Working papers series

WP ECON 07.01

The Productivity Paradox and the New Economy: The Spanish Case

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JEL Classification Numbers: O30, O40, E22.
Keywords: Information and Communication Technologies, productivity, New Economy, Technological Change, Productivity Paradox.

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Abstract: This paper studies the impact of the information and communication technologies (ICT) on economic growth in Spain using a dynamic general equilibrium approach. Contrary to previous works, we use a production function with six different capital inputs, three of them corresponding to ICT assets. Calibration of the model suggests that the contribution of ICT to Spanish productivity growth is very relevant, whereas the contribution of non-ICT capital has been even negative. Additionally, over the sample period 1995-2002, we find a negative TFP and productivity growth. These results together aim at the hypothesis that the Spanish economy could be placed within the productivity paradox.

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Acknowledgments: We thank an anonymous referee for insightful comments. An earlier version of this paper has benefited from comments by Salvador Barrios, Gonzalo Fernández de Córdoba, Matilde Mas, Ana Moro, Javier Pérez and Javier Quesada. The authors thank Fundación Centro de Estudios Andaluces for financial support through grants ECOD1.07/085 and 1.05/025. Diego Martínez and Jesús Rodríguez acknowledge financial support from the Spanish Ministry of Science and Technology through grant SEC2006-04803/ECO. Corresponding author: José L. Torres, Dpto. de Teoría e Historia Económica, Universidad de Málaga, Campus de El Ejido 29071 Málaga (Spain). E-mail: jtorres@uma.es.

1 Introduction

An easy beginning for this paper could highlight the impact of information and communications technologies (ICT) on economic growth. Indeed, the U.S. has experienced a robust acceleration in its productivity growth rate during the 1990s, compared to that of E.U. This episode has taken place in a context in which the U.S. investment in ICT has been much higher than that of the E.U. Particularly, Jorgenson and Stiroh (2000) and Jorgenson (2001) have related the increase in the U.S. productivity growth since the mid-1990s to the growth rate of investment in ICT and the rise in total factor productivity (TFP) growth, mainly in IT production. Oliner and Sichel (2000) and Baily and Lawrence (2001) have extended these positive effects to the non-IT production sector of the U.S. economy. By contrast, investment in ICT appears to be less growth-enhancing in a number of countries where the levels of ICT investment are smaller (Colecchia and Schreyer, 2002; Daveri, 2002; Vijselaar and Albers, 2002).

But things are more complex than a first sight might guess. The measured impact of ICT on aggregate productivity has been very limited so far and their effects take long to become visible in the macro-economic aggregates. Even for the successful cases, a number of papers have found that the positive impact of ICT on growth is not so straightforward as expected, but a set of issues appear as necessary conditions to be hold (Wolff, 1996; Samaniego, 2006). 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). Henceforth, we will refer to the case where investment in ICT does not seem to be reflected in productivity as the productivity (or Solow) paradox.

In this context, Spain is an interesting case to be studied. Its high growth rates of output since 1995 (above 3.5 per cent a year as average) contrast to the small contribution of ICT to growth and labor productivity (the smallest within the EU-15). Moreover, this situation is compatible with higher rates of growth in ICT capital assets than in non-ICT capital and a negative growth rate of the TFP. Mas and Quesada (2006) detect that the behavior of ICT intensive sectors in terms of growth rates of output is better as relative to the non intensive ICT sectors. However, they also find negative TFP growth rates even in the ICT intensive sectors.

This paper tries to shed light on the effect of ICT expansion on output and labor productivity growth in Spain. With this aim, we have used a computable dynamic general equilibrium (DGE) model. Papers by Greenwood, Hercowitz and Krusell (1997, 2000), Kiley (2001), Pakko (2002a, 2005) -all of them calibrated to the U. S. economy-, Carlaw and Kosempel (2004) for the Canadian economy and Bakhshi and Larsen (2005) for the U.K. economy, provide examples of this methodology applied to technological changes. To the best of our knowledge, this is the first paper dealing with a DGE model for capturing the impact of ICT on Spanish economy and the first paper calibrating a DGE model with six types of capital and considering the technological change specific to each type of capital. Moreover, regarding the data used in the calibration, we follow the main branch of recent literature of growth accounting and the recommendations of OECD (2001a and b; Mas and Schreyer, 2006), which focus on the concept of capital services, instead of gross or net capital stocks.

On the basis of model calibration over the period 1995-2002, our main results show that Spain may be placed in the productivity paradox. Despite the relatively high growth rates of ICT investment, we find a negligible impact on productivity of the traditional capital assets while the ICT capital inputs have a positive influence on productivity. The growth of the TFP has a negative dominant effect on this dynamics. Though striking, these results are consistent with the evidence found by other papers for the U.S. economy (Hornstein and Krusell, 1996; Greenwood and Yorukoglu, 1997; Pakko 2002a and b; Samaniego, 2006) or the Canadian economy (Carlaw and Kosempel, 2004) and highlight the relevance of changes in the organizational capital, training of labor forces and efficiency or markets to capture the full benefits of new technologies. Spain still has a way to walk in the direction of improving these conditions.

The paper is organized as follows. Section 2 presents a conventional growth accounting exercise in the EU-15 countries and the U. S. economy, as an attempt to place the Spanish economy in an international and historical perspective. Section 3 presents the theoretical model, in which six types of capital are considered, with the characterization of its balanced growth path. Section 4 shows the calibration exercise. Section 5 presents the results and makes an interpretation using the related literature. Finally, Section 6 concludes.

2 International evidence

Table 1 reports calculations of labor productivity growth in hours worked ($\Delta(Y/L)$), total factor productivity growth (ΔTFP), and the ratio of ICT capital over the sum of all asset types of capital (ICT/K), for the EU-15 countries and the U.S., over four subperiods from 1980 to 2004, as measured by Timmer *et al.* (2003). Countries in this table are ordered according to the ICT-capital deepening (ICT/K) during the last period 2000-2004. Some statistics are calculated in the lowest rows of the table.

The ratio of capital deepening ICT/K has had a continuous growth from 1980 to 2004, indicating that the proportion of this capital stock accumulated by these economies is on average four times in 2004 than that in 1980 (measured by the mean). According to this criterion for the period 2000-2004, five countries can be considered as intensive ICT users: Belgium, Finland, United Kingdom, Sweden and the United States. The ratio corresponding to the U. S. economy in 2000-2004 is well above the mean (9.67% over 5.4%). France and Spain appear as non-intensive ICT users (see also Daveri, 2000; and Colecchia and Schreyer, 2002). Interestingly, the heterogeneity in the ICT use has increased across the total period, as shown by the standard deviation, from 0.6% to 1.6%.

