Information and Communication Technologies in a Multi-Sector Endogenous Growth Model*

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Abstract

This paper investigates the impact of Information and Communication Technologies (ICT) on growth in an economy consisting of three main sectors, ICT-producing, ICT-using and non-ICT-using. The benefits from ICT come from the falling prices of the ICT-using sector's good, which is used for the production of intermediate goods. Their falling prices provide incentives for investment for sectors using them, so the non-ICT-using sector experiences sustained growth driven by capital accumulation. Rates of growth across the three sectors differ, but the aggregate economy is on a constant growth path with constant labour shares across sectors. The model's predictions are consistent with U.S. evidence.

JEL Classification: O40, O41
Keywords: multi-sector economy, endogenous growth, constant growth path, Information and Communication Technologies

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1 Introduction

Current research on economic growth puts emphasis on examining the sources of growth at the industry level. The advantage of this approach is that it allows the identification of both the growth-generating industries and the mechanism through which their growth is spread to the rest of the economy. This paper is in this spirit. It studies a multi-sector economy. The first sector produces Information and Communication Technologies (ICT). The second sector uses ICT to produce intermediate goods for itself, and for the third sector, which does not use ICT. It shows that innovations in the ICT-producing sector lead to a growth equilibrium characterized by falling intermediate good prices. This provides incentives for capital deepening in the entire economy. The falling intermediate good price mechanism is still present, yet weaker, when the non-ICT-using sector contributes also to the production of intermediates. The model derives the conditions for the existence of a constant growth steady-state path for the aggregate economy. On this path there is no labour reallocation across sectors, but sectorial output growth rates differ, with the ICT-producing sector exhibiting the fastest growth, followed by the ICT-using one and then the rest of the economy.

The motivation for this paper comes from the empirical literature that studies the United States economy over the past thirty years (Jorgenson et al., 2005, Oliner and Sichel, 2002). These studies use data at the three-digit ISIC level and perform a detailed growth accounting exercise that identifies the ICT-producing sector as the source of growth, in spite of its small value added and employment share. Complementary growth accounting exercises (Albers and Vijselaar, 2002, O' Mahony and van Ark, 2003) investigate the sources of United States and European Union growth by looking at three sectors with the same broad structure as in this paper. These studies confirm the high productivity growth in the ICT-producing sector and find important gains in productivity that stem from it for all sectors. The benefits are mainly for the ICT-using industries.

Table 1 presents the real value added growth for the total economy and the ICT-producing, ICT-using and non-ICT-using sectors and its sources (capital, labor and TFP growth)[1,2]. The data show that the ICT-producing sector

[1]The classification of industries into the three sectors follows that of Jorgenson et al. (2005). The "ICT-producing" industries produce computer hardware, electronic components, telecommunication equipment and computer services (includes software production). Industries are classified as "ICT-using" or "non-ICT-using" according to their ICT-capital intensity in 1995. See Appendix B for details regarding the industries in each major sector.

[2]Calculations are by the author. Any differences to Tables 8.1 and 8.2 of Jorgenson et

experiences the highest value added growth across the three sectors, which is driven mostly by TFP growth. This sector contributes all of the economy's TFP. The value added growth for both the ICT-using and the non-ICT-using sector is driven by capital accumulation, while the ICT-using grows faster than the non-ICT-using. In their empirical investigation, Jorgenson et al. (2005) conclude that the most important source of United States growth has been the accumulation of ICT and non-ICT-capital, especially during the 1990s.

Table 1

	Value added growth 1977-2000	Sources of VA growth		
		Capital	Labor	TFP
Total Economy	3.18	1.74	1.17	0.28
ICT-producing	20.42	4.06	3.40	12.97
ICT-using	4.04	2.33	1.68	0.03
non-ICT-using	2.38	1.46	0.92	0.00

Source: Jorgenson et al. (2005)

The incentives for ICT-capital accumulation come from the dramatic price declines of ICT goods. This fall has generated incentives to invest in these goods, by driving down the production cost for ICT-using industries. The resulting falling prices of the goods produced by the ICT-using industries give rise to investment opportunities for the industries that use the ICT-using sector's goods. Through this mechanism, the gains from the fall in costs are transmitted to the entire economy. In order to develop intuition for the impact of price declines of ICT goods on aggregate productivity, one may consider the following example: An ICT-producing industry develops a new microprocessor. This chip is embodied in computers, which are used in the production of general-purpose machinery that is of higher quality and can be made available at a lower price. The air-conditioners that will be part of this production will become available to financial institutions, as well as to hairdressers. So, despite the fact that the hairdressers do not use directly ICT, they benefit from its advances because it lowers their costs.

