported that the marginal product of IT capital is substantially higher than the non-IT capital implying excess returns (lichtenberg 1995). In case of Singapore Wong (2001) finds that the net return to IT capital (37.9%) is about two and a half times higher than that for non-IT capital (14.6%). More recently a number of studies have confirmed the positive contribution of IT to productivity [Siegel and Griliches (1992) Oliner and Sichel (2000), Dunne et. al. (2000) Stiroh (2001) Jorgenson and Stiroh (2000) Wong (2001) Nordhaus (2001); Jeong, Oh and Shin (2001); Niininen(2001][3].

Broadly, studies have conceived productivity-enhancing effect of IT in two different ways. The first set of studies highlighted the substitution of IT capital for labour or other type of capital, due to drastic fall in the cost of IT capital. Studies by Card, Kramarz and Lemieux (1997); Oliner and Sichel (2000) show that computers act as a substitute for routine labour, while Doms, Dunne and Trotske (1997) demonstrated that skilled labour and computers are complementary. Oliner and Sichel (2000) find that the investment in the IT goods and services is a key factor behind the observed increase in output growth and labour productivity in the US economy during the late 1990s. They also find that during the period prior to 1995, the returns to IT investment were nominal, while the

[3] See Indjikian and Siegel (2005) for a recent and detailed survey

returns increased by many folds during the period 1996-1999. Using the growth accounting framework they concluded that approximately half of the growth in labour productivity during 1996-99 could be accounted by the capital deepening related to information technology capital. Dunne et. al. (2000) studying the manufacturing sector reported rising labour productivity growth with the use of information technology. Similarly, Jorgenson and Stiroh (2000) also confirmed that IT capital was acting as a substitute in both business and household sectors. As the price of computers fell dramatically in the 1980s and 1990s, profit-maximizing firms and utility-maximizing consumers substituted IT for other goods and services and economizing on the use of labor effort.

Second set of studies consider the role of IT in an economy as much more complex than being substitute for labour and other type of capital. Malone, Yates and Benjamin (1987) and Bresnahan,Brynjolfsson and Hitt (2002) argued that the greatest impact of IT is in its role as a coordination technology. IT has generated possibilities of hitherto unexplored inter and intra-organizational coordination. IT has also reduced the costs of already existing organizational coordination, which can ultimately lead to rise in both labour productivity and Total Factor Productivity. Focusing on the organizational transformation that accompanies IT investment by firms and the resultant intangible benefits accrued, Brynjolfsson and Hitt (2000) argue that impact of IT investment is complimentary to the changes in the organizational structure of the firm such as allocation of decision rights leading to increased delegation of authority, workforce composition, investment in human capital, reduced vertical integration of firms and reduced firm size, which in turn makes it possible to have flexible production strategies and greater productivity. Such complex effect of IT on enhancing efficiency gets captured in the residual of economic growth devised by Solow (1957), after accounting for the growth of all inputs. Their study (Brynjolfsson and Hitt, 2000) at the firm level suggests that computerization is accompanied by 'relatively large and time-consuming investments' in complementary inputs, whose productivity effects may not show immediately. But the IT investment along with such complimentary changes shows increase of total factor productivity (TFP) by more than five times when the IT investment is lagged by five to seven years. (Bresnahan, Brynjolfson and Hitt 2002). The industry and firm level studies find that enhanced IT use and productivity have been associated with a cluster of complementary organizational practices. These include, a transition from mass production to flexible manufacturing technologies, changing interaction with suppliers and customers, decentralized decision making, enhanced communication and increased use of skilled manpower. The industry level study on UK and US economies by O'Mahony and Vecchi (2002), after controlling for industry heterogeneity also yielded a positive and significant long-run impact of IT on TFP.

IT and Developing Countries

While the earlier GPTs involved 'lumpy' investments in innovation, capacity creation, market acquisition and therefore necessitated access to critical size of capital as precondition to entry, IT is known to be less capital intensive and knowledge base is fairly universally available. This makes it relatively easy for wholly new entrants to acquire the knowledge base required for cutting edge technological contributions to the industry (Chandrasekhar 2006). IT also offers new opportunity for developing countries ito participate in the global production networks and acquire the tacit and codified knowledge and (Ernst and Lundvall, 2000) thus breaking the vicious circle of idea gap and object gap (Romer 1993) that lies at the root of persisting poverty and underdevelopment. Moreover, in the context of globalization, the ability to harness this technology improves the capability of developing country-firms to withstand competition from multinational corporations or in developing partnership with them and ensure wider market for their products and services. Conversely, there is a potential threat that if unable to harness this new source of wealth, they will fall even more behind the developed countries (Pohjola 2001).