On the other hand, Table 1 also shows a labor productivity slowdown during the last period 2000-2004 for the non-intensive ICT users (the average falls from 2.4% to 1.2%). For the intensive ones, there is an upwards trend in productivity beginning in 1990. A similar pattern is also worth noticing for the dynamics of efficiency, as captured by the TFP growth.

The lowest panel of this table calculates the correlation matrix of ICT deepening, productivity and TFP. Correlation of ICT deepening with the two other variables is rather low and negative. However, such correlation becomes positive for the period 2000-2004. The correlation between productivity growth and TFP growth is interestingly high for all periods, indicating that these countries are following a balanced growth path, as predicted by the neoclassical model (i.e., productivity tends to grow parallel to the technological change).

Relative to its E.U. partners, Spain exhibits a poor performance in productivity growth and a negative TFP growth during 2000-2004. Spain is a low intensive ICT user but there is an interesting dynamics to be interpreted. While the values corresponding to the ratio of ICT capital assets over total capital and productivity and TFP growth were not so far away from the international average during the eighties, things dramatically change since the mid of nineties. Negative rates of growth for TFP and productivity are found, and ICT capital deepening decreased below reference values. At the end of this paper, we shall offer an explanation of this striking issue, once we calibrate a model for the Spanish growth over the period 1995-2002.

[**Table 1 here**]

3 The model

Following Greenwood *et al.* (1997) we use 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 production of capital. We incorporate two new features. First, while Greenwood *et al.* (1997) disaggregate between structures and equipment capital assets, we distinguish among six different types of capital inputs. This implies a larger disaggregation of capital inputs than the one used in previous similar works. Therefore, our production function relates output with seven inputs: L is labor in hours worked; K_1 constructions and non residential buildings;

K_2 transport equipment; K_3 machinery and other equipment; K_4 communication equipment; K_5 hardware; and K_6 is software. The first three types of capital are grouped into non-ICT capital inputs, whereas the remaining three ones are ICT inputs.

Second, we consider the investment-specific technological change associated to each capital input. Denote Q_i as the price of asset i in terms of the amount of which that can be purchased by one unit of output. This price reflects the current state of technology for producing each asset. Greenwood *et al.* (1997) consider that this price is constant for structures, but is allowed to vary for equipment assets. Note that, according to this definition, equipment embodies both ICT and non-ICT inputs.

3.1 Household

The economy is inhabited by an infinitely lived, representative household who has time-separable preferences in terms of consumption of final goods, $\{C_t\}_{t=0}^{\infty}$, and leisure, $\{O_t\}_{t=0}^{\infty}$. Preferences are represented by the following utility function:

$$\sum_{t=0}^{\infty} \beta^t \left[\gamma \log C_t + (1-\gamma) \log O_t\right], \tag{1}$$

where β is the discount factor and $\gamma \in (0,1)$ is the elasticity of substitution between consumption and leisure. Private consumption is denoted by C_t. Leisure is $O_t = N_t H - L_t$, where H is the number of effective hours in the year ($H = 96 \times 52 = 4992$), times population in the age of taking labor-leisure decisions (N_t), minus the aggregated number of hours worked a year ($L_t = N_t h_t$, with h_t representing annual hours worked per worker).

The budget constraint faced by the consumer says that consumption and investment cannot exceed the sum of labor and capital rental income net of taxes and lump-sum transfers:

$$(1+\tau^c) C_t + \sum_{i=1}^{6} I_{i,t} = \left(1-\tau^l\right) W_t L_t + \left(1-\tau^k\right) \sum_{i=1}^{6} R_{i,t} K_{i,t} + T_t, \tag{2}$$

where $I_t = \sum_{i=1}^{6} I_{i,t}$ is total investment in the six types of capital, T_t is the transfer received by consumers from the government, W_t is the wage, $R_{i,t}$ is the rental price of asset type i, and τ^c, τ^l, τ^k, are the consumption tax, the labor income tax and the capital income tax, respectively. Note that capital income has six components, each of them with a different rental rate, $R_{i,t}$.

A key point of the model is that capital holdings evolve according to:

$$\left\{K_{i,t+1} = (1-\delta_i) K_{i,t} + Q_{i,t} I_{i,t}\right\}_{i=1}^{6}, \tag{3}$$

where δ_i is the depreciation rate of asset i. Following Greenwood *et al.* (1997), $Q_{i,t}$ determines the amount of asset i than can be purchased by one unit of output, representing the current state of technology for producing capital i. In the standard neoclassical one-sector growth model $Q_{i,t} = 1$ for all t, that is, the amount of capital that can be purchased from one unit of final output is constant. Greenwood *et al.* (1997) consider two types of capital: equipment and structures, where structures can be produced from final output on a one-to-one basis but equipment are subject to investment-specific technological change. However, in our model, $Q_{i,t}$ may increase or decrease over time, representing technological change specific to the production of each capital. In fact, an increase in $Q_{i,t}$ lowers the average cost of producing investment goods in units of final good.

The problem faced by the consumer is to choose C_t, O_t, and I_t to maximize the expected utility (1), subject to the budget constraint (2) and the law of motion (3), given taxes $\left\{\tau^c, \tau^k, \tau^l\right\}$ and the initial conditions $\{K_{i,0}\}_{i=1}^{6}$.

3.2 Firms

The problem of firms is to find optimal values for the utilization of labor and the different types of capital. The production of final output Y requires the services of labor L and six types of capital K_i, $i = 1, ...6$. The firm rents capital and employs labor in order to maximize profits at period t, taking factor prices as given. The technology is given by a constant return to scale Cobb-Douglas production function,

$$Y_t = A_t L_t^{\alpha_L} \prod_{i=1}^{6} K_{i,t}^{\alpha_i}, \tag{4}$$

where A_t is a measure of total-factor, or sector-neutral, productivity and where $\{0 \leq \alpha_i \leq 1\}_{i=1}^{6}$, $\sum_{i=1}^{6} \alpha_i \leq 1$, and $\alpha_L = 1 - \sum_{i=1}^{6} \alpha_i$. Final output can be used for seven purposes: consumption or investment in six types of capital,

$$Y_t = C_t + \sum_{i=1}^{6} I_{i,t}, \tag{5}$$

where both output and investment are measured in units of consumption.

