Neutral, Investment-Specific Technical Progress and the Productivity Slowdown

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1 Introduction

After the Second World War, the US economy and other western economies have displayed a long time of prosperity characterized by high growth rates of both GNP per capita and total factor productivity (TFP). However, this piece of luck was cut short about 1974. Two facts characterize the period after 1974 :

(i) *The growth rates of TFP and GNP per capita are lower after 1974 than before 1974.* The so-called Productivity Slowdown is a topic playing a dominate role in the last twenty years in macroeconomics.[1] Paradoxically, casuistry suggests that period after 1974 has been one of great technical change (arising and developing of information technologies is one of the most important facts characterizing this period). This puzzle was expressed in the famous Solow paradox, "Computers are everywhere except in the productivity statistics".[2] The following table taken from Gordon (2000a) reveals the extent of the slowdown for the US economy.[3]

(ii) *The rate of investment-specific technical progress (ISTP) has raised after 1974 and the rate of neutral technical progress (NTP) has decreased after* 1974. This *technical reassignment* after 1974 is hold by several sources of

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[1] See Wolff (1985) for a survey.

[2] The question about the end of the productivity slowdown remains open. The growth rate of productivity has undergone a recovery after 1995. But, the nature and extent of this recovery are discussed (see Gordon (1999, 2000b) and Nordhaus (2001) to know the different points of view in the debate).

[3] Wolf (1996) documents the extent of the productivity slowdwon for six developed countries.

Table 1 : *Output and TFP for Non-farm Non-housing Business GDP, Annual Growth Rates over Selected Intervals, 1950-1996.*

Years	Output	TFP
1950-1964	3.50	1.47
1964-1972	3.63	0.89
1972-1979	2.99	0.16
1979-1988	2.55	0.59
1988-1996	2.74	0.79

Source : Table 1 in Gordon (2000a).

empirical evidence. Greenwood and Yorukoglu (1997) find that the decline of the relative price of equipment, which can be seen as a proxy of the rate of ISTP, has experienced a significant acceleration after 1974 in the US economy, passing from 3.3% per year to 4%. The analysis of the growth rate of productivity by sectors can also put some light about the composition of technical progress. Sectorial changes in productivity after 1974 with respect to the previous period suggest that technical progress is more investment-specific and less neutral after 1974. As Kortum (1997) noticed "two industries display much more rapid productivity growth after 1974 than before, industrial machinery (which include computing equipment) and electrical equipment. All the rest either had roughly constant productivity growth or slower productivity growth after 1974". The data of Table 2 are consistent with a change in the composition of technical progress. Technical reassignment has been suggested also by works on growth accounting. Hulten (1992) found that the rate of NTP suffers an important fall after 1974 in the US economy, passing from 1.57% per year in the period 1949-1983 to 0.20% per year in the period 1974-1983. Hulten (1992) adjusted output of investment goods by quality. If this quality-adjustment is dropped of his exercise, the rate of NTP is 1.18% per year before 1974 and −0.22% per year after 1974. This dramatic downturn in the rate of NTP after 1974, accompanied by an acceleration of the rate of ISTP, is also reported by Greenwood, Hercowitz and Krusell (1997).[4]

Table 2 : *Output per Hour, 1950-1996, Percentage Growth Rate at Annual Rate.*

Sector	1950 : 2 – 1972 : 2	1972 : 2 – 1995 : 4
Durables	2.32	3.05
Nonfarm Nondurables	2.68	0.80

Source : Table 1 in Gordon (1999).

In this paper I show that the observed increase of the rate of ISTP might be responsible for the Productivity Slowdown suffered by the US economy

[4] The importance of the ISTP is undenaible today. In particular, Greenwood, Hercowitz and Krusell (1997) using the Gordon's (1990) price index of equipment have found that around 60% of US productivity growth can be atributed to ISTP.

after 1974. I build a dynamic general equilibrium model in which technical progress is both investment-specific and neutral, and in which newer and more efficient capital goods are more expensive. I show that if this economy undergoes a permanent positive shock on the rate of ISTP, it will experience a period of low growth of both output per capita and TFP, as calculated by the Solow residual. The reason is that a higher rate of ISTP increases obsolescence costs of capital and production and/or adoption costs of new and more efficient capital. I also show that the extent of this productivity slowdown crucially depends on the elasticity of the marginal cost producing a unit of capital good with respect to the rate of ISTP. Moreover, the productivity slowdown might be a long run feature. Since the available data suggest that the rise of the rate of ISTP was accompanied by a fall of the rate of NTP, I also explore consequences of this technical reassignment on the growth rate of both output per capita and TFP. Not surprisingly, technical reassignment enhances the productivity slowdown.

My paper is closely connected with that of Greenwood and Yorukoglu (1997) and Greenwood and Jovanovic (1998), and specially with that of Hulten (1996). But, differently to Greenwood and Yorukoglu (1997) and Greenwood and Jovanovic (1998) I do not assume learning and diffusion costs of the new technologies. I assume that production and/or adoption of new and more efficient capital goods is more expensive, just as Hulten (1996). I should be noticed that in my model the economy might display a productivity slowdown even if technical progress is costless. However, the elasticity of the marginal cost of producing a unit of capital good with respect to the growth rate of efficiency of capital goods is a key parameter in the model because the extend of the Productivity Slowdown crucially depends on its size. Differently to Hulten (1996) I develope a model in which saving decisions are taken by a household maximizing its intertemporal utility.

The rest of the paper is organized as follows. In Section 2 I present the model. In Section 3 I show as an increase in the rate of ISTP might be responsible for the Productivity Slowdown, and two numerical exercises are performed. Finally, Section 4 concludes.