But the available empirical evidence on the contribution of IT towards productivity and growth pertains mainly to developed countries, barring a few studies on specific industries in developing economies. Lal (2001) studying the garment manufacturing firms in the Okhla region of India, found that there existed a positive relation between labour productivity and IT investment. Another study by Basant et al (2007) based on a survey of 1000 firms in six skill and export oriented industries (auto components, soaps and detergents, electronic components, machine tools wearing apparels and plastic products) in India and Brazil has similar conclusions to offer. However, to our knowledge, there is no study reporting the effect of IT on productivity growth in the whole manufacturing sector of India, perhaps due to non-availability of a comprehensive dataset on IT investment in the manufacturing sector. The present study intends to fill up this gap in our understanding on the contribution of IT towards productivity in India's manufacturing. The study is also unique as we use, for the first time, an unpublished dataset on IT investment obtained from CSO, the official statistical agency of India.

3. Method of Analysis and Database

Given the above background we focus on three questions. To what extent IT investments in India's manufacturing sector have contributed towards the observed levels and growth in labour productivity and total factor productivity? Has there been substitution of IT capital for labour? What has been the contribution of IT investment and non-IT investment towards the observed productivity growth?

To analyze the first issue we have estimated a heuristic labour productivity determinants model (1a) as specified below. In the model the influence of IT investment intensity on labour productivity is analyzed with a set of control variables like capital labour ratio, average size of firm in the industry and skill intensity of the industry.

The literature on growth economics, starting from Harrod and Domar has emphasized the pivotal role played by capital in economic growth. Capital could not only help effective utilization of human skills but also embody the latest knowledge and innovations important for productivity. Schultz (1989), reviewing research on the contribution of human capital to economic growth, has shown that human capital enhances the productivity of both labour and physical capital. Similar notions of productivity growth has been found in Arrow (1962) and the endogenous growth model by Romer (1986) wherein the spillovers of knowledge accruing due to a large human capital stock improves the level of technology for the producers and hence the overall productivity. It is hypothesized that skill intensity indicating the quality of labour will have a positive impact on labour productivity. Size of the firm is expected to influence labour productivity positively *inter alia* through scale economies.

Based on the above hypotheses the following model is specified:

$$\ln(LPROD_{it}) = a + \beta_1 \ln(ITINT_{it}) + \beta_2 \ln(KLINT_{it}) + \beta_3 \ln(SIZE_{it}) + \beta_4 \ln(SKILLINT_{it}) + \eta_i ITTECH_{it} + u_{it} \qquad (1a)$$

Where; *LPROD* is the measure for labour productivity; *ITINT* is IT Investment Intensity; *KLINT* is capital intensity in production; *SIZE* is the average size of a factory; *SKILLINT* is the measure of skill intensity in the industry. All values are taken in natural log, marked as *ln* in the equation (1a). All the variables are observed for the i^{th} industry and t^{th} year as denoted in the equation. ; and *u* is the error term.

After estimating the effect of IT investment on labour productivity levels we explore the effect of IT investment intensity on the growth of labour productivity. After accounting for the growth of labour productivity using the growth of factor inputs, viz capital and labour, we take into account the effect of IT investment intensity. Such a specification would essentially capture the growth of labour productivity, which is not due to capital deepening, rather due to qualitative changes in the composition of investment. In other words, this specification captures the effect of IT investment levels on the residual growth in productivity, after accounting for the growth and substitution effects of factor inputs.

