Nexus of Total Factor Productivity, IT & Skills: A Literature Review

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The contribution of the information and technology (IT) to Indian economy is well acknowledged. In this context, this study carries out a comprehensive literature review to find the linkages among IT, skills and productivity. Results indicate that majority of the studies support the hypothesis that IT promotes productivity and skills play the role of an enabler. The study also reveals three preconditions to accept the nexus. First, it takes time to establish the IT infrastructure and skill building and therefore time lag plays an important part. Second, it is important to have skilled workforce and people practices to reap the benefit of IT and turn them into higher productivity. Third and finally, the maturity of IT adoption is precursor for IT implementation and skill building.

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Introduction

Mr. Modi, the Prime Minister of India quoted jokingly describing the power of Information Technology, "status is now not whether you are awake or asleep, it is whether you are online or offline". Taking the analogy from Mr. Modi, Information Technology in the context of India has truly evolved. It is an important pillar that established India on global map. Over the years, India has made its own unique place in the global arena of IT and ITeS sectors due to its large pool of skilled resources and state of the art IT infrastructure. It is needless to say that IT has tremendous potential to transform organizations, economies and regions. This is why by acknowledging this fact and the way India transformed itself with the help of IT service sector, several developing countries have started investing into IT infrastructure, skill building, IT adoption and framing IT friendly policies to foster their own turf positively. Indian IT sector played an unusual role to shape the country's economy. According to NASSCOM, the sector aggregated revenues of US$160 billion in the year of 2017. The export revenue share stands at 65% and domestic revenue is at 30%. The advent of startups culture in India is a major driving force in IT expenditure which is expected to boost the domestic revenue of IT services to 13% year on year. While the expenditure of IT has been growing steadfast, it is important to examine the role of IT in the domestic industrial productivity.

In 2012, Government of India unveiled a new IT policy to focus on application of technology-enabled approaches to promote growth in education, health, skill development, financial inclusion, employment generation and governance. The policy outlined two key goals: first-materialize the full potential of ICT by making it accessible within the reach of whole country and second, leveraging the capability and human capital to make India as the global hub for IT and ITES Services by 2020. Therefore, the goal of the IT policy is to deploy ICT in all segments of economy and provide IT solutions to the world. The policy targets to achieve these objectives by enabling the collaboration between central and state administrations and adopting several key programs like Make in India, Startup India, Standup India and Ease of doing business (National Information Technology Policy, 2012).

Given that India has already established itself as a leading global player in IT exports and in the light of new IT policy, it is important to carefully examine the role of IT and skills to promote productivity. To achieve this objective, we undertake a literature review due to two reasons: first, literature review is relatively easier to undertake, and second, findings are relatively simple to interpret. Although, there is a major drawback that it may not yield the right outcome if sample (number of papers) is not large enough. To overcome this shortcoming, this paper considered two approaches. First, key papers are taken into consideration. Second, it took a large enough sample (35 papers) to avoid selection biases. The study is divided into four sections. First section classifies the literature into various categories such as types of productivity estimation technique employed, types of data used and based on the major findings observed. Second section carries out a deep dive of the papers chosen and draw findings. Third section brings in Indian context and fourth section concludes the review.

Classifying the Studies

Table 1 exhibits some of the important productivity studies in the context of linkages among IT expenditure, total productivity and skills after 2000. The table summarizes the studies using 8 key factors, namely, research with year of publication, period of data considered, countries considered, scope in terms of data i.e. industry, country or plant, sector if applicable, econometric techniques employed, variables and their relationship explained, results in terms of relationship among IT, productivity and skills that exists and major findings.

In terms productivity estimation techniques that are employed to estimate TFP, the studies can be grouped into 3 major categories. First, quantitative studies that employ the traditional estimation techniques such as Growth Accounting Model (GAM), Coubb-Douglas Production Model (CDPM), Dynamic General Equilibrium Model (DGEM) or Stochastic Frontier (SF). Second, quantitative studies that employ the advanced productivity estimation techniques such as Levinsohn and Petrin (LP in short). Third, qualitative researches that employed surveys or literature reviews.