2 The Economy

A competitive firm produces a good using capital and labor, which is consumed or invested. This good is used as numeraire and its price therefore normalized to 1. Its production function is Cobb-Douglas,

$$y_t = e^{\gamma t} k_t^{\alpha}, \tag{1}$$

where $0 < \alpha < 1$, y_t is the flow of output per worker at time t, $e^{\gamma t}$ is the state of neutral technical knowledge at time t, and $\gamma \geqslant 0$ the rate of NTP.

k_t is the efficient capital stock per worker at time t, and its evolution law is

$$\dot{k}_t = i_t e^{\lambda t} - (\delta + n)\, k_t, \tag{2}$$

where i_t are the amount of capital goods per worker produced and added to capital at time t, $e^{\lambda t}$ is efficiency of capital goods of vintage t, which grows at the constant rate $\lambda \geqslant 0$ (λ is the rate of ISTP), and $\delta \geqslant 0$ and $n \geqslant 0$ are respectively the depreciation rate of capital and the population growth rate.[5]

I assume that newer and more efficient capital goods also are more expensive, because their production and/or adoption is more costly. So, I assume that the cost of adding a unit of capital good of vintage t to capital stock is $e^{\mu\lambda t}$, $0 \leqslant \mu \leqslant 1$. The parameter μ is the elasticity of the marginal cost of producing a unit of capital good with respect to the growth rate of efficiency of capital goods.[6] When $\mu = 0$, innovation occurs without affecting the cost of new capital. This is the original assumption of Solow (1960). Jorgenson (1966) criticizes Solow's specification and advocates that output of investment good must be adjusted by quality. In our model, Jorgenson's specification is captured by assuming $\mu = 1$.[7]

The representative firm maximizes its discounted flow of profits subject to (1) and (2). The first order conditions of this maximization problem establish that the marginal productivities of production factors must be equal to their user costs,

$$\alpha e^{\gamma t} k_t^{\alpha - 1} = e^{-(1-\mu)\lambda t} \left(r_t + \delta + (1-\mu)\lambda \right), \tag{3}$$

$$(1-\alpha) e^{\gamma t} k_t^{\alpha} = w_t, \tag{4}$$

where r_t is the interest rate at time t, and w_t is the wage rate paid per unit of labor services. The user cost of efficient capital depends on the obsolescence cost, $e^{-(1-\mu)\lambda t}(1-\mu)\lambda$, which depends on the rate of ISTP and the elasticity of the marginal cost of producing a unit of capital good with respect to the rate of ISTP, but not on the rate of NTP. Hence, a increase of the rate of ISTP is likely to have consequences on capital accumulation.

The economy is populated by a representative household. At time t the representative household contains $N_t = e^{nt}$ individuals who have infinite lives. Each individual of the representative household supplies inelastically 1 unit of labor services per unit of time. In equilibrium, the labor market clears and the household obtains the desired quantity of employment. If C_t is household's consumption at time t, then $c_t = \frac{C_t}{N_t}$ is consumption per individual at time t. I assume that the instantaneous utility function of each individual is CIES and that the household's utility at time 0 is a weighted

5 Variables per worker equal variables per capita.

6 See Hulten (1996) for a discussion on the inclusion of this parameter in a vintage capital model.

7 See Hercowitz (1998) for a recent review of this controversy.

sum of all future flows of utility. So, the representative household wishes to maximize overall utility given by $\int_0^\infty e^{-(\rho-n)t}\frac{\left(e^{\kappa t}c_t\right)^{1-\sigma}}{1-\sigma}dt$, where $\sigma > 0$ is the inverse of the intertemporal elasticity of substitution, $\rho > 0$ is the rate of time preference, and $e^{\kappa t}$ represents quality of consumption goods at time t, which grows at the constant rate $\kappa \geqslant 0$. I assume that the price of consumption goods grows at the constant rate $\nu\kappa$, $0 \leqslant \nu \leqslant 1$. The price of consumption good at time 0 is normalized to 1. Hence, newer and higher quality consumption goods also are more costly. Moreover, I assume that

$$\kappa = \widetilde{\kappa} + \zeta\lambda, \qquad \nu = \widetilde{\nu} + \varepsilon\mu, \tag{5}$$

ζ, $\widetilde{\kappa}$, ε and $\widetilde{\nu}$ equal or higher than zero. Assumption (5) allow the growth rate of quality of the consumption goods and the elasticity of their price with respect to their growth rate of quality to be constituted out of two components: an autonomous component, which is independent from that taking place in the sector of capital goods, and other component tied to this sector. This relation can be justified because many innovations can be used to improve efficiency of new capital goods and quality of consumption goods.

The Euler condition of the household's optimization problem is

$$\frac{\dot{c}_t}{c_t} = \frac{1}{\sigma}\left(r_t - \rho + ((1-\sigma) - \nu)\,\kappa\right), \tag{6}$$

and the transversality condition is $\lim_{t\to\infty} e^{-(1-\mu)\lambda t}k_t e^{-\int_0^t (r_s - n)ds} = 0$.