3.3 Government

Finally, we consider the existence of a tax-levying government in order to take into account the effects of taxation on capital accumulation. For simplicity, we assume that the government balances its budget period-by-period by returning revenues from distortionary taxes to the agents via lump-sum transfers T_t. The government has no role in our model and obtains resources from the economy by taxing consumption and income from labor and capital. Consequently, the government budget constraint in each period is:

$$\tau^c C_t + \tau^l W_t L_t + \tau^k \sum_{i=1}^{6} R_{i,t} K_{i,t} = T_t. \tag{6}$$

3.4 Equilibrium

The first order conditions for the consumer are:

$$\begin{aligned} \gamma \frac{1}{C_t} - \lambda_t (1+\tau^c) &= 0, & (7)\\ -(1-\gamma)\frac{1}{N_t\overline{H} - L_t} + \lambda_t\left(1-\tau^l\right) W_t &= 0, & (8)\\ E_t \beta^t \lambda_{t+1}\left[\left(1-\tau^k\right) R_{i,t+1} + \frac{(1-\delta_i)}{Q_{i,t+1}}\right] - \frac{\lambda_t}{Q_{i,t}}\beta^{t-1} &= 0, & (9) \end{aligned}$$

for each $i = 1, ...6$. λ_t is the Lagrange multiplier assigned to date's t restriction. Combining (7) and (8) we obtain the condition that equates the marginal rate of substitution between consumption and leisure to the opportunity cost of one additional unit of leisure:

$$\frac{1}{N_t\overline{H} - L_t} = \frac{\gamma}{(1-\gamma)} \frac{\left(1-\tau^l\right)}{(1+\tau^c)} \frac{W_t}{C_t}. \tag{10}$$

Equation (9) is a set of Euler equations that equate the marginal cost of additional capital with the expected return to the investment for each type of capital. Combining (7) with (9) yields:

$$\frac{1}{\beta}\frac{C_{t+1}}{C_t} = \left(1-\tau^k\right) Q_{i,t} R_{i,t+1} + (1-\delta_i)\frac{Q_{i,t}}{Q_{i,t+1}}. \tag{11}$$

Condition (11) implies that marginal rate of consumption equates the rates of return of the six investment assets.

The first order conditions for the firm profit maximization are given by

$$\left\{ R_{i,t} = \alpha_i \frac{A_t}{K_{i,t}} L_t^{\alpha_L} \prod_{i=1}^{6} K_{i,t}^{\alpha_i} = \alpha_i \frac{Y_t}{K_{i,t}} \right\}_{i=1}^{6}, \tag{12}$$

and

$$W_t = \alpha_L A_t L_t^{\alpha_L - 1} \prod_{i=1}^{6} K_{i,t}^{\alpha_i} = \alpha_L \frac{Y_t}{L_t}, \tag{13}$$

that is, the firm hires capital and labor such that the marginal contribution of these factors must equate their competitive rental prices.

Additionally, the economy satisfies the feasibility constraint:

$$C_t + \sum_{i=1}^{6} I_{i,t} = \sum_{i=1}^{6} R_{i,t}K_{i,t} + W_t L_t = Y_t. \tag{14}$$

First order conditions for the household (10) and (11), together with the first order conditions of the firm (12) and (13), the budget constraint of the government (6), and the feasibility constraint of the economy (14), characterize a competitive equilibrium for the economy.

Definition. A competitive equilibrium for this economy is a sequence of consumption, leisure and private investment for the consumers $\left\{C_t, N_t H - L_t, \{I_{i,t}\}_{i=1}^{6}\right\}_{t=0}^{\infty}$, a sequence of capital and labor utilization for the firm $\left\{\{K_{i,t}\}_{i=1}^{6}, L_t\right\}_{t=0}^{\infty}$, a sequence of the state of technology for producing each capital asset $\{\{Q_{i,t}\}_{i=1}^{6}\}_{t=0}^{\infty}$, and a sequence of government transfers $\{T_t\}_{t=0}^{\infty}$, such that given a sequence of prices $\left\{W_t, \{R_{i,t}\}_{i=1}^{6}\right\}_{t=0}^{\infty}$ and taxes $\left\{\tau^c, \tau^k, \tau^l\right\}$:

i) The optimization problem of the consumer is satisfied.

ii) The first order conditions of the firm hold.

iii) The sequence of transfers is such that the government constraint is satisfied, and

iv) The feasibility constraint of the economy holds.

3.5 The balanced growth path

Next, we define the balanced growth path, in which the steady state growth path of the model is an equilibrium satisfying the above conditions and where all variables grow at a constant rate. The balanced growth path requires that hours per worker must be constant. Given the assumption of no unemployment, this implies that total hours worked grow by the population growth rate, which is assumed to be zero.

According to the balanced growth path, output, consumption and investment must all grow at the same rate, which is denoted by g. However, the different types of capital would grow at a different rate depending on the evolution of their relative prices. From the production function (4) the balanced growth path implies that:

$$g = g_A \prod_{i=1}^{6} g_i^{\alpha_i}, \tag{15}$$

where g_A is the steady state exogenous growth of A_t. Let us denote g_i as the steady state growth rate of capital i. Then, from the law of motion (3), we have that the growth of each capital input is given by:

$$\{g_i = \eta_i g\}_{i=1}^{6}, \tag{16}$$

with η_i being the exogenous growth rate of $Q_{i,t}$. Therefore, the long run growth rate of output can be accounted for by neutral technological progress and by increases in the capital stock. In addition, expression (16) says that the capital stock growth also depends on technological progress in the process producing the different capital goods. Therefore, it is possible to express output growth as a function of the exogenous growth rates of production technologies as:

$$g = g_A^{1/\alpha_L} \prod_{i=1}^{6} \eta_i^{\alpha_i/\alpha_L}. \tag{17}$$

Expression (17) implies that output growth can be decomposed as the weighted sum of the TFP (neutral technological progress) growth and embedded technological progress, as given by $\{\eta_i\}_{i=1}^{6}$. Along the balanced growth path, growth rate of each capital asset can be different, depending on the relative price of the new capital in terms of output. A particular capital asset with decreasing prices (specific technological progress) will display a growth rate higher than the output growth rate. On the contrary, capital assets whose relative prices increase, will grow over time at a lower rate than output.

On this basis, the following steady state ratios can be defined:

$$\rho_i \equiv \left(Q_i \frac{Y}{K_i}\right)_{ss} > 0, \tag{18}$$

$$s_i \equiv \left(\frac{I_i}{Y}\right)_{ss} \in (0,1), \tag{19}$$

$$c \equiv \left(\frac{C}{Y}\right)_{ss} \in (0,1), \tag{20}$$

$$v \equiv \left(\frac{L}{NH}\right)_{ss} = \left(\frac{h}{4992}\right)_{ss} \in (0,1), \tag{21}$$

where the subscript ss denotes its steady-state reference.