The theoretical framework presented in this paper can account for the findings of the growth accounting exercises. In the model, the ICT-producing sector is the technology producing sector; by construction, it is the engine of

al. (2005) are due to rounding and limitations in the available data. Details on the data and the aggregation method used are in Appendix B.

growth. The sector that directly benefits from the advances in ICT production is the one using ICT capital; the ICT-using sector. As long as this sector is producing capital goods that are used throughout the economy, by both the ICT-using and the non-ICT-using sectors, the ICT-production growth is transmitted to the entire economy. This is because the falling costs for the ICT-using sector allow for falling prices of its output and therefore falling capital prices. Thus, growth is driven by the accumulation of both ICT and non-ICT-capital goods.

In equilibrium, the sector that exhibits the fastest growth is the ICT-producing. Its source of growth is TFP growth, where TFP growth is defined as the part of production growth that is not due to capital and labour accumulation. The ICT-using sector will be growing faster compared to the non-ICT-using sector. Its source of growth is the accumulation of ICT-capital, which embodies the advances in the ICT-production. The slowest growing sector in the economy is the non-ICT-using sector. Its source of growth is the accumulation of non-ICT-capital, which has lower productivity than the ICT-capital, since it does not embody the advances of the ICT. Under some restrictions on preferences the aggregate economy is on a constant growth path with constant employment shares. On this path, while aggregate growth is driven by the advances in the ICT-production, the economy's output growth rate is bound to be lower than the ICT-producing growth rate, because the non-ICT-using output is also used for the production of capital in the economy.

The paper is closely related to the endogenous growth literature that focuses on R&D (Romer, 1990, Grossman and Helpman, 1991). It introduces into a Romer (1990)-type model the non-ICT-using sector that is using only capital goods that come from an old technology. The old technology is assumed to have achieved its innovation potential. The aim is to account for the fact that for a long period after the introduction of new large scale technologies, some productive industries do not make use of them.

Another strand of literature related to this paper is the recent theoretical literature that deals with the impact of ICT upon growth. Following the "paradox" of the low productivity growth of the 1970s and 1980s (Quah, 2001), the recovery of productivity growth in the United States economy in the 1990s has been explained in the context of General Purpose Technologies (GPT) (Helpman and Trajtenberg, 1998)[3]. Several empirical studies find

[3]Economic historians were the first to draw the analogy between ICT and great inventions of the past, such as the combustion engine, electricity and railways, that pioneered the first and second industrial revolutions (David, 1991, David and Wright, 1999). The features of a GPT, as given by Lipsey, Bekar, Carlaw (1998), are: "wide scope for improvement and elaboration; applicability across a wide range of uses; potential for use in a wide

supportive evidence for the hypothesis that ICT is a GPT, i.e. that the use of ICT goods involves important externalities for the ICT intensive industries (Jorgenson et al., 2004, Oliner and Sichel, 2002, Triplett and Bosworth, 2002, Basu et al., 2003). The technology producing sector of the model of this paper captures important features of a GPT, but does not aim to explain the cycle involved in the introduction and adoption of a new large scale technology. Instead, it shows how uneven growth at the disaggregate level, caused by the lack of adoption of a new essential technology, can still be consistent with constant growth at the aggregate level.

Making use of United States data at the three-digit ISIC level, this paper provides some supportive evidence for the model's results given its assumption on the economy's structure, inter-industry relations and consumers' preferences. The model's main parameters are calibrated from the data. The data provide a measure for the magnitude of the price mechanism described in the model. They also support the model's prediction that the employment, value added and capital goods shares should match. They show no reallocation of labour across these sectors. The model's calibration matches the relative labor allocation in the two final good sectors._

This paper is organized as follows: Section 2 presents the model. Section 3 analyses the conditions for the existence of a unique steady-state and explores its properties and the implied comparative statics. Section 4 presents some supportive evidence by analyzing United States data over the period 1979-2001. Section 5 concludes.