Finally, the description of the economy is accomplished by the clearing condition in the good market:

$$e^{\nu\kappa t}c_t + e^{\mu\lambda t}i_t = y_t \tag{7}$$

In the steady-state, output per capita, y_t, and the real market value of capital stock per capita, a_t, grow at the same constant rate

$$g = \frac{(\gamma + \alpha(1-\mu)\lambda)}{1-\alpha} \tag{8}$$

Consumption and investment per capita in physical units, c_t and i_t, grow at the rates $g_c = g - \nu\kappa$ and $g_i = g - \mu\lambda$, and efficient capital per capita, k_t, grows at the constant rate $g + (1-\mu)\lambda$. In order to guarantee that utility at equilibrium is bounded, I impose the following condition on the parameters: $\rho > (1-\sigma)(g + \kappa(1-\nu)) + n$. This condition ensures that the transversality condition holds and that equilibrium utility is bounded. The model has only one positive steady-state which exhibits saddle-path stability. The proof is omitted here because it is similar to that corresponding to the Ramsey model with only neutral technical progress.

3 The Productivity Slowdown

In this section will be shown that an increase of the rate of ISTP might cause, at least in the short run, a fall of the growth rate of TFP as measured by the Solow residual and the growth rate of output per capita, facts characterizing the so-called Productivity Slowdown. The section ends with some numerical exercises that show the importance of the elasticity of the marginal cost of producing a unit of capital with respect to the rate of ISTP to account for the extent of the Productivity Slowdown.

The Solow residual is a concept largely used in the growth accounting literature to measure the growth rate of TFP. The Solow residual is defined as the growth rate of output per worker (uncorrected for quality) minus the share-weighted growth rate of capital per worker (also uncorrected), i.e.,

$$\Omega_t \equiv (1 - s_t)\frac{\dot{c}_t}{c_t} + s_t\frac{\dot{i}_t}{i_t} - \alpha\frac{\dot{\widehat{k}}_t}{\widehat{k}_t}, \tag{9}$$

where s_t is the share of investment in the value of output, $s_t = \frac{i_t e^{\mu\lambda t}}{y_t}$,[8] and $\widehat{k}_t$ is physical capital which is the sum of all surviving past investments and its evolution law is

$$\dot{\widehat{k}}_t = i_t - (\delta + n)\widehat{k}_t, \tag{10}$$

Following the pioneering work of Solow (1957) and predecessors discussed in Griliches (1995) a lot of works on growth accounting assume a production function exhibiting constant returns to scale and costless NTP. Using a Cobb-Douglas production function, these technological assumptions are depicted by the following equation:

$$\widehat{y}_t = c_t + i_t = z_t\widehat{k}_t^{\alpha}, \tag{11}$$

where $\widehat{k}_t$ and $\widehat{y}_t$ are respectively capital and output per worker uncorrected for quality. It follows from (11) that the Solow residual is a suitable measure of the rate of technical progress, $\Omega_t = \frac{\dot{z}_t}{z_t}$. However, when the true form of the technology is depicted by equations (1), (2) and (7), the Solow residual, computed by equation (9), is equivalent to

$$\Omega_t = \gamma + \alpha\frac{\dot{\psi}_t}{\psi_t} - s_t\mu\lambda - (1 - s_t)\nu\kappa, \tag{12}$$

where ψ_t is so-called by Hulten (1992, 1996) the average embodied technical efficiency, $\psi_t = \frac{k_t}{\widehat{k}_t}$. Equation (12) establishes that the Solow residual is equal to the rate of neutral technical progress plus the share-weighted growth

[8] Since the production function is Cobb-Douglas, capital's income share is constant and equal to α.

rate of the average embodied technical efficiency minus the growth rate of the marginal cost of producing a unit of capital good times the share of investment in the value of output and minus the growth rate of the marginal cost of producing a unit of consumption good times the share of consumption in the value of output. Equation (12) suggests that there is no a priori reason to expect the Solow residual to rise with the rate of ISTP, at least in the short run. First of all, the growth rate of the average embodied technical efficiency is not necessarily an increasing function of the rate of ISTP in the short run since the growth rate of ψ is given by

$$\frac{\dot{\psi}_t}{\psi_t} = \frac{i_t}{k_t}\left(e^{\lambda t} - \psi_t\right) \tag{13}$$

Equation (13) indicates that the growth rate of average embodied efficiency depends on the distance between average and best-practice efficiency and the ratio investment to efficient capital. When the rate of ISTP increases there are two opposite effects on the growth rate of ψ. New vintages of capital goods are more efficient and the growth rate of ψ rises (observe equation (13) and note that $e^{\lambda t}$ rises). However, an increase of λ implies that the user cost of capital rises because its obsolescence rate increases, which provokes a decrease of investment and, therefore, the growth rate of ψ falls (observe equation (13) again and note that if investment decreases, the growth rate of ψ falls). The average efficiency embodied in capital increases or decreases depending on which of these effects prevails. Instead, in the long run, the growth rate of ψ equals λ, and it will rise as λ increases. However, in the short run, an increase of λ might imply a lower growth rate of ψ, which actually happens for plausible values of the parameters, as it will be seem below. Finally, the rate of ISTP enters as a negative component of the Solow residual. Therefore, the sign of the derivative of the Solow residual with respect to λ is a priori ambiguous.

It should not be concluded that the Solow residual in the long run is an increasing function of the rate of ISTP because the long run growth rate of the average embodied technical efficiency rises as λ increases. If μ, ν and κ are strictly positive, then the long run Solow residual might even fall as λ increases. The Solow residual in the long run is

$$\Omega = \gamma + \alpha\lambda - s\mu\lambda - (1 - s)\nu\kappa,$$

where

$$s = \alpha\frac{\delta + n + (1 - \mu)\lambda + g}{\sigma g + \rho + \kappa(1 - \sigma)(\nu - 1) + \delta + (1 - \mu)\lambda}$$

is the long run share of investment in the value of output. Determining the sign of variation of the long run Solow residual with respect to the rate of ISTP is a priori impossible. It might either rise or fall as λ increases, depending on the values of several parameters.