The balanced growth path is finally characterized by the following set of equations:

$$\left\{\eta_i g = \beta\left[\left(1-\tau^k\right)\alpha_i\rho_i + 1 - \delta_i\right]\right\}_{i=1}^{6}, \tag{22}$$

$$\{\eta_i g = \rho_i s_i + 1 - \delta_i\}_{i=1}^{6}, \tag{23}$$

and

$$1 = c + \sum_{i=1}^{6} s_i, \tag{24}$$

$$1 = \alpha_L + \sum_{i=1}^{6} \alpha_i. \tag{25}$$

$$c = \alpha_L \frac{\gamma}{1-\gamma} \frac{1-\tau^l}{1+\tau^c} \left(\frac{1}{v} - 1 \right). \tag{26}$$

The system of 15 equations composed by (22)-(26) is the one used in the calibration exercise.

4 Data, parameters and calibration

Series of productive capital have been drawn from the data base elaborated by Mas, Pérez and Uriel (2005, 2007), who provide an estimation of eighteen assets for Spain for 1964-2002.[1] Non-ICT series have been grouped into three assets: constructions and non residential buildings (n.r.b.), transport equipment, and machinery and other equipment, whereas ICT series have been grouped into three assets: communication equipment, hardware and software. These ICT series have been quality-adjusted by adapting the hedonic prices of the BEA through the law of one price (see Mas *et al.*, 2005, pp. 71 and 168-173). Assets have been aggregated using a Törnqvist index. This data base also provides series for (nominal and real, gross and net) investment.

Series for Gross Value Added (GVA), inputs compensation and total hours worked have been retrieved from Instituto Nacional de Estadística (INE).[2] Since residential capital does not belong to the concept of productive capital, we do not consider it into the values of GVA and, consequently, nor into analogous measures of remuneration of employees, those referred to rents from dwellings and incomes from private households with employed persons.

Prices of assets $\{Q_{it}\}_{i=1}^{6}$ have been elaborated on the basis of deflators provided by Mas *et al.* (2007) and following the procedure that the OECD recommends to overcome the deficiencies of Spanish statistics. Price Q_{it} represents the amount of asset i that can be purchased by one unit of the consumption good at time t. We proxy these prices as $Q_{it} = CPI_t/q_{it}$, where CPI_t is the (non durable) consumption price index (downloaded from INE), and q_{it} is the deflator of asset i calculated as nominal investment relative to real investment ratio.

[1] This data base is available on the web site of Fundación BBVA: www.fbbva.es.

[2] See `http://www.ine.es/`

Table 2 reports information on relevant parameters used in the calibration. The second column shows the average price changes of the six assets ($\eta_i = T^{-1} \sum_t Q_{it}/Q_{it-1}$). It is worth noticing that price changes of the three non-ICT assets are found negligible for this particular period. The amount that hardware equipment that can be purchased by one unit of output has increased by 22 percent per year. This increase is of about 5 percent per year for communication equipment, and about 2 percent for software. Implicit technological change, as measured by the evolution of the Q_{it}, seems to be specific of these two ICT equipment.[3] The estimates of the depreciation rates δ_i are collected in the third column of table 2, and have been computed as the ratio of investment resources devoted to depreciation over the gross capital stock. Table 2 also reports the investment ratios of expression (19) averaged over 1995-2002 (s_i). Note that the highest ratio is associated to constructions (assets with null implicit technological change), that with a ratio of 0.0936 represents a half of total investment. A quarter of investment is devoted to machinery equipment (with an investment ratio of 0.0443). Hardware only represents a 3.7 per cent of this portfolio, which is the asset with the highest implicit technological variation.

[Table 2 here]

The average labor productivity growth in the period 1995-2002 for the Spanish economy was -0.39 per cent. Using the notation of our model, that means that g is equal to 0.9961. According to (21), the average working hours ratio is $v = 0.2819$. In order to take into account the distortionary effects of taxes, particularly on capital accumulation, realistic measures of tax rates are needed. Agents' decisions depend on marginal tax. However, as pointed out by Mendoza *et al.* (1994), the estimation of marginal rates is often an impractical task given limitations imposed by data availability and difficulties in dealing with the complexity of tax systems. They proposed a method to estimate effective average taxes and show that their estimated average tax rates are within the range of marginal tax rates found in previous works and display very similar trends. In this paper we use the effective average tax rates, as estimated by Boscá *et al.* (2005), who follow the methodology proposed by Mendoza *et al.* (1994) for the period 1964-2001. These rates are: $\tau^c = 0.110$, $\tau^k = 0.220$, $\tau^l = 0.340$.

Mas *et al.* (2005) follow the recommendations of OECD (2001a and b) for constructing the series of capital assets, based on the concept of *capital services*. The idea is to capture the productive services embedded into the stock of capital. This concept of productive capital can be seen as a volume index of capital services. The expression driving the concept of capital services for the asset i is as follows:

[3] For the period 1970-2003, the annual growth rates of the technological progress for machinery and transport equipment were, respectively, 1.75% and 1.30%. The evolution of these prices, however, have been much more modest during the period 1995-2002, but the results of our calibration do not hinge on it.

$$VCS_{it} = \mu_{it} K_{it-1}, \tag{27}$$

where μ_{it} is, in turn, the user cost of capital and is defined as

$$\mu_{it} = q_{i,t-1} \left(i_t + \delta_i - \Delta \ln q_{it} \right), \tag{28}$$

with δ_i being the depreciation rate. i_t is the nominal interest rate, calculated as the sum of the rate of return (exogenously fixed at 4%, as Mas *et al.* (2005, 2007) do) and the inflation rate, computed as the three year centered moving average of the CPI. Finally, $\Delta \ln q_{it}$ measures what extent the prices of assets vary and has been calculated as the three year centered moving average of the variation of prices of assets.

Let RE_t be the remuneration of employees.[4] Consequently, the cost shares of productive factors are given by the following expressions:

$$\text{CSH}_{Lt} = \frac{RE_t}{RE_t + \sum_{i=1}^{6} VCS_{it}}, \tag{29}$$

$$\text{CSH}_{it} = \frac{VCS_{it}}{RE_t + \sum_{i=1}^{6} VCS_{it}}, \tag{30}$$

with $\text{CSH}_{Lt} + \sum_{i=1}^{6} \text{CSH}_{it} = 1$. These cost shares are used in growth accounting decompositions for weighting the contribution of the different inputs to output growth and productivity growth, guided by microeconomics foundations. Therefore, on the basis of expression (29), we select a value for labor share of $\alpha_L = 0.7450$, which seems to be very stable across the period under analysis.