2 The Model

2.1 Production Side

The model examines a multi-sector economy. There are two final goods sectors in the economy producing consumption and intermediate goods. One uses ICT-capital (e.g. general purpose machinery or financial services) and the other does not (e.g. textiles or hairdressers). The third sector is the ICT-producing sector (e.g. computers or software), which performs R&D and discovers new ICT goods. These sectors interact through the production of intermediates and capital varieties. The intermediates produced by the ICT-using and non-ICT-using are combined to produce a composite intermediate good. This composite intermediate good is used for the production

variety of products and processes; strong complementarities with existing or potential new technologies".

of all ICT and non-ICT-capital varieties in the economy. The production of every ICT-capital variety is based on a "blueprint" produced by the ICT-producing sector. The production of every non-ICT-capital variety is based on "blueprints" that have already been developed.

2.1.1 ICT Production

ICT-producing Sector
The ICT-producing sector employs a fraction, u_N, of aggregate labour stock, L, and produces new ICT "ideas", $\dot{N}$.

$$\dot{N} = \lambda \left(u_N L\right) N \tag{1}$$

There are externalities present in the production due to learning-by-doing: as the production size, N, increases more new production ideas and practices become available. The exogenous productivity is given by parameter λ.

The output of the sector are "blueprints" for the production of ICT-capital varieties, priced at p_N in an auction process.

2.1.2 Final Goods Production

ICT-using Sector
The ICT-using sector absorbs a fraction, u_1, of labour and employs N varieties of ICT-capital goods, $\{x_1(j)\}_{j\in[0,N]}$, in order to produce output, Y_1. The ICT-capital goods embody the new technology (ICT), that has a scope for sustained improvement. The advances in the ICT-production imply that the available number of varieties is expanding over time.

$$Y_1 = (u_1 L)^{1-\alpha} \int_0^N x_1^{\alpha}(j)dj \tag{2}$$

This sector is perfectly competitive in the input and output markets and the price its output is p_1. The final good is used either for consumption, c_1, or the production of intermediates, h_1.

$$Y_1 = c_1 + h_1 \tag{3}$$

Non-ICT-using Sector
The non-ICT-using sector employs a fraction, u_0, of labour and combines it with the sector-specific capital varieties, $\{x_0(i)\}_{i\in[0,A]}$, to produce final good, Y_0. It uses non-ICT-capital, which has a fixed number of varieties over time, A. This stands for the assumption that the non-ICT-using sector only makes use of capital goods that embody a technology with no further scope for

improvement. As a result, it cannot directly benefit from the presence of the ICT technology[4,5].

$$Y_0 = (u_0 L)^{1-\alpha} \int_0^A x_0^{\alpha}(i)di \tag{4}$$

This sector is also perfectly competitive in the input and output markets and the price of its output is normalized to one. The final good is used either for consumption, c_0, or for the production of intermediates, h_0.

$$Y_0 = c_0 + h_0 \tag{5}$$

2.1.3 Intermediate Goods Production

The intermediates produced by the ICT-using and the non-ICT-using are used as inputs for the production of the composite intermediate good, H.

$$H = h_0^{\beta} h_1^{1-\beta} \tag{6}$$

This sector is perfectly completive in input and output markets and the price of its output is p_H. The composite intermediate good is used for the production of all ICT-capital varieties, K_1 and non-ICT-capital varieties, K_0.

$$H = K_0 + K_1 \tag{7}$$

2.1.4 Capital Varieties Production

There is a fixed number, A, of firms that produce capital varieties that are used only by the non-ICT-using sector. There is also an expanding number, N, of firms that produce capital varieties that are exclusively used by the ICT-using sector. The firms operate under monopolistic competition. Infinite-horizon monopolistic rights for every firm come from exploiting a patent over a "blueprint".

A firm that produces the ICT-using capital variety j, has a nominal market value at time t, $V_1(j)(t)$. This would be paid out to the ICT-producing sector for the acquisition of a new variety patent due to free-entry in the ICT-capital varieties market. In order to fund the patent, the firm raises funds from the households and pays out all its future profits as dividends. The real

[4] Allowing for a different capital intensity in this sector would not affect the features of the equilibrium, while complicating the analytical expressions. The simplifying assumption of setting it equal to that of the ICT-using sector is used to highlight the differences across the two sectors that stem from the type of the capital used.

