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ICT-specific technological change and productivity growth in the US: 1980–2004

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ABSTRACT

This paper studies the impact of information and communication technologies (ICT) on US economic growth using a dynamic general equilibrium approach. A production function with six different capital inputs is used, three of them corresponding to ICT assets and the other three to non-ICT assets. The technological change embedded in hardware equipment is found to be the main leading non-neutral force in US productivity growth, accounting for about one quarter of total growth during the period 1980–2004. As a whole, ICT-specific technological change accounts for about 35% of total growth in labor productivity.

1. Introduction

The US experienced robust acceleration in its productivity growth rate during the 1990s a period in which major investment in information and communications technologies (ICT) occurred. Jorgenson and Stiroh (2000) and Jorgenson (2001), among others, relate the increase in US productivity growth since the mid 1990s to the rate of growth of investment in ICTs and to the rise in total factor productivity (TFP) growth, mainly in the ICT-goods production sector. Oliner and Sichel (2000) and Baily and Lawrence (2001) extend these positive effects to the non-ICT production sector of the US economy.

However, in spite of the general view that ICTs entail a new technological revolution, the measured impact of ICTs on aggregate productivity has been very limited so far and the effects of these forces take a long time to become visible in macro-economic aggregates. In this regard, the statement by Robert Solow is probably one of the most categorical: "You can see the computer age everywhere these days, except in the productivity statistics" (New York Times Book Review, July 12th, 1987). Even for the successful cases, some papers find that the positive impact of ICTs on growth is not as straightforward as expected; there are a number of necessary conditions for it to hold. For instance, according to Hornstein and Krusell (1996), an increase in technological change can produce a temporary productivity slowdown given that average knowledge goes down, because relatively more resources are allocated to the new capital (see also Greenwood and Yorukoglu, 1997, and Yorukoglu, 1998). Other papers emphasize that

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the answer might be related to new forms of organization at plant level, changes which are required to obtain the full benefits from ICTs (Samaniego, 2006). In fact, equivalent historical episodes have already taken place in other economies (see Kiley, 2001, for a survey). In general, many of these episodes present the adoption of ICTs as a technological revolution with substantial short-run negative effects until new equipment is completely adapted. The transitional dynamics from changes in technological progress lead to a slowdown in capital accumulation and thus in productivity during the transition period. Within this line of research, Pakko (2002a,b) uses a model with stochastic growth trends to show that changes in the growth rate of technological progress may affect productivity not contemporaneously but with a lag.

In the relevant literature we find two different approaches to studying the effects of technological change on output and productivity growth. The first and more widely used of the two is traditional growth accounting, in which output or productivity growth is decomposed in terms of share-weighted growth in inputs. Examples of this approach include Jorgenson and Stiroh (2000), Oliner and Sichel (2000), Daveri (2002), Colecchia and Schreyer (2002), Jalava and Pohjola (2002) and Timmer and van Ark (2005), among others. The other approach uses dynamic general equilibrium models to quantify the contribution to growth of specific technological change. As pointed out by Cummins and Violante (2002), one disadvantage of traditional growth accounting is that it does not isolate the underlying sources of capital accumulation.

This paper studies the impact of ICTs on US productivity growth using a computable dynamic general equilibrium model. Papers by Greenwood et al. (1997, 2000), Kiley (2001), Pakko (2005) are all calibrated for the US economy; Carlaw and Kosempel (2004) for the Canadian economy; Bakhshi and Larsen (2005) for the UK economy and Martínez et al. (2008) for the Spanish economy, provide examples of this methodology applied to technological changes. Greenwood et al. (1997) obtain for the period 1954–1990 that neutral technological change accounts for 42% of total productivity growth, while the remaining 58% can be attributed to specific technological change. Using a similar analysis for the UK economy, Bakhshi and Larsen (2005) find that specific technological change accounts for around 20–30% of total labor productivity growth for 1976–1998. Both these papers consider that capital is disaggregated into ICT and non-ICT assets, where specific technological progress is motivated solely by ICT capital. Finally, in analyzing the slowdown in Spanish productivity in 1995–2004 via an extension of the framework of Greenwood et al. (1997), Martínez et al. (2008) find that despite rapid growth in ICT investment-specific technology growth in those assets provides little support for overall output growth in Spain. When the dynamics of productivity are decomposed into implicit and neutral technological progress, the former exerts a positive impact while the latter has a clear negative dominant effect. Behind the small contribution of implicit technological change, they find a modest negative impact coming from traditional capital inputs, while communications and mainly hardware equipment appear as significant growth-enhancing assets.

The present paper extends the work for the US economy of Greenwood et al. (1997) who decompose productivity along the balanced growth path of the economy into investment-specific technological change and neutral technological progress. They distinguish between two types of capital: equipment and structures, where specific technological progress is associated only with equipment. On this basis, a more disaggregated production function is used, with six capital assets: three of them ICT assets (hardware, software and communications equipment) and the other three non-ICT assets (constructions and structures, machinery and transport equipment). Moreover, we consider the existence of investment-specific technological progress in all capital assets. Labor productivity growth is therefore split into seven factors: neutral technological change plus six specific or embodied technological changes. These extensions are crucial because they provide a more appropriate measure of the sources of productivity growth. This allows the contributions to growth of ICT and non-ICT capital assets to be compared.

On the basis of model calibration over the period 1980–2004, our main results show that ICT-specific technological change accounts for about 36% of total productivity growth, whereas non-ICT-specific technological change accounts for only 7%. These results imply that 57% of total labor productivity growth can be attributed to neutral technological change, while 43% (i.e. 36% + 7%) can be attributed to specific technological change, mostly due to technological change embedded in hardware equipment. When the sample is split into two subperiods, 1980–1995 and 1995–2004, ICT's contribution to productivity growth is found to increase, while the non-ICT contribution decreases. These results support the view of the increasing importance of ICT as a leading force in US productivity growth in recent years. We also find that the contribution of TFP is larger in the second subperiod. The discrepancies between our findings and those of Greenwood et al. (1997) thus mainly reflect differences in the sample period. Using a more disaggregated portfolio than the one that they propose (which decomposes capital into structures and equipment), we check whether our results are due to this particular portfolio, and find that they are fairly robust to disaggregation.

The rest of the paper is organized as follows. Section 2 presents the theoretical model and characterizes the balanced growth path. Section 3 shows the calibration exercise. Section 4 presents the results. Section 5 provides additional evidence using different levels of aggregation of capital assets. We find that our results are robust regardless of the level and quality of aggregation, in terms of both calibrated productivity growth and the contribution to productivity growth of each capital asset. Section 6 concludes.

2. The model

Following Greenwood et al. (1997) this paper uses a neoclassical growth model in which two key elements are present: the existence of different types of capital and the presence of technological change specific to the