From the previous discussion, it should be clear that it is not necessary that the economy undergoes a lower rate of technical progress for the growth rate of TFP, as measured by the Solow residual, to fall. Higher rates of technical progress, as long as it is more investment-specific, might imply lower Solow residual in the short run, or even in the long run. This is a possible explanation of Solow's paradox.

The period post 1974 is characterized by a fall in the growth rate of TFP together with lower growth rates of output per capita. It has been shown that higher rates of ISTP might imply lower Solow residual. This shortening of the Solow residual will likely be accompanied by lower growth rates of output per capita which is given by $g_t = \gamma + \alpha\left(\frac{\dot{\psi}_t}{\psi_t} + \frac{\dot{\hat{k}}_t}{\hat{k}_t}\right)$. This equation implies that if the reduction of the Solow residual is due to the fact that the growth rate of ψ falls when λ increases, then the growth rate of output per capita must also decrease. Note that the growth rate of ψ can fall only because investment decreases, therefore the growth rate of $\widehat{k}_t$ must reduce at the same time. The growth rate of output per capita can fall only in the short run. In the long run, the growth rate of output per capita is given by (8) which is an increasing function of λ.

I will undertake two numerical exercises. I assume that economy until 1974 was on a balanced growth path. In Exercise 1 a positive permanent shock on the rate of ISTP shakes the economy in 1974. Then, the process of adjustment to a new balanced growth path is analyzed. In Exercise 2, I assume that the positive permanent shock on the rate of ISTP is accompanied by a negative permanent shock on the rate of NTP so that the long run growth rate of output per capita remains constant. As suggested by Greenwood and Jovanovic (1998) the first balanced growth path can be seen as the path associated with the second industrial revolution. The rise in the decline rate of the relative price of equipment could be a reflection of a new technological paradigm based on information technologies. Thus, 1974 could be seen as the point of inflexion of the third industrial revolution.

I perform the quantitative exercises trying to be as close as possible to Greenwood, Hercowitz and Krusell (1997). Their production technology employs two different types of capital goods, namely equipments and structures. For the US economy, they calibrate the equipment and structures factor shares to 0.17 and 0.13, respectively, with the corresponding depreciation rates 0.056 for structures and 0.124 for equipments. The average depreciation rate, consistent with their Cobb-Douglas technology is around 0.095. Consequently, I set $\alpha = 0.3$ and $\delta = 0.095$. I take $\rho = 0.05$, $\sigma = 1$ and $n = 0$ from the same authors. They set the average growth rate of per capita output to 1.24% for the period 1954-1990. I have calibrated the growth rate of output per capita to 1.4% before 1974, $g_0 = 0.014$. Finally, they assume that only equipments profit from ISTP.[9] The decline rate of relative price

[9] Recently, Greenwood, Gort and Rupert (1999), using panel data on the age and rents of buildings interpreted with the help of a vintage capital model, find that the rate of structure-specific technological progress is about 1% per year.

of capital good is $\pi = (1-\mu)\lambda - (1-\nu)\kappa$. There is little or none empirical evidence on the values of κ, ν and μ. However, given the importance of μ for the extent of the productivity slowdown, I must mention Hulten (1996). He points out that the sum of price elasticities obtained in several price-hedonic regressions suggests that the value of μ could be near to one. I assume that κ, ν are equal to zero in all exercises, and alternative values of μ will be considered. It follows from the decline rates of equipment reported by Greenwood and Yorukoglu (1997) for both periods that the decline rate of the relative price of capital goods (equipment + structures) before 1974 has been 1.85%, $\pi_0 = 0.0185$, and after 1974 2.27%, $\pi = 0.0227$. The values of all parameters named in this paragraph remain constant in all numerical exercises. Whenever a parameter takes different values before and after 1974 I use subscript zero to denote the value before 1974 and no subscript at all to denote the value after 1974. Table 3 contains the values of parameters remaining constant in all exercises.

Table 3 : *Parametric Values Remaining Constant in Exercise 1 and 2.*

σ	α	ρ	δ	$\tilde{\kappa}$	$\tilde{\nu}$	ε	ζ	n
1	0.3	0.05	0.095	0	0	0	0	0

The selected values of μ in Exercise 1 and Exercise 2 are 0, 0.25, 0.5 and 0.8. The values for γ_0, γ, λ_0 and λ are chosen so that to be consistent with $g_0 = 0.014$, $\pi_0 = 0.0185$ and $\pi = 0.0227$. In all simulations of Exercise 1 and Exercise 2, the value of γ_0 consistent with g_0 is 0.00425.

Exercise 1 : Higher investment-specific technical progress

In this first exercise, the response to a permanent positive shock on the rate of ISTP is analyzed. I assume that the rate of NTP remains constant, $\gamma = \gamma_0$. I perform four simulations. Each one with a different value of μ. The selected values of μ are 0, 0.25, 0.5 and 0.8. Different values of λ_0 and λ are chosen so that the value of the decline rate of the relative price of capital goods before and after the shock respectively are $\pi_0 = 0.0185$ and $\pi = 0.0227$. Table 4 contains the parametric values in this first exercise.

Table 4 : *Parametric Values in Exercise 1.*

	Simulation 1.1	Simulation 1.2	Simulation 1.3	Simulation 1.4
μ	0	0.25	0.5	0.8
λ_0	0.0185	0.024666	0.37	0.0925
λ	0.0227	0.032667	0.0454	0.1135
γ_0	0.00425	0.00425	0.00425	0.00425
γ	0.00425	0.00425	0.00425	0.00425

Figure 1 depicts the behavior of the growth rate of output per capita, which is the same in the four simulations. The growth rate of output per capita initially decreases from 1.4% to 1.26%. After around two years it recovers its initial value and converges monotonically to a higher value, $g = 0.0158$.