Fair amount of research has been carried out under the first category that takes traditional productivity estimation techniques into account. Authors such as Schreyer (2000), Gordon (2000), Pohjola (2001), Kraemer et al. (2001), Lee et al. (2003), Qiang (2004), Gretton et al. (2004), Maliranta et al.(2004), Hempell, et al. (2004), Doms et al. (2004), Spyros (2004), Black et al. (2004), Jorgenson (2005), Indjikianet et al. (2005), Hempell (2005), Brynjolfsson et al. (2006), Joseph et al. (2007), Han et al. (2011), Chang et al. (2012), Bloom et al. (2012), Dedrick et al. (2013), Shahiduzzaman et al. (2015), Wamboye et al. (2016), Liao et al. (2016), Chung (2018) and Edquist et al. (2017) supported this. Handful of studies employed the advanced estimation techniques to unveil the linkages of IT, skills and productivity. A few key ones are: Liu at el. (2011) and Sharma et al. (2013) wherein both the authors employed LP technique. A few studies employed qualitative techniques such as survey and literature reviews and are categorized under third group. The key ones include: Kenny (2002), Baldwin et al. (2002), Holt et al. (2009), Chandra (2009) and Tisdell (2017).

In terms of data employed, the studies can be classified into three broad categories. First, those with focus on plant level or unit level data. Second, studies which employed industry level data. Third, those which were carried out with country level or regional level data.

Many studies were carried out with plant level data. A few key ones are included in Table 1, e.g. Baldwin et al. (2002), Chandra et al. (2002), Gretton et al. (2004), Maliranta et al. (2004), Hempell et al. (2004), Doms et al. (2004), Spyros (2004), Black et al. (2004), Hempell (2005), Brynjolfsson et al. (2006), Chandra (2009), Chang et al. (2012), Bloom et al. (2012) and Sharma et al. (2013).

Similar to plant level data, good amount of research was done by taking industry level data to unveil the linkages among IT, skills and productivity. Key ones that are included in this literature review are: Schreyer (2000), Gordon (2000), Lee et al. (2003), Jorgenson (2005), Joseph et al. (2007), Han et al. (2011), Dedrick et al. (2013), Shahiduzzaman et al. (2015), Wamboye et al. (2016), Liao et al. (2016), Tisdell (2017), Chung (2018) and Edquist et al. (2017). A handful of studies that were focused on country or regional level data are also included; Pohjola (2001), Kraemer et al. (2001) and Qiang et al. (2004).

By looking at the outcome, the studies can be broadly divided into 3 categories: first, those who accepted the relationship among skills, IT and productivity. Second, those who either rejected this relationship or were inconclusive. Third, those who accepted the relationship with conditions. The first category is represented by a large number of authors: Schreyer (2000), Gordon (2000), Kenny (2002), Baldwin et al. (2002), Chandra et al. (2002), Qiang et al. (2004), Gretton et al. (2004), Maliranta et al. (2004), Hempell et al. (2004), Doms et al. (2004), Arvanitis (2003), Black et al. (2004), Jorgenson (2005), Hempell (2005), Brynjolfsson et al. (2006), Joseph et al. (2007), Hold et al. (2011), Chang et al. (2012), Sharma et al. (2013), Shahiduzzaman et al. (2015), Wamboye et al. (2016), Chung (2018), Edquist et al. (2017).

There are a handful of studies that fall into second category with either inconclusive evidences or refute the claim that IT and skills promote productivity. Kraemer et al. (2001), Lee et al. (2003), Holt et al. (2009), Chandra (2009) and Dedrick et al. (2013) are a few of those that come in the second category. There are a handful studies that accepted the nexus of IT, skills and productivity with a condition such as: Pohjola (2001), Indjikian et al. (2005), Bloom et al. (2012), Liao et al. (2016) and Tisdell (2017).

