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How does information technology improve aggregate productivity? A new channel of productivity dispersion and reallocation

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ABSTRACT

Using U.S. firm-level data from 1971 to 2000, this paper quantifies the importance of production input reallocation in explaining the information technology (IT) driven productivity growth. We find that cross-industry variation in input reallocation explains more than 30% of differences in the 5-year productivity growth rates of industries utilizing similar levels of IT. Our findings illustrate a new channel through which IT affects the aggregate productive growth and are consistent with recent papers that emphasize the destructive nature of technology innovation and the importance of firm-level reallocation in explaining aggregate productivity growth. Our paper implies that policy makers should focus not only on implementing IT but also on instituting policies aimed at improving reallocation efficiency to maximize the effect of IT on the productivity growth.

1. Introduction

The impact of information technology (IT) on productivity growth has been widely studied during the last decades. Most studies focus on how IT adoption makes firms more productive (Brynjolfsson and Hitt, 1996, 2003; Bloom et al., 2012). However, recent empirical and theoretical researches (Hobijn and Jovanovic, 2001; Gârleanu et al., 2012a,b; Bartelsman, 2013; Kogan and Papanikolaou, 2013, 2014) emphasize the destructive nature of IT-driven innovation. For example, the advent of digital technology in the photography industry in the early 1990s increased the entry of new firms equipped with new technology. This new technology shifted the base of technological knowledge from chemical to digital, which challenged incumbents by destroying the value of their accumulated knowledge and skills in the old technologies (Benner, 2007), creating a performance gap between new entrants and old established firms. The performance gap necessitates the reallocation of inputs from failing firms toward more productive ones, which would enhance the aggregate-level productivity in the long-run. This implies that IT-driven aggregate productivity growth may be associated with the efficiency of input reallocation. Thus, if the efficiency of input reallocation is different across industries, IT-driven industry-level productivity growth would also exhibit a substantial cross-industry variation. However, there has been no empirical study which analyzes the role of reallocation efficiency on the productivity growth associated with IT.

In this paper, using U.S. firm-level data covered in Compustat from 1971 to 2000, we investigate a new mechanism on how IT affects aggregate-level productivity through the creative destruction process envisioned by Schumpeter (1912). We provide robust empirical evidence of the IT-driven productivity dispersion among firms, highlighting the destructive nature of IT, and the resulting resource reallocation from less productive firms to more productive ones. Furthermore, we show that the cross-industry variation in reallocation effect explains substantial differences in the 5-year productivity growth rates of industries with similar levels of IT. This finding supplements recent papers emphasizing the reallocation effect in explaining long-run productivity growth (Foster et al., 2001, 2006; Acemoglu et al., 2012; Kogan et al., 2012).

Information technology is an example of general purpose technology (GPT).[1] GPTs are introduced very infrequently but they have a significant impact on the productivity of an economy. When a GPT is introduced, at its propagation stage, it is adopted by firms at different rates across different firms (Bresnahan and Greenstein,

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[1] GPTs are technologies that change the ways in which firms conduct business. Examples include electricity, internal combustion, and most recently information technology (Bresnahan and Trajtenberg, 1995; Jovanovic and Rousseau, 2005).

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1996). This is because the new technology might not be compatible with incumbents' existing production lines or with old technologies embedded in old capital. As a result, GPTs are first adopted by new firms and the vintage of capital plays an important role in determining the overall productivity of firms. This also implies that the propagation of a GPT necessarily accompanies the destruction of incumbents (Hobijn and Jovanovic, 2001). Thus, while IT propagates, a performance gap might be observed between new and young firms and old established firms (Hobijn and Jovanovic, 2001). In addition, even among IT adopters, the impact of IT could be different across firms due to the unequal distribution of complementary assets such as management practices or the internal organization required to deploy IT successfully (Bresnahan et al., 2002). For example, some may apply IT successfully to important business tasks including enterprise resource management (ERP), customer relationship management (CRM), and enterprise content management (ECM), while others who lack the necessary complementary assets may not. For example, Bloom and Van Reenen (2011) and Bloom et al. (2012) emphasize that management practices play an important role in explaining the different productivity effects of IT investment for U.S. and European firms.

Consistent with these studies, we find that the average productivity growth rates of top and bottom terciles of U.S. firms are 22% and −23%, respectively, during our sample period and that the gap is higher in IT intensive industries after controlling for other industry characteristics.[2,3] The results are robust to the correction of the possible endogeneity problem using 2SLS and alternative methodologies of calculating productivity.

