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The Productivity Paradox and the New Economy: The Spanish Case

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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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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. And that 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 as straightforward as expected, but a set of issues appear as necessary conditions to be hold (Wolff, 1996, 2006; 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" (The Economist, July 24th-30th, 1999). 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.

Hernando and Nuñez (2004) find that ICT producing sector has contributed positively to output growth although this contribution has remained small. Additionally, in terms of TFP, ICT manufacturing has experienced much higher growth rates than other sectors, in a sharp contrast to the TFP slowdown of the economy as a whole. Mas and Quesada (2005, 2006) also detect a better behavior of ICT intensive sectors in terms of growth rates of output but they find negative TFP growth rates even in 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 *et al.* (1997), Greenwood *et al.* (2000), Kiley (2001), Pakko (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 results show that Spain may be placed in the productivity paradox. Despite the relatively high growth rates of ICT investment, the steady-state we have computed is characterized by a negative growth of labor productivity. This result is caused by a negative impact of the traditional capital assets while the ICT capital inputs as a whole have a positive influence on the growth of output per worker. Growth of TFP has a negative and substantial effect on the dynamics of productivity. Though striking, these results are consistent with the evidence found by other papers for the U.S. economy (Greenwood and Yorukoglu, 1997; 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 and makes an interpretation of the results. Finally, Section 6 concludes.

2 A look at international evidence: a growth accounting exercise

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 (ascending) according to the ICT-capital deepening (ICT/K) during the last period 2000-2004. Some useful 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 average). 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 ICT non-intensive 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 ICT non-intensive users (see the fall in the average 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).

Finally, Table 2 computes a simple decomposition of the GDP growth and the productivity growth for the last period 2000-2004, using the same data base. Output is assumed to be produced by three inputs: labor (in hours worked), ICT capital and non-ICT capital. The first panel of table collects the growth rates of both GDP and the three inputs. ICT growth rates contrast sharply with those of non-ICT capital. Employment negatively grows in most of the countries. The second panel of Table 2 presents the cost shares. Labor cost share is about 2/3 of total costs, as is usual in this type of analysis. The use of ICT input represents about a 3% of total costs. Using these shares for weighting the growth rates, the following two panels present a decomposition analysis for the GDP growth and productivity growth. TFP growth is calculated as a residual.

ICT capital appears as the main GDP growth contributor in the ICT intensive group, except Belgium. Outside this group, ICT is also the most relevant factor for German GDP growth. Ireland and Greece are two important particular cases, where GDP growth has been mainly based on non-ICT capital inputs, and TFP growth rates are even higher than those of the ICT intensive group. The contribution of ICT to labor productivity growth is always more important than that of non-ICT in the ICT intensive group. In the rest of countries, productivity growth is mainly due to the non-ICT input. Hence, ICT account for an important fraction of output growth and productivity growth for the intensive users. In the EU-15 as a whole, non-ICT capital favors output and productivity growth more than ICT input. Therefore, the European growth pattern is totally different to that of the U. S. economy (see the first and the last row of Table 2).

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 (see Table 1). 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 90s. Negative rates of growth for TFP and productivity are found, and ICT capital deepening decreases 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.

In view of Table 2, ICT assets is the least source to GDP growth in Spain while employment is the main one. The effect of non-ICT capital on productivity is higher than that of ICT (0.41% > 0.19%), but the negative sign in TFP growth almost absorbs both contributions, implying that productivity poorly grows by 0.07%. By contrast, labor and non-ICT assets are the main sources of GDP growth. The contribution of ICT assets is about 5 to 6 times smaller than those of labor and non-ICT capital.

[**Tables 1 and 2 about 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. As a contribution, we incorporate two new features. First, 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. Second, we consider the price of each capital 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.

We use a production function that relates output with seven inputs: L is labor in hours worked; K_1 constructions and other (non-residential) buildings; K_2 transport equipment; K_3 machinery and other equipment; K_4 communication equipment; K_5 hardware; and K_6 software. The first three types of capital are grouped into non-ICT capital inputs, whereas the other three types are ICT inputs. The economy is inhabited by an infinitely lived, representative agent of household who has time-separable preferences in terms of consumption of final goods, $\{C_t\}_{t=0}^{\infty}$, and leisure, $\{O_t\}_{t=0}^{\infty}$. In order to take into account the effect of taxation on capital accumulation we introduce the role of government. The government levies private consumption goods, capital income and labor income, to finance an exogenous sequence of lump-sum transfers, $\{T_t\}_{t=0}^{\infty}$. For simplicity, the government balances its budget in each period.

3.1 Household

Consider a model economy where the decisions made by a representative consumer whose preferences are represented by the following utility function:

$$U\left(C_t, N_t\overline{H} - L_t\right) = \gamma \log C_t + (1-\gamma)\log\left(N_t\overline{H} - L_t\right), \tag{1}$$

where $0 < \gamma < 1$. Private consumption is denoted by C_t. Leisure is $O_t = N_t\overline{H} - L_t$, and is computed as the number of effective hours in the week times the number of weeks a year ($\overline{H}$), times population in the age of taking labor-leisure decisions (N_t), minus the aggregated number of hours worked a year (L_t). γ is the elasticity of substitution between consumption and leisure. The budget constraint faced by the consumer is:

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

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, K_t is total capital, where $K_t = \sum_{i=1}^{6} K_{i,t}$, W_t is the wage, $R_{i,t}$ is the interest rate of capital type i, and τ^c, τ^l, τ^k, are the private consumption tax, the labor income tax and the capital income tax, respectively. The budget constraint says that consumption and investment cannot exceed the sum of labor and capital rental income net of taxes and lump-sum transfers. Note that capital income has six components, each of them with a different rental rate $R_{i,t}$.