IT, Productivity & Skills: A Deep Dive

Based on the widely used estimation technique of productivity literature-growth accounting (GA) model, Schreyer (2000) acknowledged the importance of IT capital goods on economic growth for G7 countries. He analyzed that there is little evidence that they are inherently different from other capital goods. Using GA framework, Black et al. (2004) found a positive and significant relationship between the proportion of non-managers using computers and productivity of establishments. Using the same technique, while Jorgenson (2005) acknowledged previous findings of Schreyer (2000) and questioned the special treatment of IT capital goods over the other capital goods, he also demonstrated that ICTs generate spillovers and "free" benefits that exceed the direct returns to ICT capital. They concluded that if such effects are large, they should translate into an acceleration of multi-factor productivity (MFP) growth. Brynjolfsson et al. (2006), Bloom et al. (2012) and Wamboye et al. (2016) also employed GA model and acknowledged IT investments promotes the productivity growth. Brynjolfsson et al. (2006) concluded that over the short-term, the long-term (five to seven years) impact of IT into productivity growth is five times greater. Bloom et al. (2012) found that the US IT-related productivity advantage is primarily due to its tougher "people management" practices. Wamboye et al. (2016) showed significant increasing returns for labor productivity growth from fixed-telephone and mobile-cellular penetration by approximately 0.12-0.15 per cent, and 0.05 per cent, respectively, confirming the presence of network effects.

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Table 1 Studies Showcasing the Nexus among IT, Skills & Productivity

Research	Period	Country	Scope (Industry/ Unit level)	Sector	Technique	Relationship	Nexus Factors – Accepted/ Rejected	Major Findings
Schreyer (2000)	1996	G7 countries	Industry level panel data	Country level aggregated data	Q1 - Growth accounting	ICT, Economic Growth, Labour and Multi Factor Productivity –	Accepted	ICT capital goods contribute to economic growth but there is little evidence that they are inherently different from other capital goods.
Gordon [2000]	1972-1999	United States	Industry level panel data		Q1 - CDPF & PCA	labour input, capital input, Output, and multi-factor productivity (MFP)	Accepted	IT contributes to MFP growth, but entirely in the IT-producing and other durable industries instead in the IT-using industries
Pohjola (2001)	1980-1995	39 countries	Country level aggregated data		Q1 – GAM	IT investments and gross return	Accepted with condition	While IT investment provides around 80 percent gross returns for OECD countries, it does not yield significant return for developing countries.
Kraemer et al. [2001]	1985-1995	43 Countries	Country level aggregated data		Q1 – GAM	IT Investments and productivity growth	Rejected	Growth in IT investment correlated with productivity Level of IT investment does not yield productivity growth.
Kenny (2002)	-	Literature Review	Meta-analysis/ literature review	Meta-analysis/ literature review	Literature survey	Skilled Workforce in IT and Productivity	Accepted	Importance of a skilled workforce in increasing the returns to investment in IT growth.
Baldwin et al.	1990-1998	Canada	Unit level panel data	Manufacturing	Q2 - Survey	Advanced Technologies and	Accepted	Firms that used either one or more ICT technologies found to

(2002)				sector		Productivity		have higher level of labour productivity
Chandra et al. (2002)	1997	India	Unit level panel data from a national survey	Manufacturing sector	Q1 - Survey findings	Dynamic control of shop floors, network linkages-innovation with output growth	Accepted	Only 13% firms use IT decision system for supply chain. Only 23% firms use web for placing orders, and 11% sell online to customers. Overall picture of using ICT is grim
Lee et al. (2003)	1990-1998	Asia	Industry level panel data	Country level aggregated data	Q1 - CDPF	Stock of ICT capital and growth	Rejected	TFP growth impacted by ICT capital stock is found to be relatively small
Qiang et al. (2004)	1995-2000	Developed, developing countries	Country level aggregated data	Country level aggregated data	Q1 and Q2- GAM & regression	ICT and output growth	Accepted	Promoting IT adaptation close to use to match local capacity and local needs have been identified as policies to fuel output growth
Gretton et al. (2004)	1994-1998	Australia	Unit level panel data	14 sectors	Q1 – CDPF	ICT use, Skills and productivity growth	Accepted	Significant interactions were found between ICT use, skill, improved business practices and business restructuring) in raising productivity
Maliranta et al. (2004)	1998-2001	Finland	Unit level panel data	Manufacturing and Service sectors	Q1 - CDPF & PCA	ICT, human capital and productivity	Accepted	ICT can lead to productivity in the range of 8% to 18%. ICT and human capital are certainly correlated and quite likely also complementary.
Hempell et al. (2004)	1994-1999	Germany and Netherland	Unit level panel data	Manufacturing sector	Q1 - CDPF	ICT capital deepening, innovation & productivity	Accepted	ICT capital deepening is raised when firms combine ICT use and technological innovations on a more permanent basis.
Doms et al. (2004)	1992-1997	United States	Unit level panel data	Retail sector	Q1 - CDPF	Investments in IT and retail firm performance	Accepted	Large firms account for most retail IT investment. Evidence of a significant relationship between