Differing productivity growths among firms would change the marginal productivity of inputs. Firms whose productivity increases would have higher marginal productivity of inputs, whereas firms whose productivity decreases would have lower marginal productivity of inputs. In this case, the profit maximization principle implies that more productive firms should increase inputs while less productive firms should reduce inputs.[4] This implies that if the reallocation process is more active in one industry than in another, we should expect a higher long-run growth effect of IT in the former even though the IT intensity is similar for the two industries. For example, when workers are released from failing firms, more active input markets would minimize the job-search period for workers and allocate them to the firms with highest productivity. We propose measures that capture the degree of resource reallocation in each industry and test whether the 5-year growth effect of IT is stronger in industries with more active input reallocation. We find that the reallocation effect explains more than 30% of differences in the 5-year productivity growth of industries utilizing similar levels of IT. The results are robust to an alternative reallocation measure, the correction of the possible endogeneity problem using 2SLS, and differing methodologies of calculating productivity.

This study provides a new channel to explore why industries with higher IT intensity would exhibit higher long-run productivity growths. The well-known view is that each firm may become more productive overtime (*within-firm* effect) through the efficient use of IT which requires an initial learning period, thereby increasing the average productivity of firms in the long-run. For example, Brynjolfsson and Hitt (1996, 2003) emphasize that the contribution of IT to productivity is jointly determined by the computerization itself and a complementary organizational investment that allows the efficient use of IT. According to them, even after investing in IT, it takes time for a firm to prepare an IT-friendly organizational structure. Eventually, the firm's productivity increases as IT improves timeliness, inventory control, and relationships with customers and suppliers. Our paper provides an additional channel: aggregate productivity growth could further increase *via* resource reallocation from unsuccessful adopters of IT to more productive ones (*between-firm* effect). The effect of the second channel would be larger in countries or in industries with better reallocation mechanisms such as more efficient input (labor and capital) markets. Even though most IT productivity studies have focused on the first channel, the economic importance of the second channel should not be overlooked. For example, the recent macroeconomic literature highlights the importance of resource reallocation in explaining aggregate productivity growth in the U.S. and other countries (Foster et al., 2001; Bartelsman et al., 2009). Hsieh and Klenow (2009) show that aggregate manufacturing total factor productivity (TFP) growth would increase approximately 40% in China and about 50% in India if reallocations in China and India were as efficient as that in the U.S.

Chari et al. (2008) emphasize that despite accumulating evidence suggesting a positive impact of IT on productivity, one still needs to understand why and how IT affects firm- and aggregate-level productivity. We hope that our paper constitutes a step forward in this direction. Our results also provide insights into the differing effects of IT on productivity growths across countries. The higher U.S. productivity growth of the 1990s, after stagnant productivity growth in the 1970s and 1980s, is attributed primarily to IT investments (Oliner and Sichel, 2000; Stiroh, 2002). However, the IT-driven productivity miracle is not observed in European countries (Colecchia and Schreyer, 2002; Basu et al., 2003; Timmer and Van Ark, 2005). Differences in available complementary assets and organizational changes between U.S. and European firms may be factors in this phenomenon.[5] Our results show that differing reallocation efficiency can be another relevant factor. In agreement with our results, Dewan and Kraemer (2000) find a differing effect of IT on productivity between developed and developing countries. In light of our results, their findings may reflect the fact that developed countries tend to have better functioning markets than undeveloped ones, including developed financial markets and less regulated input markets, thus prompting more active reallocation.

This paper is structured as follows. Section 2 provides a literature review and discusses the hypotheses. Sections 3 and 4 explain the variable construction and empirical methodology, respectively. Sections 5 and 6 report the empirical results and robustness checks, respectively. Section 7 concludes with possible policy implications.

2. Theoretical backgrounds and hypotheses

In Section 2.1, we review recent papers on the theoretical underpinning for technology-driven productivity dispersion among firms and build our first hypothesis. In Section 2.2, we review recent papers on reallocation among firms in general and the

[2] If IT increases the productivity dispersion among firms especially at its propagation stage, rather than increasing the productivity of all firms, it would be difficult to have a short-run aggregate productivity growth effect from IT investment. In the early 1990s, researchers were puzzled by the low productivity gains observed, despite large investments in IT, which is known as the IT paradox (Brynjolfsson, 1993; Brynjolfsson and Hitt, 1996, 2003). The more strongly observed IT growth effect since then is known as the IT miracle.

[3] Section 3.4 discusses possible alternative determinants of the productivity growth dispersion.

[4] It is possible that more productive firms would hire fewer workers due to higher productivity. This would be especially so if the nature of the technology innovation is labor-saving. However, we find that firms with higher productivity growth hire more workers during our sample period. Using a different measure of technology innovation, Kogan et al. (2012) also find that more innovative firms in the U.S. hire more workers. See Section 2 for more discussion of this issue.

[5] Consistent with this, Basant et al. (2011) find general infrastructure to be a key complementary input for the efficient use of IT in developing countries.

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