The problem faced by the consumer is to choose C_t, L_t, and I_t to maximize the present expected value of lifetime utility as given by:

$$\underset{\{C_t,L_t\}_t^\infty}{Max} E\sum_{t=0}^{\infty}\beta^t\left[\gamma\log C_t + (1-\gamma)\log\left(N_t\overline{H} - L_t\right)\right], \tag{3}$$

subject to the budget constraint, given τ^c, τ^l, τ^k. β is the discount factor.

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

$$K_{i,t+1} = \left(1-\delta_i\right)K_{i,t} + Q_{i,t}I_{i,t}, \tag{4}$$

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 depending on the type of capital we consider, 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.

Thus, the budget constraint of household can be expressed as:

$$(1+\tau^c) C_t + \sum_{i=1}^{6} \frac{K_{i,t+1} - (1-\delta_i) K_{i,t}}{Q_{i,t}} = \left(1-\tau^l\right) W_t L_t + \left(1-\tau^k\right) \sum_{i=1}^{6} R_{i,t} K_{i,t} + T_t. \quad (5)$$

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:

$$Y_t = F\left(A_t, L_t, \{K_{i,t}\}_{i=1}^{6}\right), \quad (6)$$

where A_t is a measure of total-factor, or sector-neutral, productivity and F is assumed to displays constant returns to scale in factor inputs. Assuming a Cobb-Douglas production function,

$$Y_t = A_t L_t^{\alpha_L} \prod_{i=1}^{6} K_{i,t}^{\alpha_i}, \quad (7)$$

where α_i is assets i's output share, $\{\alpha_i > 0\}_{i=1}^{6}$, $\sum_{i=1}^{6} \alpha_i < 1$, and $\alpha_L \in [0,1]$, with $\alpha_L + \sum_{i=1}^{6} \alpha_i = 1$. Final output can be used for seven purposes: consumption or investment in the six types of capital,

$$Y_t = C_t + \sum_{i=1}^{6} I_{i,t}, \tag{8}$$

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. 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

$$\tau^c C_t + \tau^l W_t L_t + \tau^k \sum_{i=1}^{6} R_{i,t} K_{i,t} = T_t. \tag{9}$$

3.4 Equilibrium

The first order conditions for the consumer are:

$$\gamma \frac{1}{C_t} - \lambda_t (1 + \tau^c) = 0, \tag{10}$$

$$-(1-\gamma) \frac{1}{N_t \overline{H} - L_t} + \lambda_t \left(1 - \tau^l\right) W_t = 0, \tag{11}$$

$$E_t \beta^t \lambda_{t+1} \left[\left(1 - \tau^k\right) R_{i,t+1} + \frac{(1-\delta_i)}{Q_{i,t+1}} \right] - \frac{\lambda_t}{Q_{i,t}} \beta^{t-1} = 0, \tag{12}$$

for each $i = 1, ...6$. λ_t is the Lagrange multiplier assigned to date's t restriction. Combining (10) and (11) we obtain the condition that equates the marginal disutility of additional hours of work with the marginal return to additional hours:

$$\frac{1}{N_t \overline{H} - L_t} = \frac{\gamma}{(1-\gamma)} \frac{\left(1 - \tau^l\right)}{(1 + \tau^c)} \frac{W_t}{C_t}. \tag{13}$$

Equation (12) 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.

The first order conditions for profit maximization are:

$$R_{i,t} = \alpha_i \frac{A_t}{K_{i,t}} L_t^{\alpha_L} \prod_{i=1}^{6} K_{i,t}^{\alpha_i},\ i = 1, ...6, \tag{14}$$

$$W_t = \alpha_L A_t L_t^{\alpha_L - 1} \prod_{i=1}^{6} K_{i,t}^{\alpha_i},\ i = 1, ...6. \tag{15}$$

From the above equations we can obtain the following relations that will be useful for our calibration:

$$R_{i,t} K_{i,t} = \alpha_i A_t L_t^{\alpha_L} \prod_{i=1}^{6} K_{i,t}^{\alpha_i} = \alpha_i Y_t,\ i = 1, ..., 6, \tag{16}$$

$$W_t L_t = \alpha_L A_t L_t^{\alpha_L} \prod_{i=1}^{6} K_{i,t}^{\alpha_i} = \alpha_L Y_t,\ i = 1, ..., 6. \tag{17}$$

Additionally, the economy satisfies the feasibility constraint:

$$C_t + \sum_{i=1}^{6} I_{i,t} = \sum_{i=1}^{6} R_{i,t} K_{i,t} + W_t L_t. \tag{18}$$