Finally, the rest of parameters will be adjusted given these economic conditions of productivity, investment decisions, taxes and technological change. Thus, expressions (22) to (26) define a complete system of fifteen equations in fifteen unknowns, $\{\alpha_i, \rho_i\}_{i=1}^{6}$, β, γ, and c, for given $\{\delta_i, s_i, \eta_i\}_{i=1}^{6}$, α_L, g, v, and $\{\tau^c, \tau^k, \tau^l\}$. Once we determine $\{\alpha_i\}_{i=1}^{6}$, expression (17) will be used to evaluate the sources of technological change, and their contribution to productivity growth, under the conditions of period 1995-2002. The results we obtain are: $\alpha_1 = 0.1396$, $\alpha_2 = 0.0253$, $\alpha_3 = 0.0570$, $\alpha_4 = 0.0134$, $\alpha_5 = 0.0088$, $\alpha_6 = 0.0107$, $\beta = 0.99$, and $\gamma = 0.4580$.[5]

5 Investment-specific technological change in Spain

Using the parameters calibrated in the previous section, we proceed to study the quantitative importance of investment-specific technological change in explaining la-

[4] Mixed incomes are reassigned into labor and capital according to the weight of remuneration of employees over the GVA.

[5] The values for $\{\rho_i\}_{i=1}^{6}$ are not reported here but they are available upon request.

bor productivity growth in Spain over the period 1995-2002, following the strategy proposed by Greenwood *et al.* (1997). However, instead of using a disaggregation into two assets, structures and equipment, we use six different capital inputs. As explained before, asset prices as relative to the CPI will be our measure for investment-specific technological change. This will allow us to quantify the contribution of the different ICT inputs to productivity growth.

Table 3 reports the growth rates for output, labor (in hours worked) and capital assets across 1995-2002, and within two subperiods, 1995-1998 and 1998-2002. It is worth mentioning the weak evolution experienced by labor productivity growth over the sample. While real GVA grew at a yearly average rate of 3.41 per cent, labor did at 3.80 per cent, which yielded an average productivity growth of -0.39 per cent per year. This rate was also negative during the first and second half of the sample. Regarding the growth rates of capital assets, a clear difference appears when ICT and non-ICT capital inputs are distinguished. While the later showed growth rates around 4 percent a year, the former experienced annual increases by more than 10 percent. Specifically, investment in hardware grew at a stable rate greater than 20 percent over the period, and communication and software inputs increased their stocks at growth rates of 8 and 10 per cent by year, respectively. These two ICT assets also experienced an acceleration in their growth rates when both subperiods are compared. These facts are consistent with the intense declining trend in (nominal) prices, as compared to the CPI.

[**Table 3 here**]

Expression (17) is used to decompose the long-run growth of labor productivity into contributions from neutral technological progress and from technological progress from specific use of the six capital assets. Results are reported in Table 4. While the actual observed growth rate of productivity is -0.39 percent (taken from Table 3), our calibration reports a value of -0.71 percent a year for this variable. This slight difference between both growth rates comes from the fact that we calibrate the balanced path of the Spanish economy, which is unlikely to be the same than the actual one. Considering the period as a whole, it should be mentioned that technological change coming from the non-ICT capital assets had a poor effect on productivity (a negative contribution of -0.08 percent), while the technological change from ICT capital inputs had a substantial positive impact. Of special interest is the case of hardware equipment, with a positive effect of 0.24 percent, while the software exerts a negligible impact on productivity growth (0.03 percent). Communications also plays a small role of 0.09 percent.

With respect to technological change implicit from the non-ICT capital assets, the calibrated model gives a negative impact coming from capital accumulation in constructions and n.r.b. Transport equipment and machinery and other equipment showed a positive modest impact on productivity growth.

Neutral change has a negative impact on the observed productivity across the entire period (-0.99). The observed productivity growth worsens in the second subperiod, from -0.15 to -0.56 percent. The calibrated results expand this difference between subperiods (-0.03 vs -1.22). This is a result that combines the weaker positive impulse of the investment-specific technological change in the second sub-period, from 0.57 to 0.06, with an increase of the negative contribution from the neutral change, from –0.60 to -1.28 percent. Therefore, implicit technological change represents a minimal impulse of total productivity growth. Neutral technical change seems to dominate the evolution of productivity during the period.

[**Table 4 here**]

The phenomenon of slowdown in TFP growth has been already found in previous contributions and linked to an increase in the rate of capital-embodied technical change from ICT adoption in U.S. (Greenwood and Yorukoglu, 1997; Gordon, 1999). Carlaw and Kosempel (2004) for the Canadian economy and Bakhshi and Larsen (2005) for the U.K. obtain similar results. Additionally, it should be taken account that as we consider different types of capital in the production function instead of only one aggregated, the magnitude of the downturn appears as more relevant, as was shown by Greenwood *et al.* (1997).[6]

In terms of TFP and ICT, Spanish economy in 2000 performs like U.S. economy in the late 70s and early 80s. Figure 1 illustrates the evolution of the deepening in ICT as a fraction of the total stock of capital, ICT/K, for both the U.S. and Spain during 1980-2004. In 2004 this ratio was 3.7% for Spain and 10.21% for the U.S. The ratio of this last country reached a 3.7% in 1991. Hence, ICT penetration presents a delay of about 13 years in Spain as compared with that of the US.

Spanish economy follows here a different path than that corresponding to the most advanced countries in terms of new technologies. In the second half of the nineties, nations such as U.S., Sweden, Finland and U. K. experienced an upsurge of their productivity growth (see Table 1). Hence, the question is: why this decreasing trend in productivity levels when Spain is increasing its ICT capital stocks at two-digit rates?

[**Figure 1 about here**]

TFP suffers a decrease below its long-run value during the periods in which the investment in ICT is more intense. This issue is illustrated in Figures 2 and 3. Figure 2 presents the growth rates of TFP in Spain and the U.S. as calculated by the growth accounting exercise of Timmer *et al.* (2003), and Figure 3 collects

[6] Particularly, they show how considering equipment and structures capital stocks in the production function (instead of an unique broad concept of capital) increases the slowdown in the TFP.

the ICT growth rates in these two countries. Both figures represent quinquennial averages starting on 1980. The dynamics of TFP in Spain is asymmetric to that of the US. Until the mid of the nineties, Spain showed a positive growing trend in its TFP, while that of the US was negligible. In 1995, things changed and this rate has become negative for Spain and positive for the US ever since.