We estimated a labour productivity growth model, taking first difference of the dependent variable in equation 1a, $\Delta \ln(LPROD_{it})$. The independent variable ITINT is the same as equation1a. In addition the growth of capital and labour are added in the model, by taking the first differences of the log of these two inputs, $\Delta \ln(K_{it}), and \Delta \ln(L_{it})$ and u_{it} is the error term.

$$\Delta \ln(LPROD_{it}) = a + \beta_1 \ln(ITINT_{it}) + \beta_2 \Delta \ln(K_{it}) + \beta_3 \Delta \ln(L_{it}) + u_{it} \qquad (1b)$$

To study the productivity effect of capital composition (IT capital vs the non-IT capital) some of the earlier studies estimated production function of the Cobb-Douglas type using IT capital as a variable along with labour and Non-IT capital to explain the contribution of IT capital in productivity. However given the available data with us, construction of a capital stock series of IT was not possible. Therefore the study adopts an indirect approach to draw inference on the productivity effect of IT investment. Assume that recently purchased machinery contains more technology per unit of money invested than old ones. Then the share of capital stock made up of recent investment in plant and machinery would have a positive and significant effect on productivity. If the recent investment in capital stocks consists of both IT and non-IT investment then their respective shares in capital stock would have differential effect on productivity. Thus, apart from validating the effect of IT investment on productivity this specification would also help bringing out the relative effect of the two types of investments on productivity. These two terms are therefore added as factors that affect productivity in a typical cobb-douglas production function framework[4].

The production function, which is of Cobb-Douglas form for the ith industry is specified as below:

$$\log \overline{Q}_i = b_0 + b_1 \log \overline{K}_i + b_2 \log \overline{L}_i + b_3 \log ITINV_i + b_4 \log NONITINV_i + e_i \qquad (2)$$

Where $log\overline{Q}$ denotes log of average gross value added during the period 1998-99 to 2001-02, $log\overline{K}$ is log of average fixed capital stock, $log\overline{L}$ is log of total employment *logITINV* is log share of recent Information Technology investments in capital goods in the total capital stock, *logNONITINV* is the log share of recent investment in capital goods that does not belong to Information Technology, in the total capital stock, and *e* is the error term.

The earlier specifications (1a and 1b) allow us to study the effect of IT investment intensity on labour productivity levels and its growth. But to affirm whether these effects of IT investment is truly associated with quality and efficiency improvements we

[4] See Hassan (2002) and Parameswaran (2007) for similar methodology to arrive at the R&D capital stock.

construct an index of total factor productivity for the manufacturing sector and compare the levels and growth of this index to IT intensity.

A multilateral TFP index is used to measure the level of TFP in different manufacturing industries for each year. Multilateral TFP index, suggested by Caves, Christensen and Diewert (1982) and extended by Good , Nadiri and Sickles (1996) gives the advantage of comparison of productivity across industries and across time. Multilateral TFP index is a comparative index whereby the generated TFP index is in comparison to a base industry-year TFP. In our study we have used the Basic and other chemical industries (NIC code 241+242) of 1998-99 as the base and the productivity level in each industry-year is compared to this base. This particular base was chosen as this industrial group had the largest share in gross value added in the initial year of study1998-99.

Multilateral TFP estimates are made for 52 industries at the 3 digit NIC level for the four-year period 1998-99 to 2001-02. Gross value added is taken as the output and physical capital and labour as the two inputs. As mentioned above Gross value added has been deflated using the relevant industry wholesale price index, capital is measured using the perpetual inventory method and labour is the total number of persons engaged as reported in ASI.

The Multilateral TFP[5] index based on the value added function can be written as

$$TFP_{bc} = \left(\frac{Q_b}{Q_c}\right) \prod_i \left(\frac{X_{zi}}{X_{bi}}\right)^{(S_{bi}+S_{zi})/2} \prod_i \left(\frac{X_{ci}}{X_{zi}}\right)^{(S_{ci}+S_{zi})/2} \quad i=(K,L) \qquad (3)$$

The index varies across industries and over time. It expresses the productivity level in industry-year b as a ratio to the productivity level in industry-year c. Q denotes real gross value added. X_{bi} is the i'th input for industry-year b, and X_{ci} is that for industry-year c. X_{zi} is the geometric average of i'th input across all observations. S_{bi} and S_{ci} are the income shares of i'th input for industry-

[5] See Veeramani and Goldar (2004) and Banga and Goldar (2004) for application of the same methodology in Indian context.

year b and c respectively. S_{zi} is the arithmetic average of income share of i'th input across all observations.

There has not been any systematic attempt to collect data related to the extent of diffusion of IT in Indian economy till recently. However, in 1997, the Annual Survey of Industries (ASI), conducted by Central Statistical Organization CSO), had a specific binary choice question on the use of computers, Internet, Intranet and Robots. In the next year onwards, ASI collected data on the total amount of investment in computer hardware and software by the firms. This data, though unpublished by CSO, was obtained at three-digit level of aggregation for the period 1998-99 to 2001-02. The present study makes use of this data set for information on IT investment. All other indicators are constructed from the data published by ASI, for the same period as mentioned above. All variables are in 1993-94 prices using appropriate price indices published by the Economic Adviser, Ministry of Finance, and Government of India. Details of the deflation procedures are given below.