First order conditions for the household (10), (11) and (12), together with the first order conditions of the firm (16) and (17), the budget constraint of the government (9), and the feasibility constraint of the economy (18), 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 $\left\{C_t, N_t\overline{H} - L_t, I_{i,t}\right\}_{t=0}^{\infty}$, a sequence of capital and labor utilization for the firm $\{K_{i,t}, L_t\}_{t=0}^{\infty}$, a sequence of the state of technology for producing each capital asset $\{Q_{i,t}\}_{t=0}^{\infty}$, and a sequence of government transfers $\{T_t\}_{t=0}^{\infty}$, for all $i = 1, ..., 6$, such that given a sequence of prices $\{W_t, R_{i,t}\}_{t=0}^{\infty}$ and taxes $\left\{\tau^c, \tau^k, \tau^l\right\}$:

i) The optimization problem of the consumer is satisfied.

ii) Given the prices for capital and labor, the first order conditions of the firm hold.

iii) Given a sequence for taxes, 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 at the rate of population. As we assume no population growth along the balanced growth path, this implies no hours worked growth.

Note that along a balanced growth path, output, consumption and investment have to grow at the same rate. However, the different types of capital would grow at a different rate, slower or faster, depending on the evolution of their relative prices. The rest of variables will grow at the same rate as output, which is denoted by g. Consequently, the balanced growth path is characterized by the following set of equations:

$$\beta\left[\left(1-\tau^{k}\right)\overline{R}_i Q_i + 1 - \delta_i\right] - 1 = 0, \tag{19}$$

$$\overline{I}_i = \frac{\delta_i \overline{K}_i}{Q_i}, \tag{20}$$

for $i = 1, ..., 6$, and

$$\overline{Y} = \overline{C} + \sum_{i=1}^{6} \overline{I}_i, \tag{21}$$

$$\overline{L} = \overline{NH} - \frac{1-\gamma}{\gamma}\frac{(1+\tau^{c})}{(1-\tau^{l})}\frac{\overline{C}}{\overline{W}}, \tag{22}$$

where a bar over a variable denotes its steady-state value. From the production function the balanced growth path implies that:

$$g = g_A \prod_{i=1}^{6} g_i^{\alpha_i}, \ i = 1, ..., 6, \tag{23}$$

where g_A is the steady state exogenous growth of A_t and where the growth of each capital input is defined as:

$$g_i = \eta_i g, \ i = 1, ..., 6, \tag{24}$$

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 (or labor augmenting technological progress, given the Cobb-Douglas function), and by increases in the capital stock. However, expression (24) says that the capital stock growth depends on technological progress in the process producing the different capital goods. Therefore, it is possible to express the output growth rate as a function of the exogenous growth rates of production technologies:

$$g = g_A^{1/\alpha_L} \prod_{i=1}^{6} \eta_i^{\alpha_i/\alpha_L}, \; i = 1, ..., 6. \tag{25}$$

This implies that 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.

4 Data and Calibration

Before simulating the model, values must be assigned to the parameters. The parameters of the model are:

$$\left(\{\alpha_i, \delta_i\}_{i=1}^{6}, \beta, \gamma, \tau^c, \tau^i, \tau^k \right).$$

In calibrating the model presented in the previous section we need four different sets of information: input and output series, technological parameters, taxes rates and preference parameters.

4.1 Input and output series and technological parameters

As was pointed out in the Introduction, we follow the recommendations of OECD (2001a and b) for constructing the series of capital assets, which are based on the concept of *capital services*, instead of *gross* or *net* capital stocks. The idea is to capture the productive services embedded into the stock of capital. Formally, let $K(i)_t$ be the productive capital of asset i at time t.

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:

$$VCS_{it} = \mu_{it} K\left(i\right)_{t-1}, \tag{26}$$

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

$$\mu_{it} = Q_{i,t-1}\left(r_t + \delta_{it} - q_{it}\right), \tag{27}$$

where r_t is the nominal interest rate, δ_{it} is the depreciation rate and q_{it} is the rate of variation of price Q_i of asset i.

Data we have used to deal with these variables come from several sources. Productive capital $K\left(i\right)_t$ series have been drawn from Mas *et al.* (2005a). Prices of assets $Q_{i,t-1}$ have been elaborated on the basis of deflators provided by Mas *et al.* (2005), and following the procedure they use for the Spanish case, that is, taken account the U. S. deflators for ICT assets and the relative prices between Spain and USA, as the OECD recommends to overcome the deficiencies of Spanish statistics. The nominal interest rate r_t consists of the sum of the rate of return (exogenously fixed at 4%, as Mas and Quesada (2005) do) and the inflation rate, computed as a three year centered moving average of the RPI.

Depreciation rate δ_{it} has been obtained according to the methodology of Mas and Quesada (2005). It has been computed as the ratio of investment resources devoted to depreciation over the gross capital stock. Finally, 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.

As regards data, we use the work of Mas and Quesada (2005), who provide an estimation of eighteen productive capital assets for Spain for 1964-2002. Non-ICT series have been grouped into three assets: buildings and constructions, machinery and other equipment, and transport equipment, whereas ICT series have been aggregated into three assets: communication equipment, hardware and software.