[**Figures 2 and 3 here**]

Spanish case also replicates the U.S. example regarding the dynamics of ICT and non-ICT investment. U.S. economy began its ICT revolution in the early 70s with increasing investment rates in the new capital assets (Wolff, 2006). But since the late 70s and during a significant part of the 80s, a deceleration in the (ICT and non-ICT) investment growth rates is appreciated (Wolff, 1996). In Figure 3, the ICT capital growth rate evince an important contraction from 1985 to 1995 in the US. This contrasts with the rapid acceleration of this growth rate in Spain during this period. According to Pakko (2002a) and Samaniego (2006), this fact can be viewed as an anticipation of the organizational shock which took place at the beginning of the eighties. Spain seems to have followed a similar pattern but 15 years overdue: the Spanish ICT revolution starts in the mid of eighties, suffers a deceleration in early 90s and TFP growth shows its declining trend since that moment. Accordingly, Spain would be now facing the organizational changes in the production process, capital factor adjustment and learning process, to absorb the challenges of new technology.

In the related literature, several arguments can be found that help to explain this apparent coexistence between technology progress and productivity slowdown. For instance, according to Hornstein and Krusell (1996), an increase in the 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)). Closely related, a number of papers have emphasized that the answer might be related to changes in new forms of organization at plant level which are required to obtain the full benefits from ICT. In fact, this historical episode has already taken place in other economies (see Kiley, 2001, for a synthetic survey). Many of them present the adoption of ICT as a technological revolution with substantial short-run negative effects until the new equipment have been completely adapted. The transition dynamics from a change in technological progress leads to a slowdown in capital accumulation and thus in productivity during the transition period. According to this line of research, Pakko (2002a and b) using a model with stochastic growth trends, shows that changes in the growth rate of technological progress may not affect productivity contemporaneously, but with a lag. Basu, Fernald, and Shapiro (2001) suggest that factor adjustments implied by technological progress play an important role in the timing of productivity changes. They conclude that factor adjustments can explain the contemporaneous differences between productivity growth and technological change.

Alternatively, Hornstein and Krusell (1996) argue that the slowdown can be due to an inappropriate or noisy perception of the quality embedded in the production of final goods (see Baily and Gordon (1988) and Griliches (1984)). To the extent that quality improvements can be non appropriately measured, this may cause serious downward biases in the measures of productivity.

On the basis of Table 1 we think that this complementary strategy to ICT adoption can be explained combining these previous arguments, which can be proxied in our case by the ICT/K ratio. The higher the ICT capital deepening, the more likely to adopt the required changes for obtaining the full returns from ICT investment. Therefore, we think that this tentative interpretation is well suited to the Spanish experience, which has low levels of ICT in relation to the total capital services. Viewed in this manner, the economy needs a period for adapting its production process to the new equipment and organizational requirements and consequently the positive effects of ICT is being delayed.

6 Conclusions

This paper has tried to shed some light on a difficult issue to be explained: to what extent have the ICT influenced labor productivity and TFP dynamics over the recent years in Spain? This question is a non trivial one and has been labeled as the productivity paradox. The case of U.S. is the most useful one to illustrate this point. Since the mid of nineties, the U.S. economy has experienced an acceleration in its productivity and TFP growth rates, which many authors attribute to the substantial efforts made in ICT investment. But things have not been always so clear. In fact, during at least a couple of decades, U.S. productivity remained below its long-run value precisely when the "New Economy" revolution began and several organizational challenges had to be faced to adapt the new equipment.

Spain is an interesting case to be studied. The dynamics of its productivity has showed a negative pattern since the mid of nineties until now. TFP presents a worse behavior. This has occurred in a context where the investment in ICT assets is increasing at high growth rates. Given these coordinates, the productivity paradox arises as long as the bigger resources devoted to new technologies do not lead to higher growth rates of productivity. In this context, we have carried out a growth accounting exercise in an attempt to make clearer the forces driving the labor productivity growth, particularly those related to ICT inputs.

We have built a dynamic general equilibrium model which has been calibrated for the Spanish economy over the period 1995-2002. This approach allows us to gain some insights about the long-run growth pattern which Spain would follow in the case of using the conditions of the late 90s as a starting point towards the steady-state. Hence, our research has to be seen as a tentative exercise aimed at assessing the role played by the ICT in a dynamic context. We provide an alternative framework to study the sources of growth, beyond the conventional growth-accounting exercises, and based on the standard ideas of dynamic equilibrium.

In addition, we have defined a production function with six different capital inputs, three of them corresponding to non-ICT inputs (constructions, machinery and transport equipment) whereas the other three correspond to hardware, software and communications equipment. Additionally, we have used series of capital assets based on the concept of capital services, following recent recommendations of OECD. To the best of our knowledge, this paper is the first one which employs this new data methodology in this context.

The results provide revealing indications. On the basis of the model calibration over the period 1995-2002, the steady-state of Spanish economy is characterized by a negative productivity growth rate, despite an increasing effort in ICT investment. When the dynamics of productivity is 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, we find a modest negative impact coming from the traditional capital inputs, while communications and mainly hardware equipment appear as significant growth-enhancing assets. These results remain even when different subperiods are taken as basis of model calibration.

As happened in other past technological revolutions, it seems to be clear that the relevant (but potential) benefits of ICT need time to come true. Adjustments costs and inefficiencies derived from inappropriate qualifications in labor force lead to a transitional dynamics in which productivity suffers low and even negative growth rates. New organizational forms at level-plant and a renewal of labor training and human capital accumulation adapted to the new equipment have to be carried out. Moreover, as the U. S. case shows, the existence of competitive factors, services and goods markets also appears as a necessary condition for the optimal development of ICT because this environment minimizes the adjustments costs. Precisely, the experiences of other countries can make easier and less time-consuming the adoption of ICT in Spain.

References

[1] Bakhshi, H. and Larsen, J. (2005): ICT-specific technological progress in the United Kingdom. *Journal of Macroeconomics* 27, 648-669.

[2] Baily, M. and Gordon, R. (1998): The productivity slowdown, measurement issues, and the explosion of computer power, *Brookings Papers on Econonomic Activity*, 347-420.

[3] Baily, M. and Lawrence, R. (2001): Do We Have a New E-Conomy?, *American Economic Review* 91, 308-312.

[4] Basu, S., Fernald, J. and Shapiro, M. (2001): Productivity growth in the 1990s: technology, utilization, or adjustment?, *Carnegie-Rochester Conference Series on Public Policy* 55, 117-165.

[5] Boscá, J., García, J. and Taguas, D. (2005): Tipos efectivos de gravamen y convergenca fiscal en la OCDE: 1965-2001, *Hacienda Pública Española* 174 (3), 119-141.

[6] Carlaw, K., and Kosempel, S. (2004): The sources of total factor productivity growth: Evidence from Canadian data, *Economic Innovation and New Technology* 13, 299-309.