The data available is at the three-digit industry level aggregation based on the National Industrial Classification – 1998. Though the analysis pertains to the period after this classification was introduced, for purpose of capital stock measurement there was the need to take the period prior to 1998 as well. Hence the data was made comparable at the three-digit level using the concordance table for NIC-1998 and NIC-1987 published by the CSO. After reclassification the available data have 208 observations in panel data form consisting of 52 industries and four years.

4. Empirical Results

Labour productivity and IT investment: Levels and growth

Using the panel data described above we have estimated the labour productivity model specified above. Apart from the Ordinary Least Squares estimates we have also estimated the Fixed and Random effects models. Based on the Hausman specification test Fixed effects model is taken to be more appropriate than random effects for interpretation indicating the importance of industry fixed effects on explaining the productivity levels. The results of the OLS estimation are reported in column 2 of the Table 1, while Column 3 and 4 reports the random and fixed effects results respectively.

As hypothesized IT investment intensity has a positive and highly significant (at 1 percent level), effect on labour productivity level. From the estimates it appears that one percent increase in IT investment intensity would lead to an increase in labour productivity by 3.5 percent. The signs of the coefficient are the same in OLS, GLS random effects and the fixed effects estimation. This result has been obtained after controlling for other explanatory variables like capital intensity, firm size and skill intensity in the industry, all taken in natural log. The effects of capital intensity, size of firm, and skill intensity on labour productivity are found positive and significant at least at 10 percent level. The sign and significance levels of these variables are more or less consistent across the three models estimated, indicating robustness of estimation.

Table 1: Effect of IT investment per employee and IT investment intensity on Labour Productivity levels: Dependent Variable: Ln(Labour Productivity)

	OLS	Random Effects	Fixed Effects
(1)	(2)	(3)	(4)
Ln(K/L)	0.5509* (10.97)	0.4062* (7.70)	0.4792* (8.66)
Ln(SIZE)	0.0743** (3.19)	0.3517* (11.09)	0.6272* (18.22)
Ln(SKILLINT)	0.2970** (3.14)	0.2596* (3.88)	0.2339* (4.10)
Ln(ITINT_**WPI)**	0.1536* (4.23)	0.0591** (3.04)	0.0345** (2.23)
Constant	10.6317* (29.95)	-3.757* (-9.42)	4.444* (10.44)
Observations	208		208
R-squared	0.7269	0.5307	0.4104
Within		0.6628	0.7238
F test	93.82		99.60
Prob> F	0.000		0.000
Wald Chi2		250.62	
Prob> Wald Chi2		0.000	
Wu-Hausman Test		18.86	
Number of group		52	52

Note: *denotes 1% significance level, ** at 5 % and *** at 10% level.
T values in parentheses of column 2, 3 and 5; Z values in parentheses of column 4

To analyse the effect of IT investment on the growth of labour productivity we estimate the model as specified in the equation 1b. The results of the estimated equation are given in Table 2. As earlier, OLS estimation is done for the pooled data, and random and fixed effects estimation done for the panel data. The results of the OLS estimation are reported in column 2. Column 3 and 4 reports the random and fixed effects results respectively.

Table 2: IT investment intensity on Labour Productivity Growth: Dependent Variable: ($Lnlabprod_{it} – Lnlabprod_{it-1}$)

	OLS	Random Effects	Fixed Effects
(1)	(2)	(3)	(4)
Ln(ITINT_WPI)	.0592** (2.60)	.0602** (2.61)	0.1260** (2.39)
Emp_growth	-0.1437 (-1.58)	-.1452 (-1.60)	-0.2345** (-2.18)
Cap_growth	0.2477** (2.50)	.2494** (2.52)	0.3340** (2.90)
Constant	-0.0804*** (-1.63)	-.0825*** (-1.65)	-0.2190** (-2.05)
Observations	151	151	151
R-squared	0.0801	.0801	0.0758
Within			0.1067
F test	4.27		382
Prob> F	0.0064		0.0124
Wald Chi2		12.92	
Prob> Wald Chi2		0.0048	
Hausman Test		3.39	
Number of group		52	52

Employment rate changes (Emp_growth) consistently have, as expected, a negative effect on productivity growth rate across various specifications. However it turns out to be significant only in the fixed effects model. The negative sign signifies the hypothesis of diminishing employment growth with productivity growth. The positive and statistically significant coefficient of capital growth (cap_growth) points to the capital deepening process involved in productivity growth.