In turn, the expressions of cost shares are given by the following formulae:

$$\alpha_{Lt} = \frac{RE_t}{TC_t} \tag{28}$$

$$\alpha_{it} = \frac{VCS_{it}}{TC_t}, \tag{29}$$

where RE_t is the remuneration of employees and TC_t is the sum of RE_t and VCS_{it}. Mixed incomes have been reassigned into labor and capital according to the weight of remuneration of employees over the GVA.

Series for Gross Value Added (GVA) come from the *Instituto Nacional de Estadística* (INE). 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, incomes from private households with employed persons and real state businesses.

Finally, we assume that each adult has a time endowment of 96 hours a week (therefore, $H = 96 \times 52 = 4992$). Population aged 15 to 64 years and average hours worked a year are obtained from the INE.

4.2 Tax rates

We need realistic measures of tax rates in order to take into account the distortionary effects of taxes, particularly on capital accumulation. Agents' decisions depend on marginal tax. However, the estimation of marginal tax rates is a difficult task and as pointed out by Mendoza *et al.* (1994) is often an impractical task given limitations imposed by data availability and difficulties in dealing with the complexity of tax systems. Mendoza *et al.* (1994) proposed a method to estimate effective average taxes and show that their estimated average tax rates are within the range of marginal tax rates estimated in previous works and display very similar trends. On the other hand, Mendoza *et al.* (1994) argue that their definition of effective average tax rate can be interpreted as a confident estimation of specific tax rates that a representative agent takes into account. In this paper we use effective average tax rates, that we borrow from Boscá *et al.* (2005), which use the methodology proposed by Mendoza *et al.* (1994) to estimate effective average tax rates for Spain for the period 1964-2001. To that end, we use the average values for the period 1995-2001.

4.3 Preference parameters

Preference parameters are calibrated using data for the years 1995-2002, taken from the OECD National Account Database and from the input series described above. To calibrate the effective discount factor β, we use the first-order condition in steady state with respect to the capital:

$$\beta = \frac{1}{(1-\tau^k)\,\overline{R}_i Q_i + (1-\delta_i)} \tag{30}$$

Note that in equilibrium the different rental capital must be equal. Therefore, we have six conditions for matching the value of the discount factor. Similarly, the elasticity of substitution between consumption and leisure γ is calibrated using the first order conditions with respect to consumption and leisure in steady state:

$$\gamma = \frac{\overline{C}}{\left(\frac{1-\tau^l}{1+\tau^c}\right)\overline{W}\left(\overline{NH}-\overline{L}\right)+\overline{C}} \tag{31}$$

Finally, Table 3 collects the parameters we have calibrated according to the above indications.

[**Table 3 about here**]

5 ICT contribution to productivity growth in Spain

Using the parameters calibrated in the above section, we proceed to study the quantitative importance of investment-specific technological change in explaining labor productivity growth in Spain over the period 1995-2002. We follow the strategy by Greenwood *et al.* (1997), which consists of using data on equipment (communications, hardware and software) prices as a measure of investment-specific technological change. However, we use six different capital inputs, one of them with its own price. This will allow us to quantify the contribution to growth of different ICT inputs.

Previously, it is interesting to take a look at the actual values (and their dynamics) of the main variables involved. Table 4 reports the growth rates for output, labor and capital assets across 1995-2002, and within two subperiods, 1995-1998 and 1998-2002. It is worth mentioning the negative evolution experienced by labor productivity growth over the sample. While real GVA grew at an average rate of 3.41 percent a year, labor did at 3.80 per cent, which yielded a negative average growth of productivity of -0.39 percent per year. This is a fact that remains unchanged over the entire period.

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 prices, which in the case of hardware equipment was of about 15 percent a year.

The last row of this table reports the total factor productivity (TFP) as calculated by a simple growth accounting exercise, that is, as a residual from the growth rate representation of our Cobb-Douglas production function. The TFP presented an important contraction over the entire period, mainly during the second half of the period, where the negative rate doubled that of the first half. As long as TFP are associated with changes in the global efficiency by which economic resources are used, it now raises the question of the productivity paradox: are ICT inputs related to this negative growth rates? This *growth-accounting* result will now be confronted with that of the calibration.

[**Table 4 about here**]

Expression (25) is then used to decompose the long-run growth of labor productivity into contributions from neutral technological progress and from the six types of capital. Thus, the figures of contributions to growth coming from each production factor have been calculated assuming that the impact of remaining factors is zero (Greenwood *et al.*, 1997).

Table 5 shows the estimated values of the calibration exercise. While the actual observed growth rate of productivity is -0.39 percent (taken from Table 4), our calibration reports a value of -0.47 percent a year for this variable. This slight difference between both growth rates comes from the fact that we calibrate the balanced path of Spanish economy, which is unlikely to be the same than the actual one. Results reported in Table 5 do not reveal great differences in sign of factor contributions through capital deepening depending on the subperiod considered. In fact, those factors which exerted a positive impact on labor productivity growth in 1995-1998, remained as growth-enhancing in 1999-2002. Anyway, it could be said that the dynamics of productivity worsened in the second subperiod. Considering the period as a whole, it should be mentioned that non-ICT capital assets had a negative effect on productivity, while ICT capital inputs had a positive impact on the growth of output per worker. It is worth mentioning the case of hardware equipment, with positive effects within the range of 0.3-0.4 percentage points, while the software exerts a modest though negative impact on productivity growth. Communications plays the same small role than software but in a positive direction. With respect to non-ICT capital assets, the calibrated model gives a substantial negative impact coming from capital accumulation in constructions, acting as the reverse force of hardware. Investment in machinery also appears as negative for productivity growth while transport equipment showed a positive impact on productivity growth.