[7] Colecchia, A. and P. Schreyer (2002): ICT investment and economic growth in the 1990's: Is the United States a unique case? A comparative study of nine OECD countries, *Review of Economic Dynamics* 5, 408-442.

[8] Daveri, F. (2002): Information technology and growth in Europe, *Università di Parma.*

[9] Greenwood, J., and Yorukoglu, M. (1997): 1974, *Carnegie-Rochester Conference Series on Public Polic* 46, 49-95.

[10] Greenwood, J., Hercowitz, Z. and Krusell, P. (1997): Long-run implication of investment-specific technological change, *American Economic Review* 87, 342-362.

[11] Greenwood, J., Hercowitz, Z. and Krusell, P. (2000): The role of investment-specific technological change in the business cycle, *European Economic Review* 44, 91-115.

[12] Griliches, Z. (1988): Productivity puzzles and R&D: Another nonexplanation, *Journal of Economic Perspectives* 2, 9-21.

[13] Hornstein, A. and Krusell, P. (1996): Can technology improvements cause productivity slowdowns? *NBER Macroeconomics Annual* 1996, 209-259.

[14] Jorgenson, D. W. (2001): Information Technology and the US Economy, *American Economic Review* 91(1), 1-32.

[15] Jorgenson, D. W. and Stiroh, K. J. (2000): Raising the Speed Limit: U.S. Economic Growth in the Information Age, *Brooking Papers on Economic Activity* 1, 125-211.

[16] Kiley, M. (2001): Computers and growth with frictions: aggregate and disaggregate evidence, *Carnegie-Rochester Conference Series on Public Policy* 55, 171-215.

[17] Mas, M., Pérez, F. and Uriel, E. (2005): *El stock y los servicios de capital en España. Nueva Metodología (1964-2002)*. Fundación BBVA, Bilbao.

[18] Mas, M., Pérez, F. and Uriel, E. (2007): *El stock y los servicios de capital en España. Nueva Metodología (1964-2005)*. Fundación BBVA, Bilbao.

[19] Mas, M., and Quesada, J. (2005): *Las nuevas tecnologías y el crecimiento económico en España*. Fundación BBVA, Bilbao.

[20] Mas, M., and Quesada, J. (2006): The role of ICT in the Spanish productivity slowdown, Fundación BBVA, *Documento de Trabajo No.* 5.

[21] Mas, M. and Schreyer, P. (2006) (Eds.): *Growth, Capital and New Technologies*, Fundación BBVA, Bilbao.

[22] Mendoza, E., Razin, A., and Tesar, L. (1994): Effective tax rates in macroeconomics. Cross-country estimated of tax rates on factor incomes and consumption, *Journal of Monetary Economics* 34, 297-323.

[23] OECD (2001a): *Measuring capital. A manual on the measurement of capital stocks, consumption of fixed capital and capital services*, Paris, OECD.

[24] OECD (2001b): *OECD productivity manual: a guide to the measurement of industry-level and aggregate productivity growth*, Paris, OECD.

[25] Oliner, S. and Sichel, D. (2000): The resurgence on growth in the late 1990s: Is information technology the story?, *Journal of Economic Perspectives* 14, 3-22.

[26] Pakko, M.R. (2002a): What happens when the technology growth trend changes? Transition dynamics, capital growth and the "new economy", *Review of Economic Dynamics* 5, 376-407.

[27] Pakko, M. R.(2002b): "Investment-Specific Technology Growth: Concepts and Recent Estimates" *Federal Reserve Bank of St. Louis Review* (November/December 2002a), 37-48.

[28] Pakko, M.R. (2005): Changing Technology Trends, Transition Dynamics, and Growth Accounting, *The B.E. Journal of Macroeconomics, Contributions* 5 (1), Article 12.

[29] Samaniego, R. M. (2006): Organizational capital, technology adoption and the productivity slowdown, *Journal of Monetary Economics* 53, 1555-1569.

[30] Stiroh, K: (2002): Information technology and U.S. productivity revival: What do the industry data say?, *American Economic Review* 92 (5), 1559-1576.

[31] Solow, Robert M.: "Manufacturing Matters," New York Times Book Review (July 12, 1987), 36.

[32] Timmer, M., Ypma, G. and van Ark, B. (2003): IT in the European Union: Driving Productivity Divergence?, *GGDC Research Memorandum* GD-67.

[33] Vijselaar, F. W. and Albers, R. M. (2002): New Technologies and Productivity Growth in the Euro Area, *ECB Working Papers* No. 122.

[34] Wolff, E. N. (1996): The productivity slowdown: the culprit at last?, *American Economic Review*, 86, 1239-1252.

[35] Yorukoglu, M. (1998): The information technology productivity paradox, *Review of Economic Dynamics*, 1, 551-592.

A Tables and figures

Table 1: ICT-capital deepening, productivity and TFP growth: An international comparison

