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Do R & D and ICT affect total factor productivity growth differently?

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ABSTRACT

We analyze the effect of ICT and R & D on total factor productivity (TFP) growth across different industries in Sweden. R & D alone is significantly associated with contemporaneous TFP growth, thus exhibiting indirect effects. Although there is no significant short-run association between ICT and TFP, we find a positive association with a lag of seven to eight years. Thus, R & D affect TFP much faster than ICT-investments. We also divide ICT capital into hardware and software capital. To our knowledge, this distinction has not been made in any previous study analyzing TFP at the industry level. The results show that lagged hardware capital services growth is significantly associated with TFP growth. Hence, investments complementary to hardware are needed to reap the long-run TFP effects from reorganizing production.

1. Introduction

We are currently experiencing a technological breakthrough in ICT affecting virtually all aspects of our lives including what is produced, how and where it is produced, how production is organized, what skills are required, the enabling infrastructure and the regulations required to sustain or even allow the ongoing transformation (Miller & Atkinson, 2014). Over the last decades, the ICT revolution has brought innovations such as personal computers, mobile phones and the Internet. These innovations have resulted in large productivity gains in many countries. Many observers believe that ICT will continue to drive productivity growth as new innovations such as the “Internet of things” (IoT) start evolving.¹ However, it is likely that large investments in ICT and R & D are required in order to realize the productivity potential of new innovations (OECD, 2003). It is therefore crucial to understand how investments in ICT and R & D affect productivity growth.

Investments in ICT and R & D have arguably been important engines of growth throughout the world. Economists have used models derived from production theory to estimate the impact of ICT and R & D. For example, Jorgenson, Ho, and Stiroh (2008) used growth accounting to capture the direct effects from the accumulation of ICT capital. They found that ICT capital investments accounted for 37% of labor productivity growth in the U.S. in 1995–2000.² R & D has also been identified as an important contributor to growth (Griliches, 1991). In general, the output elasticities vary between 0.10 and 0.20 in econometric estimates of cross-sectional data (McMorrow & Röger, 2009).

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¹ The “Internet of things” (IoT) can be defined as: “A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies” (ITU, 2012, p. 1).

² Jorgenson et al. (2008) also found that ICT-producing industries contributed 58% of TFP growth.

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In addition to the direct effects there may also be indirect effects. These effects are the impact on value added and productivity growth in excess of the direct effects via capital accumulation. This would be an indication that ICT and R & D are also affecting productivity through more efficient organization of production and increased product quality. In this view, ICT has computerized businesses and the economy as a whole leading to increased productivity in ICT-using and -producing sectors (Cardona, Kretschmer, & Storbel, 2013). Thus, the returns on ICT and R & D investments cannot be fully internalized by the investors (van Ark, 2014). One way of investigating if there exist indirect effects would be by testing whether investments in ICT and R & D are correlated with total factor productivity (TFP). Thus, an industry investing more in ICT would also have higher TFP growth, which would indicate more efficient organization of production.

The purpose of this study is to investigate the indirect effects of ICT and R & D capital on TFP based on Swedish industry data. Sweden is one of the countries investing the most in ICT and R & D (OECD, 2015). In a previous study we found large direct effects of ICT and R & D on value added in the Swedish business sector (Edquist & Henrekson, 2015). Given the high rates of aggregate ICT and R & D investment in Sweden it is of particular interest to explore whether such investments also are associated with high indirect effects. Draca, Sadun, and Van Reenen (2007) argue that indirect effects might apply to specific forms of ICT rather than ICT in general. We therefore make a distinction between indirect effects from hardware and software. To our knowledge, this has not been done in any previous study, primarily due to data limitations.³ The following three questions will be addressed:

- Is there any evidence of indirect effects from ICT and R & D based on Swedish industry-level data?
- Are there any differences in how ICT and R & D affect TFP growth at the industry level?
- Do investments in hardware and software affect TFP growth differently?

We find that only R & D is positively associated with contemporaneous TFP growth, thus industries investing in R & D exhibit effects on productivity through more efficient organization of production and higher product quality in the short run. This suggests that at the industry level only investments in R & D results in additional productivity gains beyond capital accumulation.

When we use longer time periods, as suggested by Brynjolfsson and Hitt (2003), we still do not find any positive association between ICT and TFP. However, when we divide our sample into two periods and regress lagged growth in ICT capital services on current TFP growth we find a significant association. Average ICT capital growth in 1993–2003 is positively associated with average TFP growth in 2004–2013. The lagged ICT coefficient is positive and significant at the ten percent level, whereas the lagged R & D coefficient is insignificant.

Based on panel data with smoothed five-year moving averages we find that the ICT coefficient becomes increasingly positive and significant after seven years. A further disaggregation shows that the lagged positive effect on TFP emanates from hardware rather than software investments. This suggests that hardware investments require complementary investments to reap the full productivity effects from a reorganization of production. Thus, the productivity effects from new innovations such as IoT will by no means be instantaneous and require complementary investments. These findings also suggest that even if firms replace or update their current hardware with newer and more powerful versions, this cannot substitute for the need to continuously reorganize production around the new technology.

The paper is organized as follows. In Section 2 we review the existing research on productivity effects from R & D and ICT. In Section 3 we present the methodological framework and in Section 4 we describe the data. In Section 5 we present our results and their robustness are discussed in Section 6. Section 7 concludes.

2. Related literature

2.1. Understanding the differences between R & D and ICT

OECD (2009a, p. 90) defines ICT as products “intended to fulfil or enable the function of information processing and communications by electronic means, including transmission and display”. According to the Frascati Manual (OECD, 2002, p. 30), R & D is defined as “creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.”

ICT primarily consists of combinations of hardware and software, while R & D is made up of time spent by employees in order to increase the stock of knowledge available to the firm. Arrow (1962) argues that R & D is distinct from the traditional factors of production, labor and physical capital, in that the value of R & D spending is more uncertain. Moreover, knowledge generated from R & D are non-excludable unless the new knowledge can be totally protected by patents (Eberhardt et al. 2013), and the knowledge is neither rivalrous nor exhaustible.

ICT is considered a general purpose technology (GPT), characterized by pervasiveness, inherent potential for technical improvements and innovational complementarities (Bresnahan & Trajtenberg, 1995). Moreover, the effects from GPTs on productivity are often delayed since many GPTs require organizational restructuring to reach their full potential (David, 1990; Helpman, 1998). R & D is a means by which new technologies are developed. Although R & D is not a GPT, many of the results from R & D are characterized by general purposeness. There is also a link between R & D and ICT; R & D is necessary to develop new ICT products. For example, the ICT-producing industry in Swedish manufacturing invested the most in R & D in 2013. R & D can thus be

³ Statistics Sweden began to publish hardware and software investment separately for specific industries in 2014.

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