Figure 1 plots the computed total factor productivity showing a slowdown trend during the sample period, with an average growth rate of -0.8 percent by year. 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, we should take account, as was shown by Greenwood *et al.* (1997), 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[1].

Spanish economy follows here a different path than that corresponding to the most advanced countries in terms of new technologies. As is well-known, precisely in the second half of 90's, nations such as U.S., Sweden, Finland and U. K. (see Table 1) experienced an upsurge of their productivity growth. Hence, the question is: why this decreasing trend in productivity levels when Spain is increasing its ICT capital stocks at two-digit rates?

[**Table 5 here**]
[**Figure 1 about here**]

The answer is related to the changes in terms of new forms of organization at plant level which are required to obtain the full benefits from ICT. In fact,

[1]Particularly they show that considering both equipments and structures in the production function (instead of an unique broad concept of capital) makes the TFP slowdown increase.

this historical episode has already taken place in other economies. A number of papers (see Kiley, 2001, for a synthetic survey) have illustrated that point. 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. Further and recent research (Samaniego, 2006) remarks this issue: intensive ICT-user companies did not become less productive when they also adopted certain complementary changes to business organization.

On the basis of Table 1 we think that this complementary strategy to ICT adoption can be seen as a learning-by-doing process, 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 really 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 (see Table 2). Viewed in this manner, the economy needs a period of time to adapt its production process to the new equipment and organizational requirements, and consequently the positive effects of ICT is being delayed.

In terms of TFP and ICT, Spanish economy in 2000 performs like U.S. economy in the late 70s and early 80s. Figure 2 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.

Samaniego (2006) provides a detailed characterization for the dynamics of several variables in U.S. and some parallel thoughts might be guessed[2]. *First*, 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 3 and 4. Figure 3 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 4 collects 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

[2]Actually, the results by Samaniego (2006) cannot be directly compared to our case because he studies the effects of an organizational shock on the transitional dynamics to the steady-state while we exclusively deal with technological changes along the steady-state path.

negligible. In 1995, things altered and this rate has become negative for Spain and positive for the US ever since.

Second, 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 4, 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. Samaniego (2006) interprets this fact 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. Hence, according to our thesis, Spain would be now facing the organizational changes in the production process to absorb the challenges of new technology.

[**Figure 2, 3 and 4 here**]

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 equipments.

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 but suggestive 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. And that happens despite the increasing efforts in going up the ICT capital endowments. When the dynamics of productivity is decomposed into capital deepening and TFP, the former exerts a small positive impact while the latter has a clear negative effect. Behind the negligible contribution of capital deepening, we find a 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.

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Table(s)

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

	1980-1990			1990-1995			1995-2000			2000-2004		
	Δ(Y/L)	ΔTFP	ICT/K	Δ(Y/L)	ΔTFP	ICT/K	Δ(Y/L)	ΔTFP	ICT/K	Δ(Y/L)	ΔTFP	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%
United Kingdom	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%
United States	1,5%	0,61%	2,78%	1,2%	0,55%	4,27%	2,3%	1,14%	6,33%	2,8%	1,72%	9,67%
Averages: Total	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 intensive users	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 intensive users	2,0%	0,9%	1,6%	2,1%	1,0%	2,7%	2,7%	1,7%	4,4%	2,2%	1,5%	7,3%
Standard deviation	0,9%	0,8%	0,6%	0,9%	0,7%	0,8%	1,3%	1,1%	1,1%	1,3%	1,1%	1,6%
Correlation Coefficient	**Δ(Y/L)**	**ΔTFP**	**ICT/K**	**Δ(Y/L)**	**ΔTFP**	**ICT/K**	**Δ(Y/L)**	**ΔTFP**	**ICT/K**	**Δ(Y/L)**	**ΔTFP**	**ICT/K**
Δ(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	
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

Source: Timmer, Ypma and van Ark (2003) and own calculations

Table 2: An international outlook of factors contribution to growth and productivity, 2000-2004.