								IT investment intensity and productivity growth were found
Arvanitis (2003)	1998-2000	Switzerland	Unit level panel data	28 industries	Q1 - CDPF	ICT, organizational practices, human capital firm efficiency and performance	Accepted	All three variable blocks seem to be quite robust across several specifications
Black et al. (2004)	1993-1996	United States	1621 private establishments	Manufacturing sector	Q1 - GAM	workplace innovations, productivity and wages	Accepted	High performance workplace practices are associated with higher productivity and higher wages. A positive and significant relationship was found between non-managers using computers and productivity of establishments
Jorgenson (2005)	1948-2002	United States	Industry level panel data	Country level aggregated data	Q1- GAM	IT and multi-factor productivity (MFP) growth	Accepted	ICT capital appears to influence an acceleration of multi-factor productivity (MFP) growth
Indjikian et al. (2005)	-	Literature review	Literature review	Literature review	Q1 - CDPF	IT and economic performance	Accepted for developed world, did not conclude on developing countries	Developed world yielded evidence of a strong positive correlation among IT, economic performance & highly skilled or educated workers. Developing countries must address: lack of knowledge of "best practices" in IT usage and IT-related skill deficiencies in the workforce.
Hempell (2005)	1994-1999	Germany	Unit level panel data	Manufacturing sector	Q1 - System GMM	ICT, innovations and productivity	Accepted	Reveals significant productivity effects of ICT in service sector. Experience from past process innovations makes ICT capital more productive

Brynjolfsson et al. (2006)	1987-1994	United States	Unit level panel data	527 large manufacturing firms	Q1 - GAM	Computerization, productivity and output growth	Accepted	Computerization contributes to measured productivity and output growth in short term. For long term the impact of Computerization is five times in productivity & output
Joseph et al. (2007)	1998-2001	India	CSO level industry data	52 industries	Q1 - CDPF	ICT and manufacturing growth	Accepted	Some evidences were found that plants with higher levels of IT capital stock have higher gross value added.
Holt et al. (2009)	-	United States	-	-	Q2 - literature survey	Broadband and productivity	Not concluded	A positive economic impact from expanded broadband adoption was noted. However, various research challenges have prevented from drawing more definitive conclusions
Chandra (2009)	2007	India	Unit level panel data from a national survey	Manufacturing sector	Q2 - Survey findings	ICT adoption, skills, innovation and efficiency	Inconclusive	Some significant increases in IT use in particular areas of manufacturing, but overall IT adoption remains limited among the sample firms. The report also argues that management weaknesses contribute to lack of innovation, as well as inefficiencies in plant location and supply chains.
Han et al. (2011)	1987-1999	United States	Industry level panel data	Manufacturing sector	Q1 – CDPF	Interindustry IT spillover, IT investments and productivity of downstream industries	Accepted	Industries receive significant IT spillover benefits in terms of TFP growth through economic transactions with their respec tive supplier industries
Liu et al. (2011)	1991-1999	Taiwan	Unit level panel data	Industry, commerce	Q1-LP	IT, skills and productivity	Accepted	Skills compliments IT and both of them together promote pro-

				and service census				ductivity
Chang et al. (2012)	1987-1999	World wide	Unit level panel data	All (fortune 1000 firms)	Q1 - Probit Model, CDPF	IT outsourcing and productivity	Accepted	IT outsourcing leads to productivity gains for firms
Bloom et al. (2012)	2000-2003	United Kingdom and Europe	Unit level panel data	Manufacturing sector	Q1- GAM	Management practices management interaction, use of IT and productivity	Accepted for US multinationals not accepted for non US multinationals	US multinationals obtained higher productivity from IT than non-US multinationals. it is primarily due to tougher “people management” practices.
Sharma et al. (2013)	2003-2008	India	Unit level data (ASI)	Manufacturing sector	Q1 – LP	investment in IT and productivity	Accepted	Plants with higher levels of IT capital have higher gross value added, controlling for other inputs. Access to financial capital, electric power from the grid, and skilled workers all matter for the decision to invest in IT capital
Dedrick et al. (2013)	1994-2007	45 developed and developing countries	Industry level panel data	Country level data	Q1 - CDPF	IT investment and productivity for developing countries	Inconclusive	Productivity gets impacted by country factors, human resources, openness to foreign investment, and the quality and cost of the telecommunications infrastructure.
Shahiduzzaman et al. (2015)	1965-2013	Australia	Industry level panel data	Country level data	Q1 - ARDL Model	ICT and productivity for long-run perspective	Accepted	Provide strong confirmatory evidence of the long-run impact of ICT capital deepening on labour productivity
Wamboye et al.	1975-2010	43 sub-Saharan	Industry level panel data	Country level data	Q1 – GAM	ICTs and labour productivity	Accepted	Findings show significant increasing returns for labour pro-