Interestingly, the effect of IT investment intensity levels is positive and significant (at 5 %) on the growth rate of labour productivity. These results are consistent across specifications and are obtained after controlling for the effect of the two major inputs namely, labour and capital. The Hausman specification test accepts the random effects model as the preferred model. The Random effects model and OLS model shows the labour productivity growth rate would increase by six percent for one percent increase in IT investment intensity.

Elasticity of output to IT investment

Having argued that IT investment has a positive effect on labour productivity levels and growth we now ask the question whether IT capital perform differently from non-IT capital in terms of their effect on output. To answer this question we estimate the equation 2 in section 2.

Column (1) in Table 3 reports the usual estimation of the elasticity of output for labour and capital within the Cobb Douglas production function framework. Output elasticity with respect to both the factors is statistically different from zero. The capital elasticity is at 0.71 while labour elasticity is at 0.19. The results also show that the manufacturing sector is experiencing decreasing returns to scale. This point to the fact that mere quantitative addition of existing quality of factors of production is unlikely to enhance productivity growth in the manufacturing sector. It essentially calls for a change in the composition of the factors of production, which could propel productivity growth to higher level.

Column (2) of Table 3 adds variables ITINV and NONITINV representing cumulated IT investment and cumulated non-IT investment, respectively, expressed as ratios of the Net Fixed Capital Stock. The elasticity of output to ITINV is positive and significant at one percent level. On the other hand the effect of NONITINV is statistically not significant. The factor inputs, labour and capital are positive and significant in this specification as well. Thus an increase in the IT capital in the fixed capital stock could make considerable contribution towards output growth..

Table 3: Cobb Douglas Production Function with IT investment
Dependent Variable: Ln(GVA)

	(1)	(2)
$Ln\,\overline{L}$	.1875 (2.47)**	.1467 (1.82)***
Ln $\overline{K}$	.7095 (11.66)*	.7818 (13.19)*
Ln(ITINV)		.2618 (3.54)*
Ln(NONITINV)		-.0595 -(0.87)
Constant	.8232 (1.68)***	1.1673 (2.87)**
No. of Observations	52	52
F values	387.55	513.11
Prob,>,F	0.0000	0.0000
R-squared	0.9237	0.9470

* significant at 1% level, ** is 5 % level and *** is at 10% level
Reported t values are derived from Huber white heteroscedasticity corrected standard errors

The analysis in this section suggests that increasing IT investment intensity is associated with both rising levels and rising growth rate of labour productivity in the manufacturing sector, moreover the elasticity of IT investment on output is greater than that of non-IT investment. However, as we had mentioned earlier, IT investment could manifest in partial productivity levels and growth due to the capital deepening and labour substituting properties of IT investment. The average labour productivity growth during the period of analysis was only 3.75 percent[6] (Table 4). During the same period total employment experienced a negative growth of -0.73 percent while capital stock grew at the rate of 10.03 percent, showing trends of capital deepening in the manufacturing sector. This is expressed in the growth rate of capital intensity at 5.09 percent. However the gross fixed capital formation, an indicator of the gross investment, grew at very low rate of 1.64

[6] Calculated from the dataset used for the analysis.

percent. On the other hand IT investment, which is a part of the gross investment, grew at the rate of 13.62 percent. This in effect led the IT investment intensity to grow at the rate of 15.93 percent. This indicates the changing composition of capital stock during the period fostered by a deepening of IT capital within the total capital stock.

The above noted increasing share of IT investment can have two types of effects. One is a substitution of labour with capital due to declining cost of IT capital[7]. Secondly, there would be an efficiency increase due to the change in composition of capital stock with newer and more efficient capital. The first is a case of the movement along the same isoquant, while the second is a case of shift in isoquant toward the origin. The first case will show increase in labour productivity while it will not have any effect on the total factor productivity. The second case on the other hand will show impact on both partial and total factor productivity. The previous analysis confirms that there is some effect of IT investment on labour productivity levels and growth. However, a sharp decline in the employment growth rate along with substantial increase in IT investment intensity puts forward the doubt whether the evidenced IT effect on labour productivity is a substitution effect rather than an efficiency enhancing effect. Massive substitution of computer capital for other capital and labour due to the drastic reduction in computer costs is recorded by Jorgenson and Stiroh (2000) as well. It is towards clarifying this doubt that we turn our attention to, in the next section.