	Growth Rates					Shares			Contribution to growth						Contribution to productivity		
	Y	L	ICT	Non-ICT	Y/L	L	ICT	Non-ICT	L		ICT		Non-ICT	TFP	ICT		Non-ICT
EU-15	1,46%	0,40%	8,83%	1,70%	1,05%	0,6575	0,0347	0,3077	0,26%	<	0,31%	<	0,52%	0,36%	0,29%	<	0,40%
France	1,35%	-0,20%	8,60%	2,45%	1,54%	0,6441	0,0250	0,3310	-0,13%	<	0,21%	<	0,81%	0,45%	0,22%	<	0,87%
Spain	2,53%	2,46%	9,40%	3,77%	0,07%	0,6623	0,0278	0,3099	1,63%	>	0,26%	<	1,17%	-0,53%	0,19%	<	0,41%
Netherlands	0,63%	-0,09%	8,99%	1,14%	0,72%	0,7158	0,0270	0,2572	-0,06%	<	0,24%	<	0,29%	0,16%	0,24%	<	0,32%
Ireland	5,04%	0,86%	13,47%	5,03%	4,19%	0,5359	0,0255	0,4386	0,46%	>	0,34%	<	2,21%	2,03%	0,32%	<	1,83%
Greece	4,21%	1,26%	15,09%	5,30%	2,95%	0,7803	0,0241	0,1956	0,99%	>	0,36%	<	1,04%	1,83%	0,33%	<	0,79%
Austria	1,14%	-0,22%	10,90%	2,14%	1,36%	0,6318	0,0333	0,3350	-0,14%	<	0,36%	<	0,72%	0,20%	0,37%	<	0,79%
Luxembourg	2,71%	2,90%	12,86%	4,26%	-0,19%	0,6232	0,0313	0,3455	1,81%	>	0,40%	<	1,47%	-0,97%	0,31%	<	0,47%
Germany	0,51%	-0,69%	7,75%	0,32%	1,19%	0,6648	0,0326	0,3026	-0,46%	<	0,25%	>	0,10%	0,61%	0,28%	<	0,30%
Portugal	0,48%	-0,04%	10,16%	2,30%	0,52%	0,7158	0,0283	0,2558	-0,03%	<	0,29%	<	0,59%	-0,36%	0,29%	<	0,60%
Denmark	1,29%	-0,08%	11,16%	2,98%	1,36%	0,6490	0,0456	0,3054	-0,05%	<	0,51%	<	0,91%	-0,08%	0,51%	<	0,94%
Italy	0,88%	1,32%	10,05%	2,46%	-0,45%	0,6047	0,0375	0,3578	0,80%	>	0,38%	<	0,88%	-1,18%	0,33%	<	0,41%
Belgium	1,34%	0,74%	10,97%	0,36%	0,60%	0,7026	0,0400	0,2574	0,52%	>	0,44%	>	0,09%	0,29%	0,41%	>	-0,10%
Finland	2,27%	-0,54%	10,84%	0,24%	2,80%	0,6409	0,0493	0,3098	-0,34%	<	0,53%	>	0,07%	2,00%	0,56%	>	0,24%
United Kingdom	2,32%	0,30%	8,27%	1,09%	2,02%	0,6949	0,0440	0,2611	0,21%	<	0,36%	>	0,28%	1,47%	0,35%	>	0,21%
Sweden	2,05%	-0,60%	6,83%	0,69%	2,65%	0,6927	0,0533	0,2540	-0,41%	<	0,36%	>	0,18%	1,92%	0,40%	>	0,33%
United States	2,38%	-0,40%	9,14%	1,76%	2,78%	0,7005	0,0578	0,2417	-0,28%	<	0,53%	>	0,43%	1,71%	0,55%	>	0,52%

Source: Timmer, Ypma and van Ark (2003) and own calculations

Table 3: Calibrated parameters values

$\alpha_1 =$	0,068	$\delta_1 =$	0,015	$\beta =$	0,975
$\alpha_2 =$	0,039	$\delta_2 =$	0,143	$\gamma =$	0,458
$\alpha_3 =$	0,096	$\delta_3 =$	0,097	$\tau^c =$	0,110
$\alpha_4 =$	0,025	$\delta_4 =$	0,097	$\tau^l =$	0,340
$\alpha_5 =$	0,012	$\delta_5 =$	0,193	$\tau^k =$	0,220
$\alpha_6 =$	0,015	$\delta_6 =$	0,449		

Table 4: Output, capital and TFP growth rates

	1995-1998	1998-2002	1995-2002
Real GVA	3,56	3,30	3,41
Labor	3,71	3,86	3,80
Productivity	-0,15	-0,56	-0,39
Non ICT	3,91	4,35	4,16
Constructions	*4,19*	*4,66*	*4,46*
Transport Equipments	*3,50*	*4,44*	*4,04*
Machinery	*2,83*	*2,89*	*2,86*
ICT	9,92	13,64	12,04
Communications	*5,99*	*9,21*	*7,83*
Hardware	*20,92*	*21,31*	*21,14*
Software	*8,14*	*12,18*	*10,45*
TFP	-0,46	-1,07	-0,80

Table 5: Sources of average labor productivity growth, Spain 1995-2002

	1995-1998	1998-2002	1995-2002
Average labor productivity	-0,13	-1,02	-0,47
Contribution of capital deepening	0,09	-0,27	0,05
Non ICT	-0,34	-0,57	-0,44
Constructions	*-0,19*	*-0,41*	*-0,30*
Transport Equipments	*0,12*	*0,08*	*0,10*
Machinery	*-0,27*	*-0,24*	*-0,24*
ICT	0,42	0,30	0,48
Communications	*0,06*	*0,07*	*0,07*
Hardware	*0,42*	*0,28*	*0,46*
Software	*-0,06*	*-0,05*	*-0,05*
TFP	-0,22	-0,75	-0,52