(2016)		African countries.				growth		ductivity growth from fixed-telephone and mobile-cellular penetration
Liao et al. (2016)	1977-2005	United States	Industry level panel data	24 ICT using industries	Q1 – SF	ICT and productivity	Accepted with a condition	ICT investment does contribute to productivity but not in the usual manner – a positive (but lagged) ICT effect was found on technological progress
Tisdell (2017)	NA	Australia	Industry level panel data	NA	Q2 - Literature survey	ICT on economic productivity, welfare and social change	Accepted with condition	ICT has significantly added to GDP but these effects vary considerably between economies. The elasticity of aggregate production in relation to investment in ICT has risen with the passage of time.
Chung (2018)	1996-2005	Korea	Industry level panel data	Manufacturing sector	Q1 - DGEM	ICT investment intensity, ICT investment-specific technological change and productivity growth	Accepted	The result indicate that increased (decreased) ICT investment intensity with faster (slower) ICT investment-specific technological change lead to higher (lower) productivity growth
Edquist et al. (2017)	1993-2013	Sweden	Industry level panel data	50 industries across sectors	Q1 - CDPF	R&D, ICT and TFP	Accepted	R&D affect TFP much faster than ICT-investments.

Abbreviations: Q1: Quantitative Technique; Q2: Qualitative Technique; GAM: Growth Accounting Model; CDPM: Cobb Douglas Production Model; DGEM: Dynamic General Equilibrium Model; SF: Stochastic Frontier; LP: Levinson Petrin Technique; ARDL: Autoregressive Distributed Lag Model; PCA: Principal Component Analysis

Source: Created by Author

By employing Cobb-Douglas production function and by decomposing TFP into the contributions of non-ICT capital stock, ICT capital stock, and labor, Lee et al. (2003) argued that the contribution of ICT to growth in Asia during the 1990s is found to be mainly from capital deepening. Using firm level data, Gretton (2004) observed that significant interactions were found between firm characteristics (skill, improved business practices and business restructuring) and ICT use in raising productivity. Using unit level data employing for Finland, Maliranta (2004) observed the excess productivity of ICT-equipped labor ranges from 8% to 18%. The effect is often much higher in younger firms and in ICT-providing branches and – at least the immediate effect – can even be negative in older firms. Overall, the ICT-induced excess productivity seems to be somewhat higher in services than in manufacturing. Manufacturing firms benefit from ICT-induced efficiency in internal communication whereas service firms benefit form efficiency in external communication. He further noted that ICT and human capital are certainly correlated and quite likely also complementary. For Germany and Netherlands, Hempell et al (2004) in their study concluded that the contribution of ICT capital deepening is raised when firms associate ICT use and technological innovations on a more permanent basis. Spyros (2004) considered ICT specific variables such as intensity of use of internet and intranet as measured by the share of employees using these technologies in daily work along with variables to portray human capital (such as employee education, job associated trainings, computer focused trainings) and evaluated their interactions with productivity. They concluded their findings with mixed results. Positive outcomes were recorded for team-task, delegating production issues to specialized staff and contacting customers to resolve their issues. Negative results were observed for job rotation and overall delegation of skills from managerial staff to employees. Evidences for strong positive complementarity between ICT and human capital were also observed.

