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ICT capital and labour productivity growth: A non-parametric analysis of 14 OECD countries

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ABSTRACT

This paper uses a new set of country data for 14 countries, members of the OECD, and a non-parametric approach to provide new evidence on the impact of Information and Communication Technology (ICT) on labour productivity growth between 1995 and 2005. For the first time, in the present paper a bootstrap approach for the decomposition of labour productivity change, proposed by Kumar and Russell (2002), is employed. This approach permits to conduct statistical inference on the parameters of interest, and to analyse the effects of ICT technologies on capital accumulation. The results confirm the role of ICT as a general purpose technology that needs organisational and business process changes to fully exploit its growth opportunities. The paper also finds out, by applying a non-parametric test, that ICT technologies positively contribute to the generation of convergence clubs in the evolution of labour productivity. Finally, the empirical evidence offers some basic guidance for future policy intervention in supporting ICT capital investments.

1. Introduction

Since the mid-1990s, the rapid growth of output and labour productivity across countries has largely been driven by advances in Information and Communication Technology (ICT) (Jorgenson, 2001; Lam & Shiu, 2010; Venturini, 2009; Vu, 2011). In particular, numerous studies have shown that ICT investments boosted the economy of the United States (USA) (Jorgenson, 2001; Jorgenson & Stiroh, 2000; Jorgenson, Ho & Stiroh, 2005, 2008; Oliner & Sichel, 2002; Stiroh, 2002) and some economies of the European Union (EU) (Colecchia & Schreyer, 2002; Daveri, 2002; Jalava & Pohjola, 2007; van Ark, Inklaar & McGuckin, 2003).

One aspect of ICT investment relates to Solow's well-known paradox (Solow, 1987): "You can see the computer age everywhere but in the productivity statistics". In other words, given the nature of general purpose technology (GPT), returns to ICT are not possible without investments in complementary assets (tangible and intangible). Consequently, these returns will only become fully manifest in the long-term (Basu & Fernald, 2007; Basu, Fernald, Oulton & Srinivasan, 2004; O'Mahony & Vecchi, 2005). Previous analyses, both at the industry and macroeconomic levels, have attempted to measure the impact of ICT on growth through standard growth accounting or growth regression techniques (Bosworth & Collins, 2003; Jorgenson, 2005). The former cannot fully incorporate the effect of ICT because the share of growth due to technological progress (Solow residual) is erroneously attributed to the growth of capital (Barro & Sala-i-Martin, 1995). In contrast, the latter techniques do not assume that the returns of capital accumulation have a direct impact on growth.

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Thus, they are more appropriate to measure the role of ICT on growth and its nature of GPT (David, 1990). However, the growth-accounting approach is heavily model driven, relying on particular assumptions about the technology, market structure, technological change, and other aspects of the growth process. In contrast, Kumar and Russell (2002) employed non-parametric techniques based on Data Envelopment Analysis (DEA) to analyse international macroeconomic convergence. In particular, they decomposed the labour productivity growth components attributable to (i) technological change (shifts in the world production frontier), (ii) technological catching-up (movements toward or away from the frontier), and (iii) capital accumulation (movement along the frontier). These methods offer several potential advantages over regression techniques: they do not specify a functional form for the technology, assume that technological change is neutral, or make assumptions about market structure or the absence of market imperfections. This paper studies, for the first time according to the authors' knowledge, the effects of ICT capital on labour productivity change using DEA techniques. It is well-known that DEA models, which can account for ICT capital as a separate input, can measure the impact of this input on total factor productivity (*TFP*) change. However, unlike regression models, non-parametric techniques cannot quantify the contribution of ICT capital to TFP shifts. To overcome this drawback, this study followed a strategy like that used by Maffezzoli (2006) to measure the impact of the introduction of an additional variable. Accordingly, two DEA models were employed. In the first model, the aggregate measure of capital stock was used, and in the second model, ICT capital was disembodied from non-ICT capital. To compare the two models, the analysis tried to summarise the effect of ICT capital on growth. Finally, in the spirit of Quah's (1993, 1996, 1997) studies, this paper assessed the effects of ICT capital on the convergence process.

The remainder of this paper is organised as follows. Section 2 discusses the methodology. Section 3 describes the data. Section 4 reports the empirical findings, and Section 5 provides conclusions and policy implications based on those findings.

2. DEA, bootstrap, and convergence analysis

2.1. DEA and the decomposition of labour productivity change

This study used an approach based on DEA to analyse the impact of ICT capital on labour productivity change and its components (Charnes, Cooper & Rhodes, 1978). This non-parametric technique is data driven and allows to draw a piecewise linear production function from a sample of input–output observations. Unlike parametric methods, it relies on identifying best practice reference units without imposing any particular constraint on the form of the production function. This study did not employ the traditional growth account methodologies (Barro & Sala-i-Martin, 1995) because, even if the hypothesis of Hick's neutrality technology should be satisfied, they cannot decompose *TFP* growth at country level into changes due to technological progress, which should be common to all countries, and catching-up in terms of relative efficiency (Maffezzoli, 2006).

An exhaustive description of DEA can be found in Färe, Grosskopf and Lovell (1995), and recent applications of this non-parametric technique in the cross-country growth and convergence literature are Fare, Grosskopf, Norris and Zhang (1994) and Kumar and Russell (2002).

Let $f_t(k_{it};l_{it})$ be the aggregate production function of country i at time t, where k_{it} and l_{it} represent the capital and labour employed, respectively. Then, assuming the existence of a common technology, the dissimilarities in the observed productive levels among countries can be attributed to differences in technical efficiency. Formally:

$$y_{it} = \theta_{it} \times f_t(k_{it},l_{it}) \quad i=1,2,\ldots,n; \quad t=1,.2,\ldots,T \tag{1}$$

where y_{it}, is the output produced, and $\theta_{it} \in [0, 1]$ is the Farrell (output-oriented) efficiency index for country i at time t. DEA allows to jointly estimate θ_{it} and f_t. The Farrell efficiency index is defined by

$$\theta_{it} = \min_{\theta}\{\theta \ \left|[y_{it}/\theta,\ k_{it},\ l_{it}] \in \Omega_t\right.\} \quad i=1,2,\ldots,n; \quad t=1,.2,\ldots,T \tag{2}$$

where

$$\Omega_t \equiv \left\{[y,l,k] \in \Re^3_+ \left| y \le \sum_{i=1}^{n} \lambda_i y_{it}, l \ge \sum_{i=1}^{n} \lambda_i l_{it}, k \ge \sum_{i=1}^{n} \lambda_i k_{it}, \lambda_i \ge 0; \forall\ i=1,\ldots,n \right.\right\} \tag{3}$$

is the constant return to scale technology set (Farrel cone)[1] for the world at time t. Each observation defined in the technology set can be interpreted as a unit operation of a linear process, λ_i. Consequently, every point in the technology set is a linear combination of an observed data point or a point dominated by such a linear combination. The constructed technology is therefore a polyhedral cone, with piecewise linear isoquant (Kumar & Russell, 2002).

The Farrel efficiency index can be calculated by solving the following linear program for each country:

$$\max_{\{\theta,\lambda_1,\ldots,\lambda_n\}} \theta^{-1}$$

[1] Non increasing returns to scale technology (*NIRS*) can be obtained by adding the condition $\sum_{i=1}^{n} \lambda_i \le 1$, and variable returns to scale technology (*VRS*) are constructed by imposing $\sum_{i=1}^{n} \lambda_i = 1$.