Table 4: Growth Rates of Production Variables

Variable	Growth Rate (1998-99 to 2001-02)
Labour Productivity	3.75
Capital Stock	10.03
Employment	-0.73
Capital Intensity	5.09
Gross Fixed Capital Formation	1.64
IT investment	13.62
IT investment Intensity	15.93

[7] The cost of computing had been continuously declining. For example, from 1990 to 1996 the acquisition price of IT equipment for investment fell 16.6% annually, while the price of computers for consumption fell even faster at 24.2% per year (Jorgenson and Stiroh, 1999). Since the cost of IT capital is declining in absolute terms the relative cost of computer capital is declining vis –a-vis labour or even other capital.

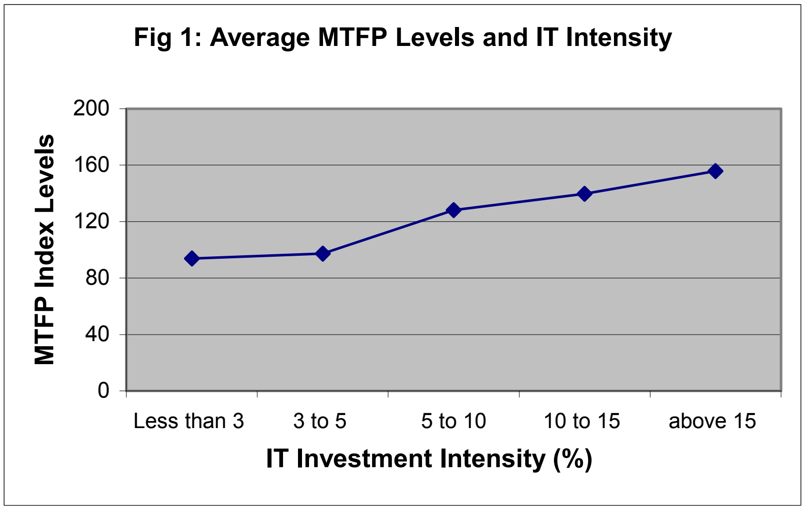
Note: Growth rate is taken to be the industry average of the first difference of the natural log of the variable

TFP and IT investment: Levels and Growth

Table 5 provides a tabulation of the average of the calculated Multilateral Total Factor Productivity Index (MTFPI) at different levels of IT investment intensity for the four years under observation. The calculation of MTFPI and the measurement of inputs and output are explained in section 2. The average MTFPI across different levels of IT investment intensity (column) shows that as one moves from lower IT intensity class to higher class the MTFP also increases. As depicted in the fig **1** at every higher class of IT intensity the level of MTFP shows substantial increase. Moreover, when IT intensity is less than 5 percent their MTFP level lies below the industry average, consistently in all years. On the other hand when it is above 5 percent, their MTFP level lies above the industry average, barring three observations.

Table 5 : IT Investment intensity and MTFP Levels

	Industry Average of MTFP Levels					
(1)	(2)	(3)	(4)	(5)	(6)	(7)
IT Investment intensity	1999	2000	2001	2002	Average	No. of obs
Less than 3 percent	102.1	88.3	91.8	81.9	93.8	45
3 to 5 percent	116.9	110.5	83.6	84.5	97.3	49
5 to 10 percent	122.0	134.9	141.1	111.3	128.2	52
10 to 15 percent	105.9	126.2	130.5	179.1	139.7	29
above 15 percent	224.9	191.8	123.0	133.2	155.8	33
Total	119.3	127.8	112.8	117.9	119.4	208