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For United States and by using unit level data, Doms et al. (2004) found the evidence of a significant relationship between IT investment intensity and productivity growth. Han et al. (2011) investigated the IT spillover effects on their respective supplier industries using industry panel data for United States. They found two characteristics of downstream industries, namely, IT intensity and competitiveness, which have been observed to moderate the effect of internal IT investments and play an important role in IT spillovers. They argued that these two characteristics moderate the effect of IT spillovers-industries that are more IT intensive and more competitive benefit from IT spillovers. Finally, they concluded that long-term effects of spillovers are greater than short-term effects, suggesting that learning periods are required to reap the benefits from the IT spillovers. Using the data of 1000 fortune firms and employing Cobb-Douglas function with Probit model, Young et al. (2012) argued that IT outsourcing does lead to productivity gains for firms that select this mode of service delivery. Their results suggested that IT-related knowledge held by IT services vendors enabled these productivity gains. Moreover, the value of outsourcing to a client firm increases with its propensity for outsourcing, which in turn depends on firm-specific characteristics such as efficiency level, financial leverage, and variability in business conditions. Dedrick et al. (2013) took the sample of developed and developing countries and argued that the productivity effects of IT are moderated by country factors, including human resources, openness to foreign investment, and the quality and cost of the telecommunications infrastructure. The policy implication is that lower-tier developing countries can also expect productivity gains from IT investments like the developed nations, particularly through policies that support IT use, such as greater openness to foreign investment, increased investment in education, and reduced telecommunications costs. More recently Herald et al. (2017) compared ICT induced productivity with the one that is promoted by R&D for Sweden by taking industry panel data. They concluded that R&D induced productivity is higher than the ICT induced one. They further debated that while computerization helps to automate the manual work to some extent, it is R&D that promotes the sustainable innovation and drives strategic growth.

Productivity effects of IT are moderated by country factors, including human resources, openness to foreign investment, and the quality and cost of the telecommunications infrastructure.

With respect to new quantitative techniques, Thomas (2004) used System GMM for German service sector firms and revealed significant productivity effects of ICT. Interestingly, ICT capital was found to be more productive when it is combined with the experience gained from past process innovations. Using Industry level panel data and applying ARDL approach, Shahiduzzaman et al. (2015) provided strong empirical results confirming the long-run impact of ICT capital deepening on labor productivity in Australia. Lio et al. (2006) used Stochastic frontier approach for industry level data and argued that ICT investment does contribute to productivity but not in the usual manner – they found a positive (but lagged) ICT effect on technological progress. They acknowledged that a learning period with complementary co-inventions needs to take place for ICT - capital to become effective and its gains to be realized. Chung (2018) used dynamic general equilibrium (DGE) model for Korean industry panel data and demonstrated that increased (decreased) ICT investment intensity with faster (slower) ICT investment-specific technological change leads to higher (lower) productivity growth.

A few interesting qualitative studies have been carried out to unveil the relationship of productivity, IT capital and skills. Charles (2002) acknowledged the importance of a skilled workforce in increasing the returns to investment in IT. Baldwin et al. (2002) carried out a qualitative survey by employing Canadian manufacturing firms and debated that firms that used either one or more ICT technologies had a higher level of labor productivity than the firms that did not. Holt et al. (2009) literature survey found a positive economic impact from expanded broadband deployment and adoption. However, various research challenges including methodological problems and access to sufficiently granular data have prevented the author from drawing more definitive conclusions from the US broadband experience. Most recently, Clem's (2017) literature survey found that as per most studies, ICT has significantly added to GDP and has been growth enhancing, however these effects differ considerably among economies. The elasticity of aggregate production in relation to investment in ICT has increased with the time. On the micro-economic level, it is evident that ICT can promote efficiency, increase consumers' surplus and producers' surplus by lowering market transaction costs.

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Combining quantitative and qualitative techniques, Zhen-Wei et. al (2004) took the sample of 12 developed and developing countries and argued that to strengthen IT investments and promote its usages, an institutional network needs to be created to encourage spillover effects and induce domestic demand. They stressed that local capacity and local needs have to be identified to promote IT uses.

Context in India

With respect to India, Joseph et al. (2007) used the data of 52 NIC 3-digit industries and found some evidence that plants with higher IT capital stock found to have higher gross value added. They argued that unobserved managerial quality played an important role to enhance the IT capital and that in turn promote productivity. They explored the impacts of skill composition, the use of imported intermediate inputs, ownership and organizational form on the productivity of IT capital and found some evidence that access to financial capital, electric power from the grid, and skilled workers all matter for the decision to invest in IT capital, but these variables are less important for the level of investment in IT, conditional on it being positive. Sharma et al. (2013) found some evidence that plants with higher levels of IT capital stock have higher gross value added, controlling for other inputs. However, this effect is weakened when plant-level fixed effects are included. One explanation of this result is that unobserved managerial quality plays an important role in the impact of IT capital on productivity. They also analyzed the impacts of skill composition, imported intermediate inputs, ownership and organizational form.