Figure 1

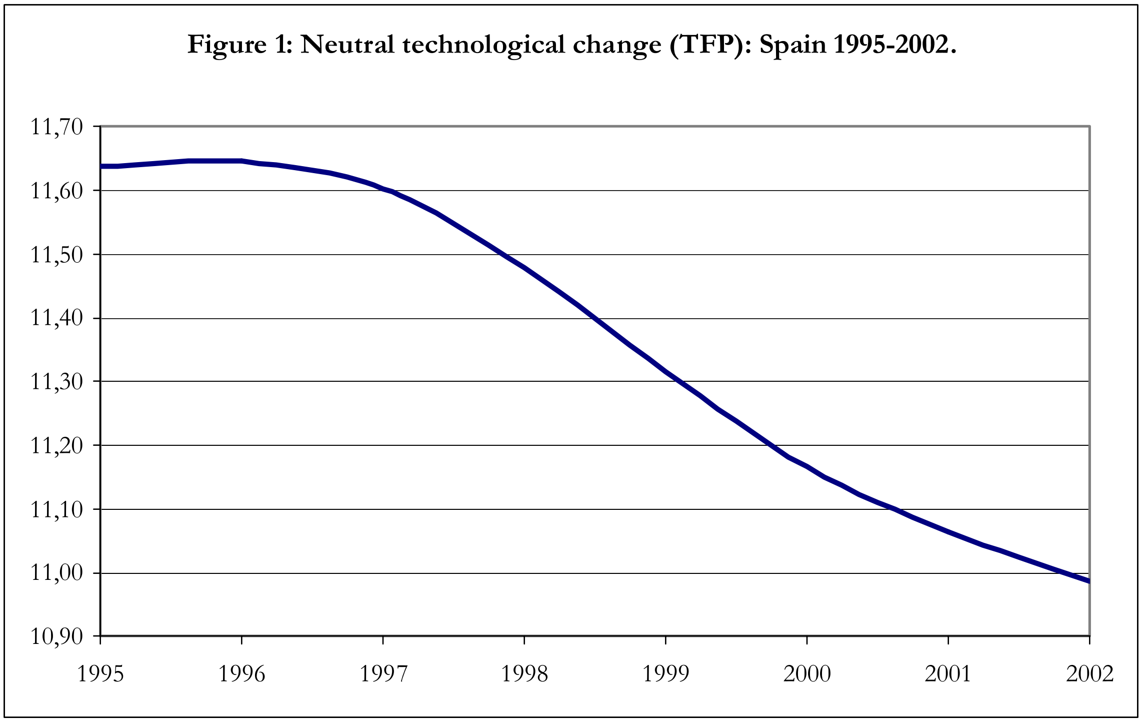


Figure 1: Neutral technological change (TFP): Spain 1995-2002.
11,70
11,60
11,50
11,40
11,30
11,20
11,10
11,00
10,90
1995
1996
1997
1998
1999
2000
2001
2002

Figure 2

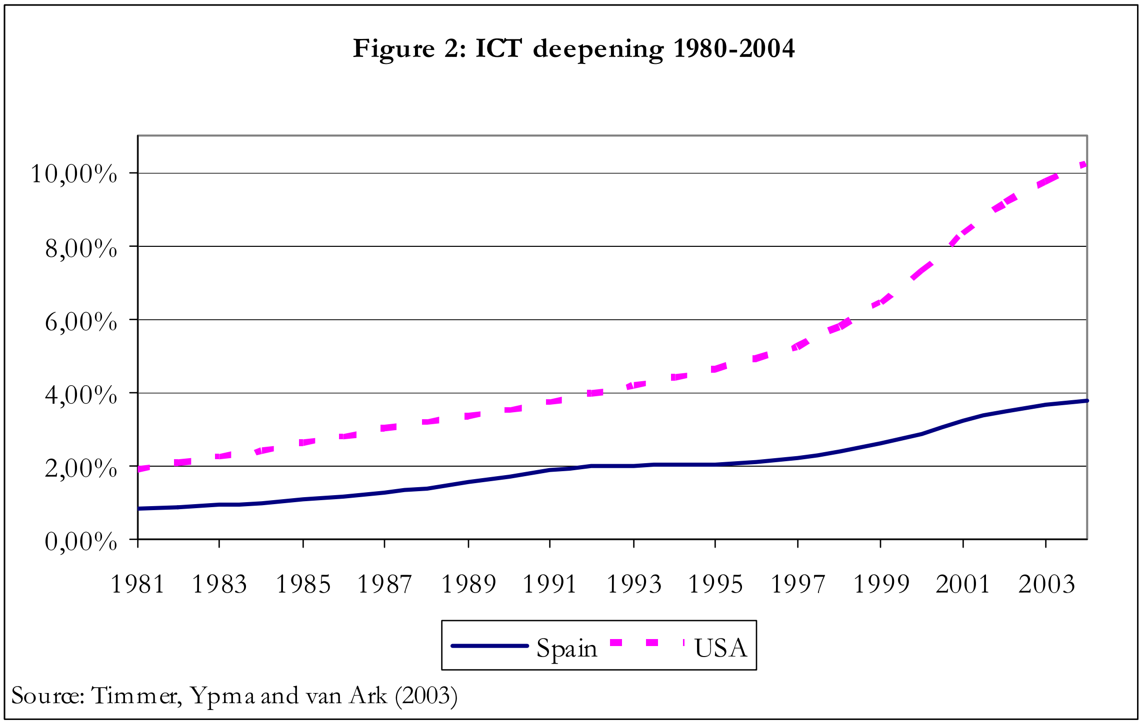


Figure 2: ICT deepening 1980-2004
10,00%
8,00%
6,00%
4,00%
2,00%
0,00%
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
Spain
USA
Source: Timmer, Ypma and van Ark (2003)