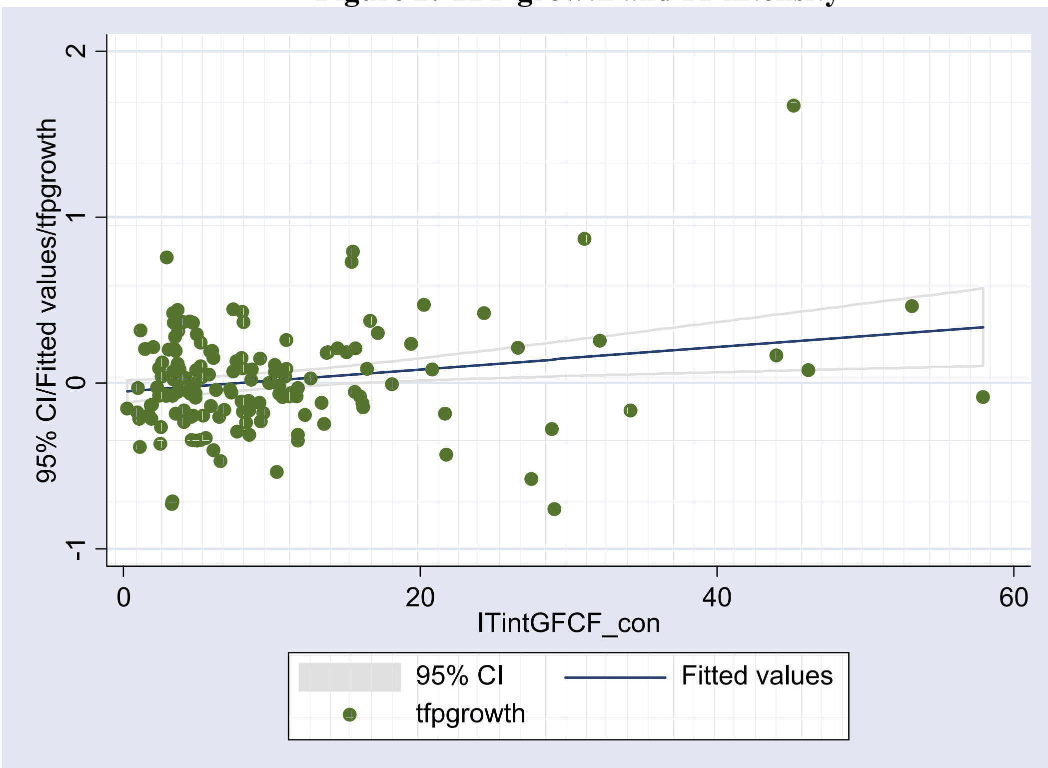


A comparison of the TFP growth trends with the five levels of IT intensity as in Table 5 did not show any convincing linear relationship. While the difference in TFP growth between the highest IT intensity class and the lowest class was substantial, there was mixed results in the intermediate levels. Instead of the previous classification if we truncate the classification into a simple two level classification of less than 10 percent and more than 10 percent IT intensity then TFP growth seems to be substantially higher for the more IT intensive group than that of the group with lower IT intensity. While the average TFP growth is nearly zero, the group of industries with more than 10 percent IT intensity has a TFP growth of more than 6.9 percent in comparison to a negative growth of –3.4 percent for the less IT intensive group. These results are similar to the findings by Dumagan, Gill and Ingram (2003) who found that productivity growth in industries with higher IT investment per worker are substantially higher than industries with lower IT investment per worker. A scatter plot of the relation, with a linear fit also shows a positive slope, (Figure 2) but the slope seems to be generated more due to outlier effect rather than a genuine marginal effect on TFP growth. Hence, while there are rudimentary evidences of a positive relation between TFP growth and IT intensity, present study cannot provide conclusive evidence on this aspect.

Table 5: TFP Growth and IT intensity Levels

IT intensity	1999-2000	2000-2001	2001-2002	average	No. of industries
Less Than 10	0.0361	-0.1390	-0.0119	-0.0344	103
More than 10	0.2837	-0.1227	0.1040	0.0698	51
Total	0.0980	-0.1332	0.0335	0.0001	154

Figure 2: TFP growth and IT intensity



5. Concluding Observations

The present study has been undertaken in a context wherein the earlier studies on IT and productivity, while confirming the positive contribution of IT towards productivity in developed countries, left behind a large knowledge deficit in our understanding on this issue in developing countries. The enquiry assumed importance on account of the remarkable performance of India in the sphere of IT production and export while the track record with respect to IT use is shown to be less remarkable as different sectors of the Indian economy were perceived as not e-ready. The main finding of this study that investment in IT in the Indian manufacturing sector does have a significant impact on productivity growth assumes immense policy relevance not only for India's manufacturing sector but also for the IT sector with respect to its market orientation. The finding may also be inspirational for many other developing countries aspiring to enhance manufacturing productivity and competitiveness through enhanced use of IT.