The behavior of the Solow residual is different across the four simulations. Figures 3, 4, 5 and 6, respectively, depict the Solow residual of simulations 1.1, 1.2, 1.3 and 1.4. It can be concluded from these figures that as μ is higher, the fall in the Solow residual is higher and more persistent. For example, when μ is zero the Solow residual falls 0.02 percentage points, and after around one year it recovers its initial value. However, when the value of μ is 0.8 the Solow residual falls 0.4 percentage points, and after around twenty years it recovers its initial value. Therefore, the extent of the productivity slowdown drastically depends on the size of μ.

Exercise 2 : Technical reassignment

In this second exercise, the response to a technical reassignment shock is analyzed. I assume that the rate of ISTP increases and the rate of NTP decreases so that the long run growth rate of output per capita remains constant, $g = g_0 = 0.014$. As in Exercise 1, I perform four simulations. Each one with a different value of μ. The selected values of μ are 0, 0.25, 0.5 and 0.8. Different values of λ_0 and λ are chosen so that the value of the decline rate of the relative price of capital goods before and after the shock are $\pi_0 = 0.0185$ and $\pi = 0.0227$. The selected value from γ is 0.00299, which is consistent with the different values of λ and μ, and with $g = g_0 = 0.014$. Table 5 contains the parametric values in this second exercise.

Table 5 : *Parametric Values in Exercise 2.*

	Simulation 2.1	Simulation 2.2	Simulation 2.3	Simulation 2.4
μ	0	0.25	0.5	0.8
λ_0	0.0185	0.024666	0.37	0.0925
λ	0.0227	0.032667	0.0454	0.1135
γ_0	0.00425	0.00425	0.00425	0.00425
γ	0.00299	0.00299	0.00299	0.00299

Figure 2 depicts the behavior of the growth rate of output per capita, which is the same in the four simulations. The growth rate of output per capita initially decreases from 1.4% to 1.18%. After that it converges monotonically to its stationary value. The recovery of the growth rate of output per capita is relatively fast in the first exercise. This second exercise suggests that if a permanent positive shock on the rate of ISTP is accompanied by a permanent negative shock on the rate of NTP, then the fall of the growth rate of output per capita will be higher and its recovery will take more time.

The behavior of the Solow residual is different in the four simulations. Figures 7, 8, 9 and 10 respectively depict the Solow residual of simulations 2.1, 2.2, 2.3 and 2.4. Comparing Figures 7, 8, 9 and 10 with Figures 3, 4, 5 and 6, it can be concluded that a technical reassignment shock amplifies both magnitude and persistence of the fall of Solow residual. For example, comparing Figure 4 with Figure 8 it can be checked that when a permanent positive shock just happen the Solow residual falls 0.05 percentage points and it recovers its initial value after around two years. However, if a technical reassignment shock shakes the economy the Solow residual falls 0.17 percentage points and it recovers its initial value after around twenty two years.

4 Conclusion

The economic experience of the USA and other western countries after 1974 is characterized by the so called Productivity Slowdown. There may be many and different reasons that can account for such phenomenon. A lot of them have been suggested in the macroeconomics literature. A new one is displayed in this article. An intriguing question of this period is that casuistry suggests that it has been one of great technical change due to the arising and developing of information technologies. How a period of impressive technological developments can experience so low growth rates of Total Factor Productivity ? This paradox is answered in this paper. The answer is based on the embodied nature of technical progress caused by information technologies.

Empirical evidence suggests that the period after 1974 is characterized by an increase of the rate of investment-specific technical progress. I show that a permanent positive shock on the rate of investment-specific technical progress might cause the fall of the growth rate of both output per capita and Total Factor Productivity, as measured by the Solow residual. The reason of this productivity slowdown is the increase of the obsolescence costs tied to the investment-specific technical change. Higher investment-specific technical progress rises the obsolescence costs of capital. This increase of costs reduce investment in newer and more efficient capital goods. Consequently, the growth rate of average embodied efficiency in capital lows and the Solow residual falls.

The productivity slowdown suffered by the western economies has been of a great extent. However, as my simulations show, the productivity slowdown implied by the increase of the obsolescence costs is of limited magnitude and persistence. There is now a strong empirical evidence on the importance of investment-specific technical change for growth. There is less evidence on the resource cost of achieving a given rate of specific-investment technical change. I have shown that the cost elasticity of producing capital with respect to the rate of investment-specific technical progress plays a key role in the extent of the productivity slowdown. My simulations show that a higher cost elasticity of producing capital with respect to the rate of investment-technical progress causes a higher extent of the productivity slowdown due to the increase of the rate of investment-specific technical progress. In particular, they show that if the cost elasticity of producing capital with respect to the rate of investment-technical change is 0.8, the

Solow residual take about twenty years to recover its initial value. This value of the cost elasticity is empirically plausible because price-hedonic regressions suggest that it is not greatly less that one, as pointed out by Hulten (1996).

An explanation of the economic experience of the developed countries after 1974 solely based in the increase of the rate of investment-specific technical change is not completely satisfactory because the shortening of the growth rate of output per capita will have a limited extent, even if the Solow residual might suffer a persistent fall. But, if the dramatic desacceleration in the rate of neutral technical progress after 1974 is taken into account, then it might account for the lower growth rates of output per capita displayed by the developed economies after 1974 and at the same time to enhance the extent of the Productivity Slowdown, as measured by the Solow residual. However, a question arises from my analysis : What is the reason of this impressive technical reassignment after 1974 ?