Figure 3

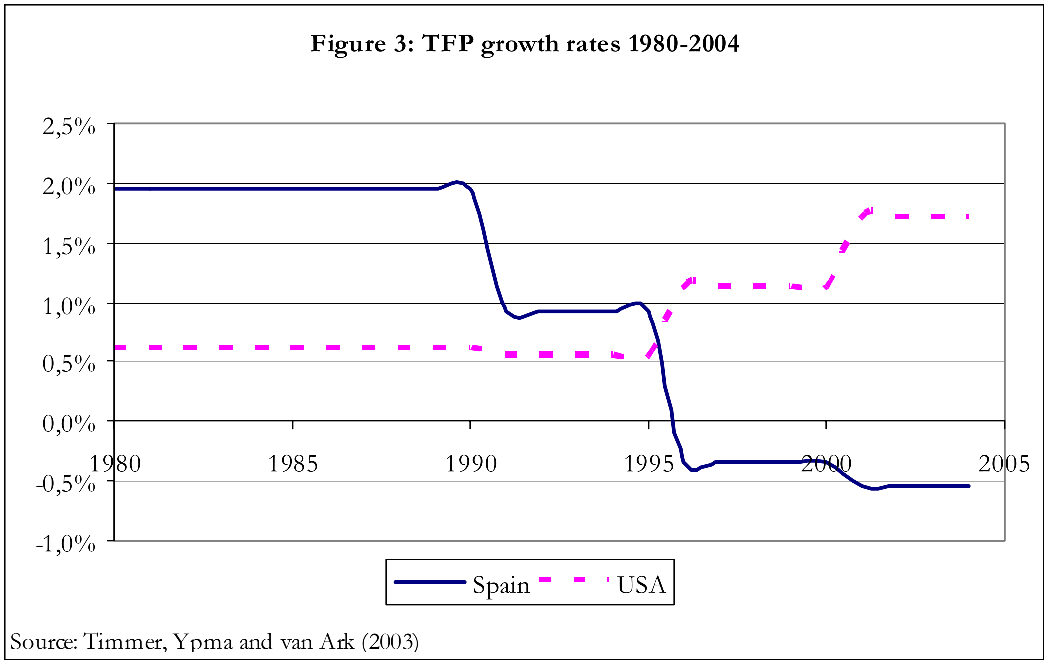
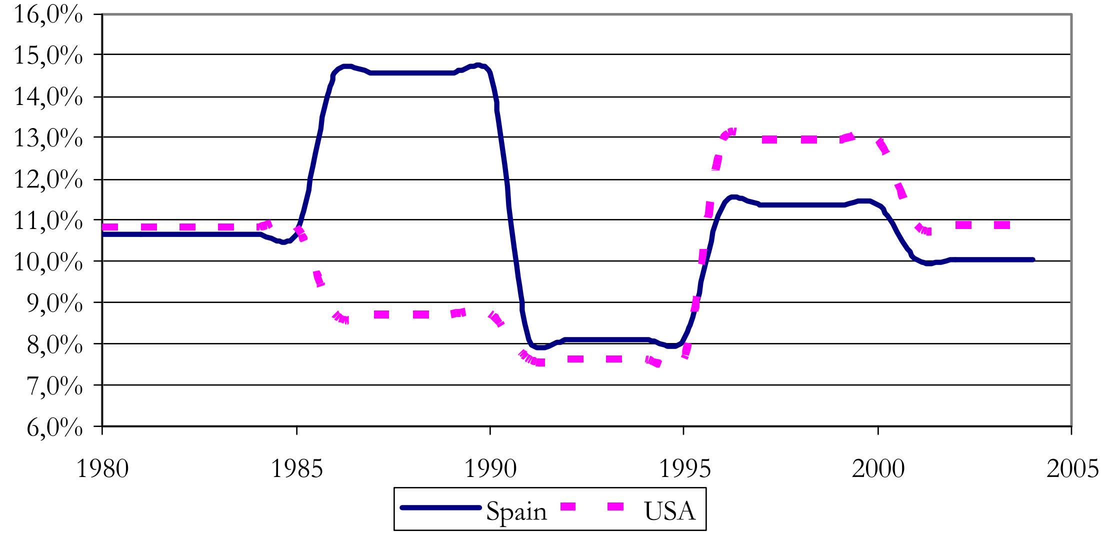


Figure 3: TFP growth rates 1980-2004
2,5%
2,0%
1,5%
1,0%
0,5%
0,0%
-0,5%
-1,0%
1980
1985
1990
1995
2000
2005
Spain
USA
Source: Timmer, Ypma and van Ark (2003)

Figure 4

Figure 4: ICT growth rates 1980-2004



Source: Timmer, Ypma and van Ark (2003)