They found some evidence that access to financial capital, electric power from the grid, and skilled workers all matter for the decision to invest in IT capital.

Indian manufacturing is also found to have supply chain weaknesses, closely related to the inability to share information throughout the supply chain.

Chandra et al. (2002) carried out a nationwide survey on 1000 manufacturing firms to investigate three distinct aspects of manufacturing management that define the capabilities of the firm: strategies related to dynamic control of shop floors, network linkages and innovation. The study noted the lack of spending on R&D and small proportion of employees with advanced degrees. They also debated that Indian manufacturing firms give low priority to investments in IT, such as computer-aided manufacturing (CAM), computer-aided design (CAD), computer integrated manufacturing (CIM), and computer-aided engineering (CAE). It is also suggested that domestic IT firms do not have the right products for Indian manufacturing firms. Indian manufacturing is also found to have supply chain weaknesses, closely related to the inability to share information throughout the supply chain. The survey noted that only 13% of firms use a computer-based decision system for supply chain management, though the percentages are higher for enterprise resource planning (43%) and shop floor scheduling (37%). Only 23 percent of firms in this sample use the web for placing orders with suppliers, and 11% sell online to customers. The overall picture is grim for the IT usage in Indian manufacturing firms. Chandra (2009) carried out another nationwide survey by taking 10000 Indian manufacturing firms. He found some significant increases in IT use in particular areas of manufacturing, but overall IT adoption remains limited among the sample firms. The report also argues that management weaknesses contribute to lack of innovation, as well as inefficiencies in plant location and supply chains. He also summarized regional differences in IT adoption and noted: IT use is highest in the South, and lowest in the East, but also in Uttar Pradesh (in the North). Interestingly, IT use tends to be concentrated among managers, and to some extent supervisors, with less IT use by operators on the shop floor. To some extent, the pattern of IT use (or non-use) is symptomatic of under-investment in both physical and human capital, reflecting high financial costs as well as an unfriendly policy environment. What was most important to note is, Indian manufacturing firms were able to make strong profits in this period, despite their inefficiencies.

A Synthesis of Results

Majority of the studies written in the topic of IT, skills and productivity indicate that IT promotes productivity and skills plays a role of enabler. In other words, skilled IT workers help promote productivity. The findings are quite simi-

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lar in the context of India as well. While there are overwhelming number of studies that accept the nexus, there are a handful that take different positions in terms of either accepting the nexus with conditions or rejecting the hypothesis.

Our sample literature presents three conditions to accept the nexus. First, the time lag in establishing the IT infrastructure and skill building and then realizing their benefits in productivity. To elaborate further, IT needs skilled workers and sophisticated infrastructure and at the same time, it takes time to implement IT solutions to replace the manual processes. This is why it takes time to reap the benefits of IT and skills in terms of productivity.

Second, skilled workforce and people practices are major enablers to reap the benefit of IT. People practices play an important part in realizing the benefit of IT. The organizations or countries where skilled workers, management and relevant IT skills exist, they help to enable the benefits of IT and that in turn promote productivity.

Third, IT adoption maturity for an organization or a state plays an important role to boost productivity. Large organization or developed economies who yield evidence of a strong positive correlation among IT, economic performance and highly skilled or educated workers get an advantage here. To overcome this limitation and reap the similar benefits, smaller organization or developing countries must address: lack of knowledge of ‘‘best practices’’ in IT usage and IT-related skill deficiencies in the workforce.

There are handful studies which rejected the nexus. One key study (Kraemer et al., 2001) used relatively old data from 1985-95. While the study rejected the nexus, there are many authors who used similar data supported the nexus. Other studies that rejected the claim found the impact of IT and skills on productivity to be relatively small rather than showing no impact.

To conclude, by carrying out systematic literature review, it was found that in majority of cases, IT promotes productivity. Skills play a role of enabler in this nexus.

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