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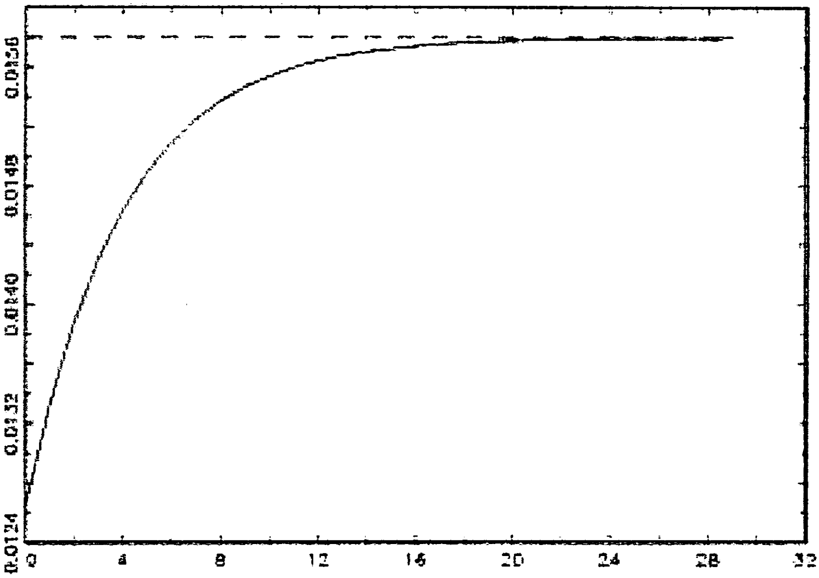
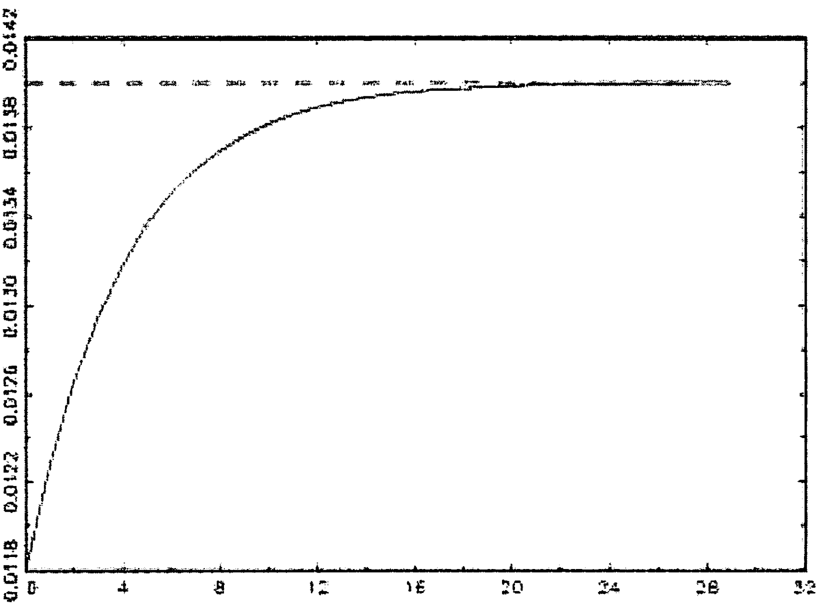


Figure 1



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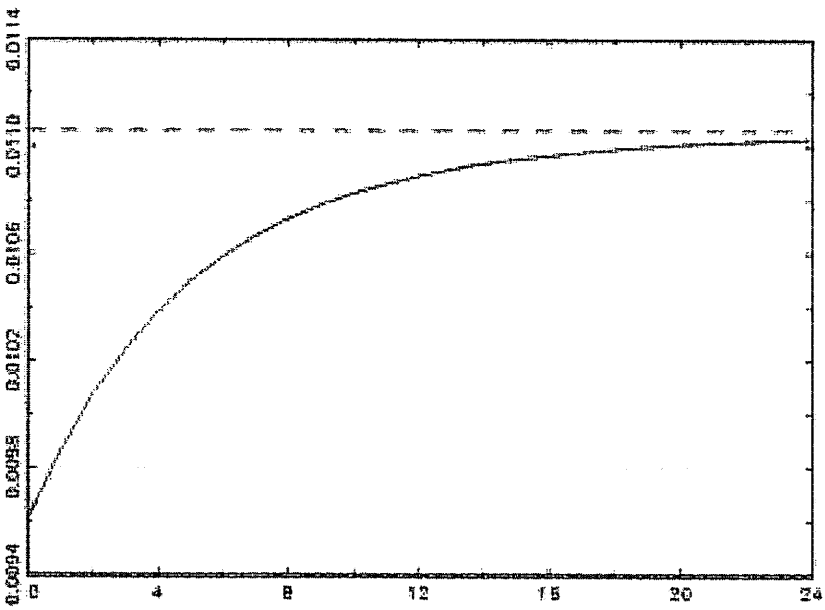