	1980-1990			1990-1995			1995-2000			2000-2004		
	$\Delta \frac{Y}{L}$	ΔTFP	$\frac{ICT}{K}$	$\Delta \frac{Y}{L}$	ΔTFP	$\frac{ICT}{K}$	$\Delta \frac{Y}{L}$	ΔTFP	$\frac{ICT}{K}$	$\Delta \frac{Y}{L}$	ΔTFP	$\frac{ICT}{K}$
EU-15	2.3	1.15	1.55	2.4	1.18	2.32	1.8	0.86	3.30	1.1	0.36	4.99
France	2.9	1.37	1.06	1.3	0.01	1.61	2.5	1.45	2.32	1.5	0.45	3.47
Spain	3.0	1.95	1.26	2.3	0.94	2.02	-0.1	-0.35	2.57	0.1	-0.54	3.60
Netherlands	2.0	1.07	0.83	1.3	0.64	1.41	0.8	0.59	2.25	0.7	0.16	3.90
Ireland	3.7	2.71	0.68	3.6	2.99	0.87	6.0	4.45	1.85	4.2	1.98	4.17
Greece	-0.1	-0.50	1.22	0.4	0.01	1.73	2.9	1.91	2.59	2.9	1.80	4.27
Austria	1.6	0.49	1.94	1.8	0.65	2.60	3.0	1.72	3.31	1.4	0.18	4.74
Luxemburg	3.6	2.13	2.04	2.3	0.98	3.04	2.7	1.63	3.40	-0.2	-0.95	4.76
Germany	2.6	1.54	1.92	3.1	1.84	2.70	2.2	1.28	3.37	1.2	0.61	4.76
Portugal	1.7	1.57	1.67	3.6	1.58	2.32	2.5	1.01	3.31	0.5	-0.35	5.32
Denmark	2.2	0.95	1.26	2.6	1.44	2.27	2.4	0.82	3.58	1.4	-0.08	5.41
Italy	1.9	0.86	1.81	2.2	1.00	2.95	1.3	0.24	4.12	-0.4	-1.19	5.92
Belgium	2.0	0.79	1.01	2.3	1.24	1.97	2.9	1.70	3.36	0.6	0.27	6.16
Finland	2.7	1.47	1.01	2.0	0.87	1.92	3.4	3.32	3.56	2.8	2.01	6.68
U.K.	2.3	1.17	1.35	2.9	1.60	2.50	2.2	1.06	4.37	2.0	1.51	7.03
Sweden	1.4	0.40	1.86	2.0	0.95	2.74	2.6	1.34	4.42	2.6	1.92	7.17
U.S.A.	1.5	0.61	2.78	1.2	0.55	4.27	2.3	1.14	6.33	2.8	1.72	9.67
Average:	2.2	1.2	1.5	2.2	1.1	2.3	2.5	1.5	3.4	1.5	0.6	5.4
Low intense	2.3	1.3	1.4	2.2	1.1	2.1	2.4	1.3	3.0	1.2	0.2	4.6
High intense	2.0	0.9	1.6	2.1	1.0	2.7	2.7	1.7	4.4	2.2	1.5	7.3
Std.Dev.×100	0.9	0.8	0.6	0.9	0.7	0.8	1.3	1.1	1.1	1.3	1.1	1.6
Corr. coeff.	$\Delta \frac{Y}{L}$	ΔTFP	$\frac{ICT}{K}$	$\Delta \frac{Y}{L}$	ΔTFP	$\frac{ICT}{K}$	$\Delta \frac{Y}{L}$	ΔTFP	$\frac{ICT}{K}$	$\Delta \frac{Y}{L}$	ΔTFP	$\frac{ICT}{K}$
$\Delta \frac{Y}{L}$	1.00			1.00			1.00			1.00		
ΔTFP	0.93	1.00		0.90	1.00		0.94	1.00		0.94	1.00	
$\frac{ICT}{K}$	-0.24	-0.25	1.00	-0.11	-0.22	1.00	-0.15	-0.25	1.00	0.27	0.40	1.00

Table 2: Parameters values

Asset	Prices Changes	Depreciation	Investment ratios
Constructions and n.r.b.	$\eta_1 = 0.9919$	$\delta_1 = 0.0145$	$s_1 = 0.0936$
Transport equipment	$\eta_2 = 1.0070$	$\delta_2 = 0.1375$	$s_2 = 0.0197$
Machinery and other equipment	$\eta_3 = 1.0070$	$\delta_3 = 0.0906$	$s_3 = 0.0443$
Communication equipment	$\eta_4 = 1.0485$	$\delta_4 = 0.0917$	$s_4 = 0.0104$
Hardware and other office equipment	$\eta_5 = 1.2253$	$\delta_5 = 0.1567$	$s_5 = 0.0069$
Software	$\eta_6 = 1.0192$	$\delta_6 = 0.4142$	$s_6 = 0.0083$

Table 3: Output, labor and capital growth rates

	1995-1998	1998-2002	1995-2002
Real GVA	3.56	3.30	3.41
Labor (hours)	3.71	3.86	3.80
Productivity	−0.15	−0.56	−0.39
Non ICT	3.91	4.35	4.16
Constructions and n.r.b.	4.28	4.91	4.64
Transport equipment	3.50	4.44	4.04
Machinery and other equipment	2.83	2.89	2.86
ICT	9.92	13.64	12.04
Communication equipment	5.99	9.21	7.83
Hardware equipment	20.92	21.31	21.14
Software	11.38	10.35	10.79

Table 4: Sources of average productivity growth

	1998-1998	1998-2002	1995-2002
Productivity growth (observed)	−0.15	−0.56	−0.39
Productivity growth (calibrated)	−0.03	−1.22	−0.71
Investment-specific: (a) + (b)	0.57	0.06	0.28
Non ICT (a)	0.15	−0.25	−0.08
Constructions and n.r.b.	0.06	−0.31	−0.15
Transport equipment	0.01	0.03	0.02
Machinery and other equipment	0.08	0.03	0.05
ICT (b)	0.42	0.31	0.36
Communication equipment	0.07	0.09	0.09
Hardware equipment	0.29	0.21	0.24
Software	0.06	0.01	0.03
Neutral	−0.60	−1.28	−0.99

Figure 1: ICT deepening 1980-2004

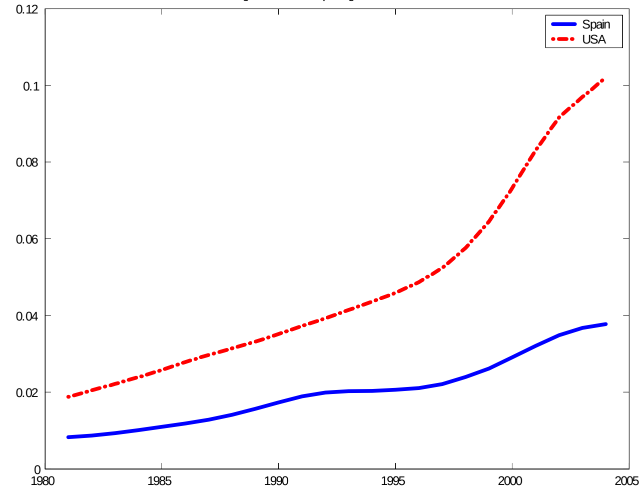

Figure 2: TFP growth rates 1980-2004

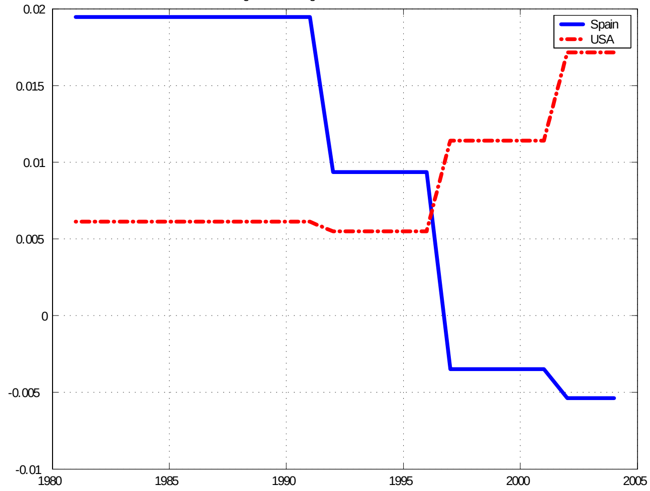


Figure 3: ICT growth rates 1980-2004
Spain
USA
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
1980
1985
1990
1995
2000
2005