The lower rate of growth of manufacturing sector in India after 1991, as compared to the service sector, has been a major concern for the policy makers. More over, it has also been shown that the manufacturing-sector growth in the post reform period has been "input driven" rather than "efficiency driven," (Kalirajan and Bhide 2005). As the input driven growth has its obvious limits in a context of heightened international competition, improving industrial growth has no easy options other than to enhance productivity and make the growth process efficiency driven. To the extent that use of IT could contribute towards increasing productivity and India's IT sector is capable of providing the needed inputs for the manufacturing sector, promoting IT diffusion in the manufacturing sector should form the top agenda in promoting the growth and productivity in the manufacturing sector. This may *inter alia* entail a reorientation of the present policies that lay emphasis on export market to one that involves "walking on two legs" wherein the domestic market oriented software units get additional incentives as compared to the export oriented units. To the extent that the IT infrastructure and connectivity are deficient in many regions, such policy initiatives need to be preceded by the provision of adequate IT infrastructure. Investment in IT also needs to be accompanied by managerial and organizational restructuring which in turn might call for among others, a more flexible labour market.

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Appendix: Method of Variable Construction

Real Gross Value Added (GVA) is taken as the measure of 'value added'. Net value added and depreciation figures reported in the ASI data are added to get the nominal gross value added. The nominal gross value added is deflated with the Wholesale Price Index to arrive at the real gross value added mentioned above. The Wholesale Price index was made comparable to the appropriate industry and price deflation was carried out at the three digit level aggregation.

Net Fixed Capital Stock (K) at constant price is taken as the measure for capital stock. Perpetual inventory method is used to arrive at the NFCS. Using the base year of 1993-94 fixed capital stock series was built for all the 52 industries for period 1998-99 to 2001-02. The Fixed capital series was constructed as follows. Firstly, to arrive at the implicit deflator for gross fixed capital formation for registered manufacturing, the ratio of current and constant prices of gross fixed capital formation published in the *National Accounts Statistics* is calculated for all the years starting from 1988-89. Secondly, the book value of fixed capital stock, net of depreciation in 1997-98 from ASI is taken for each industry group. This is adjusted for price changes by using the average value of the deflator for the previous 10 years (1988-89 to 1997-98)[8]. This provides the benchmark capital stock. Gross Investment in fixed capital is arrived at by subtracting fixed capital of current year from fixed capital of past year and summing up depreciation for the current year as reported in ASI. Real Gross investment is calculated by deflating the gross investment using the implicit deflator of GFCF. Net Fixed Capital Stock is estimated for year t is the cumulative sum of net investment from the benchmark year

[8] See Banga and Goldar (2004)

added to the benchmark capital stock. Real net investment in fixed assets is derived by subtracting depreciation of fixed capital from real gross investment in fixed assets. The rate of depreciation is taken as 5 per cent, which the same as assumed in Unel (2003).

Total Persons engaged (L), that includes both workers and supervisory and managerial staff in the sector as reported by ASI is taken to be the measure for labour use in the manufacturing sector.

LPROD is the measure for labour productivity. In this study labour productivity is measured as Gross value added at constant prices per person engaged, which is measured in Rupees.

SIZE is the average Gross Value Added per factory in the particular industry.

SKILLINT is the skill intensity measured as the share of supervisors and managerial employees in total persons engaged.

ITINT_WPI is the share of IT investment, in the Gross Fixed Capital Formation in an industry. The IT investment is deflated using the price index for computer and computer based systems; and Gross fixed capital formation is deflated using price index for machinery and machine tools. Both deflators are taken from the Wholesale Price Index (WPI) and is based on 93-94 prices.

Stock of recent investment in Information Technology capital (ITINV) is the share of cumulated investment in IT in the recent years (1998-99 to 2001-02) in the average capital stock of the period. It is measured as the cumulated real gross investment in IT, as a share of the Net Fixed Capital Stock.

Stock of recent investment in other capital (NONITINV) is the share of cumulated investment capital goods other than IT in the recent years (1998-99 to 2001-02) in the average capital stock of the period. Stock of recent investment in other capital goods is measured as residual after subtracting real gross investment in IT from total real gross investment. The indicator *NONITINV* is then constructed by taking the share of this residual in NFCS.