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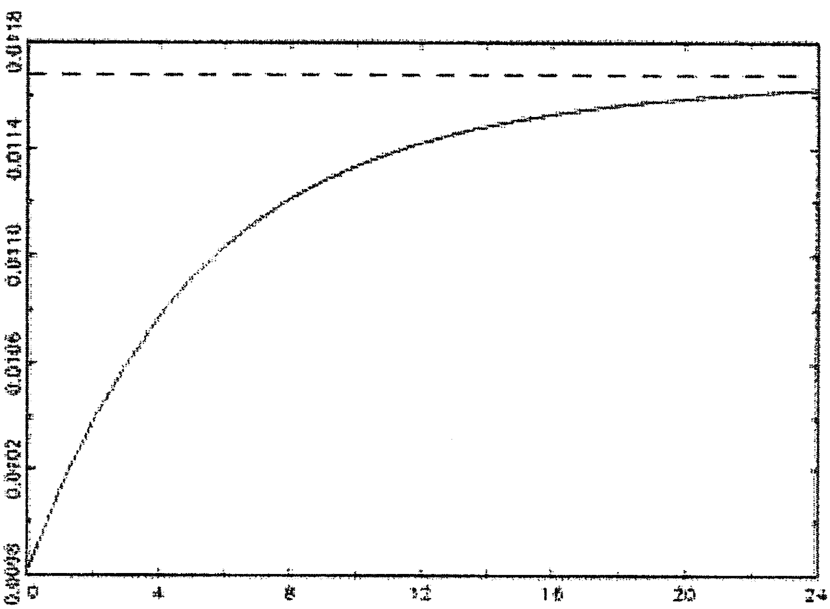

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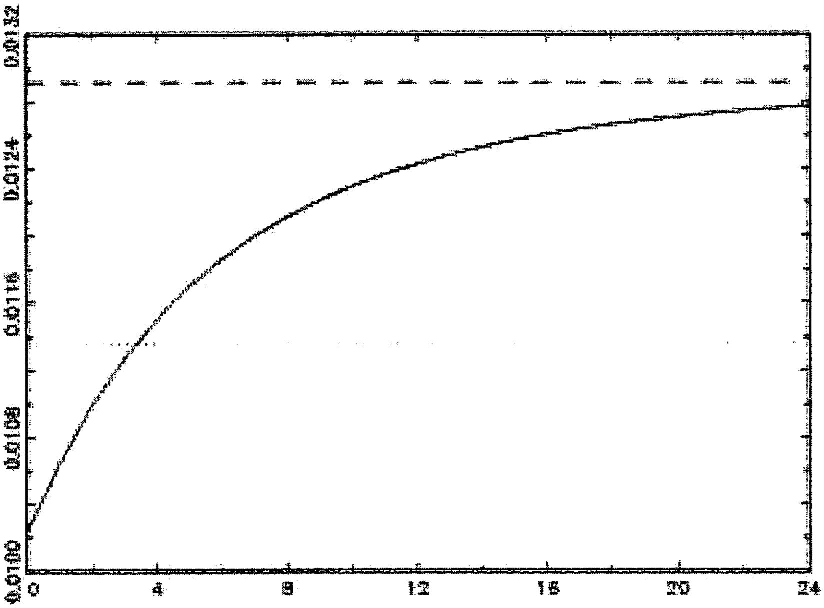

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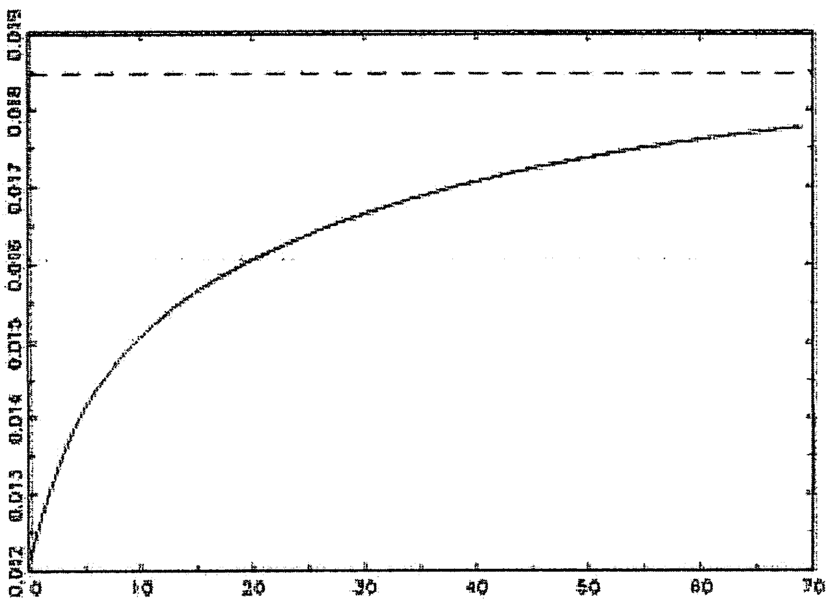

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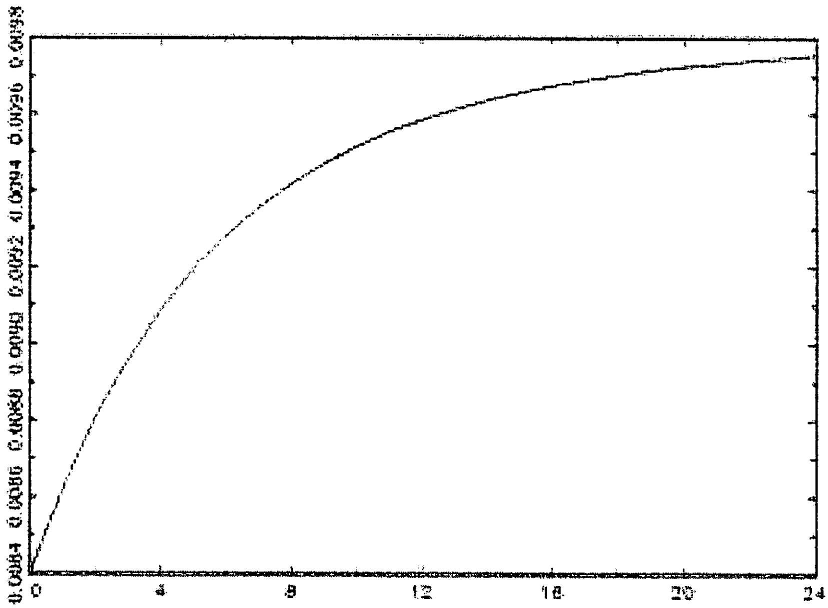

