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Empirical paper

Is innovation the key to solving the productivity paradox?

*Tomasz Kijek**, *Arkadiusz Kijek*

Maria Curie Sklodowska University, Faculty of Economics, Plac Marii Curie-Skłodowskiej 5, 20-031 Lublin, Poland

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ABSTRACT

The productivity paradox has sparked a great deal of research during the past three decades. Unfortunately, neither the results of empirical research nor the theoretical explanations for the paradox provide a convincing answer to whether investments in information and communication technology (ICT) affect the productivity of firms, sectors, and economies. This study aims to solve the productivity paradox by analysing the moderating effect of technological innovations on the link between ICT and productivity. The sample covers 2960 Polish innovative manufacturing firms. The research uses Generalized Structural Equation Model (GSEM). The findings clarify the productivity paradox and show that process innovations exert a moderating effect on the link between ICT and labour productivity in the sample firms.

Introduction

According to Porter and Millar (1985), investments in information and communication technology (ICT) are a source of competitive advantage. They argue that firms benefit from using ICT. On the one hand, ICT theoretically allows companies to perform activities in a faster, more accurate, and more flexible manner. On the other hand, ICT not only affects the way operational processes are performed, but also helps to improve the design of products to enhance their production. As such, many authors assume that ICT together with other investments including acquisition of machinery and training activities have a significant effect on a firm's productivity (Skorupinska & Torrent-Sellens, 2014).

In spite of the above-mentioned arguments, the positive link between ICT and productivity is not very clear. Solow (1987) refers to the lack of consensus among economists on the advantages of using ICT as the productivity paradox, which may occur at the micro level for different reasons. Firstly, firms may use ICT for purposes that do not target productivity growth directly. Secondly, some outlays on ICT are replacement investments that simply substitute an

* Corresponding author.
E-mail address: tomasz.kijek@poczta.umcs.lublin.pl (T. Kijek).
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existing technology by a new up-to-date solution without fundamentally changing the nature of products and production processes. In the latter case, the key issue is to separate innovation-related ICT, which can affect productivity, from non-innovative ICT, which has no productivity effects. Although innovation seems to be the missing link between ICT and productivity, few empirical and theoretical studies focus on this issue (Hagén, Glantz, & Nilsson, 2008; Hall, Lotti, & Mairesse, 2013). In fact, most existing studies on the productivity paradox use a traditional approach, which treats ICT as one of many inputs in the production function. By doing so, they reduce the mechanism linking ICT with productivity to the causal chain that runs from the ICT use to productivity.

Going beyond the previous research in the field of productivity effects of ICT investments, this study applies a modified version of the well-known model of R&D, innovation, and productivity, called the CDM model (Crépon, Duguet, & Mairesse, 1998). These analyses offer an alternative solution to the productivity paradox by measuring the effect of ICT on productivity directly and indirectly. In the first case, ICTs in parallel with product and process innovations are inputs in a productivity equation. In the second case, ICT with other innovation-related investments enter into a new product and new process implementation equation as exogenous variables. This modification of the model's specification and structure leads to difficulties in estimation; therefore, the study uses a generalized structural equation model (GSEM) with a full-information maximum likelihood estimator. This technique enables the estimation of the entire model as one system, controlling for variables affecting productivity performance such as firm size, technological opportunities, and export orientation (Bartelsman & Doms, 2000). The research employs a large sample of Polish manufacturing firms in the 2010–2012 period, extracted from the "Community Innovation Survey."

The next section provides the review of the literature on the productivity paradox and the use of ICT to introduce new products and processes, which may lead to higher productivity in firms. The following sections encompass a presentation of the model, data, and the results, followed by the conclusion and suggestions for further research.

Literature review and hypotheses

Productivity paradox: the macro and micro perspective

The Solow Paradox, concerning the limited evidence of ICT's positive effect on productivity, has been the subject of many studies. Solow's aphorism: "You can see the computer age everywhere but in the productivity statistics" (Solow, 1987) is still interesting, since it revolves around an unresolved economic question. The most comprehensive exploration of the productivity paradox at the macro level is the study by Oliner and Sichel (1994). They used the growth-accounting equation, which assumes that the rate of output growth equals the share-weighted growth in inputs plus the rate of growth of multifactor productivity. An estimation of the equation shows that even rapid rates of computing equipment/IT capital (i.e., information equipment and software) growth make relatively small contributions to growth when the share of this equipment is small. It is worth noting that the fall in IT capital prices should lead to a surge in investments in information technology and equipment. Jorgenson (2003) reports this situation and finds that the acceleration in the IT price decline in 1995 triggered a burst of IT investments and a rise in productivity growth in the IT-producing industries in all of the G7 countries. In line with these results, Dewan and Kraemer (2000) conclude that the productivity paradox is absent from developed countries but does exist in developing countries. The relatively small share of computers and information-processing technologies in Gross Domestic Product (GDP) is not the only possible explanation for the productivity paradox. Triplett (1999) presents an additional review of the conceptual issues in explaining the paradox. He stresses that measuring ICT and its effect on productivity correctly at the aggregate level is not a trivial task.

Taking into account the aforementioned issues in explaining the productivity paradox at macro level, firm-level analysis may allow overcoming some of these limitations. According to Pilat (2004), firm-level data can help to understand why outlays on ICT may not necessarily result in greater productivity, since it can point to factors/variables affecting the effects of ICT that cannot be directly measured at the aggregate level (e.g. innovation, firm size, the availability of skills, etc.). Furthermore, firm-level data gives the possibility of examining industry effects that may also affect ICT's influence. Ignoring the firm and industry-specific variables affecting productivity may bias the analysis and overestimate or underestimate the effect of ICT on productivity. Finally, firm-level data allows researchers to measure ICT with alternative proxies. Regarding empirical analyses, ICT expenditure is a desirable measure because it correlates with the ICT capital stock but is easier to use.

Table 1 presents the results of selected early and recent firm-level studies on ICT and productivity. Most of the early studies, which are comprehensively summarized by Brynjolfsson and Yang (1996), find either no effect or a negative effect of ICT on productivity. For example, a study by Yosri (1992), examining the relationship between ICT investments and revenue-contributing factors in 31 food firms in the period of 1987–1990, shows no significant correlation between IT expenditures and productivity. On the other hand, Loveman (1994), using a microeconomic production function to estimate the effect of IT on productivity, finds that the output elasticity of IT is negative. In turn, recent studies provide evidence that ICT can have a positive effect on a firm's productivity performance. As Stare, Jaklič, and Kotnik (2006), Arvanitis and Loukis (2009), and others show, ICT use has a positive effect on productivity. However, this effect may depend on a successive stage of ICT use sophistication (Miyazaki, Idota, & Miyoshi, 2012).

Comparing the results of early studies with the outcomes of recent works on ICT effects at firm level, the former usually draw on relatively small samples of firms, using non-official sources. This situation may result in non-representative samples and poor quality data. Moreover, early studies focus mainly on a direct relationship between ICT and productivity, neglecting an indirect ICT effect. Conversely, recent studies use large samples, which imply a greater quality and robustness of the data. Recent research has also advanced on

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