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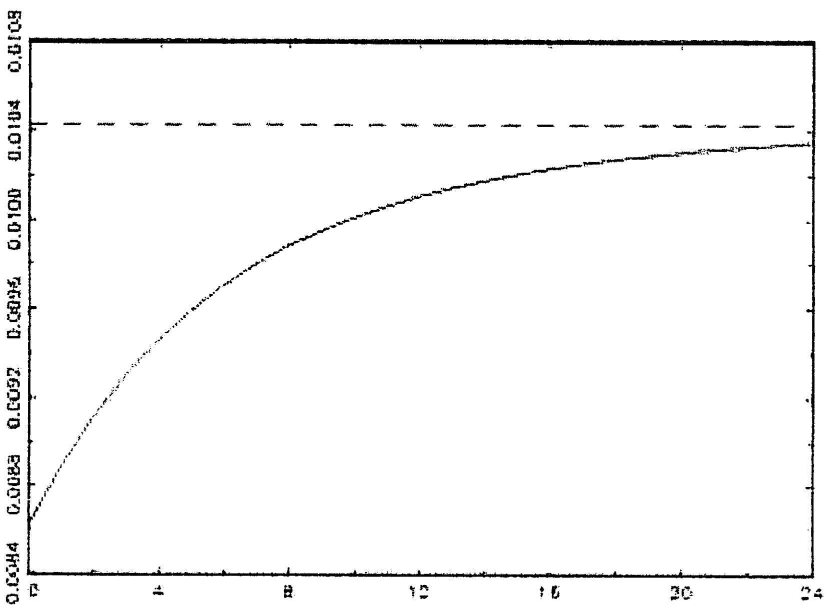

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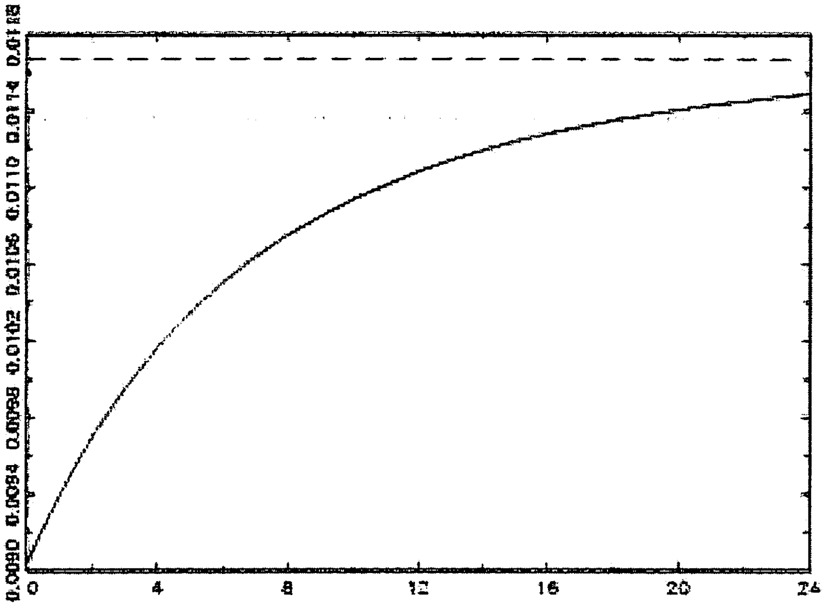

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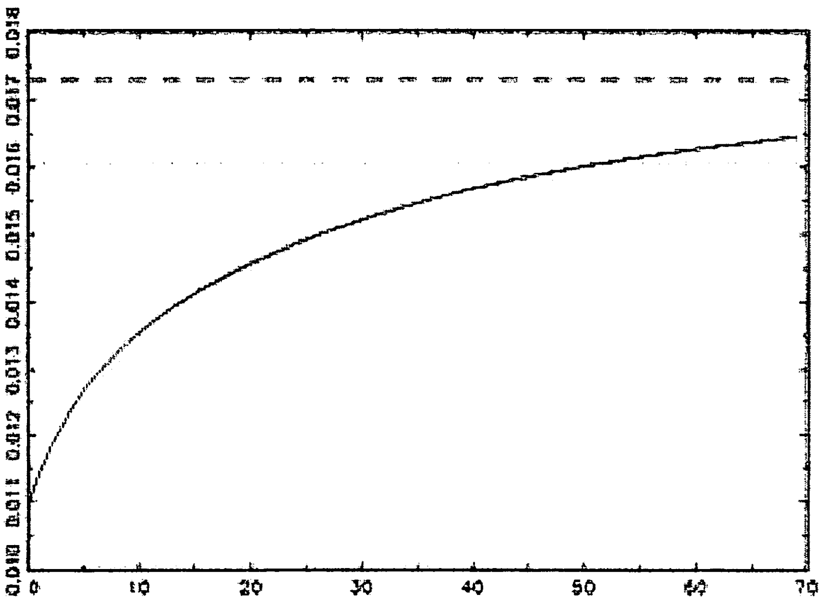

Figure 10