[5] Allowing both final goods sectors to use both ICT and non-ICT-capital at different intensities, would not change the main features of the equilibrium.

value of the firm is equal to the present discounted value of the firm's stream of real profits in consumption units. For every unit of production, the firm uses one unit of composite intermediate good, which is available at p_H. It selects its output price, $\hat{p}_1(j)$, to maximize its per-period profits, $\pi_1(j)$. The real interest rate, $r(t)$, and the price of the composite consumption good, $p_c(t)$, are taken as given.

$$\begin{aligned}
\frac{V_1(j)(t)}{p_c(t)} &= \int_t^{\infty} e^{-\int_t^{\tau} r(s)ds} \frac{\pi_1(j)(\tau)}{p_c(\tau)} d\tau & (8)\\
\pi_1(j) &= \max_{\hat{p}_1(j),x_1(j)} \left\{ \hat{p}_1(j)x_1(j) - p_H x_1(j) \ s.t.\ p_1 \frac{\partial Y_1}{\partial x_1(j)} = \hat{p}_1(j) \right\} & (9)
\end{aligned}$$

A firm that produces the non-ICT-using capital variety i, has a nominal market value at time t, $V_0(j)(t)$ defined in a similar way. For every unit of production, the firm uses one unit of composite intermediate good, which is available at p_H. It maximizes its profits every period, $\pi_0(i)$, by selecting its output price $\hat{p}_0(j)$, when taking into account the demand from the non-ICT-using final good producers.

$$\pi_0(i) = \max_{\hat{p}_0(i),x_0(i)} \left\{ \hat{p}_0(i)x_0(i) - p_H x_0(i) \ s.t.\ \frac{\partial Y_0}{\partial x_0(i)} = \hat{p}_0(i) \right\} \tag{10}$$

Aggregate profits of the capital varieties producing firms are paid out as dividends and the demand meets the supply of the two types of capital varieties. Both types of capital depreciate fully within every period.

$$\begin{aligned}
\Pi &= \int_0^A \pi_0(i)di + \int_0^N \pi_0(j)dj & (11)\\
K_0 &= \int_0^A x_0(i)di & (12)\\
K_1 &= \int_0^N x_1(j)dj & (13)
\end{aligned}$$

2.1.5 Labour Market

The labour market is perfectly competitive. The market clearing condition requires that all resources are allocated across all three sectors that use the fixed supply of labour.

$$L = u_0 L + u_1 L + u_N L \tag{14}$$

2.2 Consumer Side

2.2.1 Households

There is a continuum of identical households of size one. The representative household gains utility from its consumption of ICT-using, c_1, and non-ICT-using, c_0, goods. A general framework of joint CES and CRRA preferences allows both intertemporal and intratemporal substitution to come into play.

$$u(c_0, c_1) = \frac{\left([\theta c_0^{\epsilon} + (1-\theta) c_1^{\epsilon}]^{\frac{1}{\epsilon}} \right)^{1-\sigma} - 1}{1-\sigma}; \theta \in (0,1), \epsilon < 1, \sigma > 0 \tag{15}$$

The labour stock is uniformly distributed across all agents in the economy, so that each of them offers L. In every period, the households' income comes from the wage, w_L, they earn from supplying their labour, the dividends they receive from the firms they owe, Π, and the real interest rate, r, paid on their total asset holding, S. They use this income to finance their consumption expenditures, $c_0 + p_1 c_1$. The price of the composite consumption good, p_c, is required to make all units comparable in the households' budget constraint:

$$\dot{S} = rS + \frac{w_L L + \Pi - c_0 - p_1 c_1}{p_c} \tag{16}$$

3 Steady-State Analysis

3.1 Existence of Steady-State

A Constant Growth Path (CGP) is a steady-state equilibrium path along which the ICT-production stock, N, the aggregate output, $Y = Y_0 + p_1 Y_1$, capital, $K = p_H K_0 + p_H K_1$, and consumption, $C = c_0 + p_1 c_1$, grow at a constant rate. All proofs are given in Appendix A.

Proposition 1 *The necessary and sufficient condition for the existence a CGP with N, Y, C and K growing at constant rates is that the preferences exhibit unit intratemporal elasticity of substitution, i.e. $\epsilon = 0$.*

For constant growth rate in ICT-production, aggregate output and capital the only requirement is that the labour allocation in the ICT-producing sector is constant. The growth of the final goods sectors is driven by labour and capital growth. The growth of the quantity of capital for the ICT-using and the non-ICT-using sectors is exactly the same. This is because the prices of both the ICT and non-ICT-capital goods fall at the same rate. Only the ICT-using sector experiences higher capital productivity growth, which is driven by the use of the expanding variety of the ICT-capital. At the aggregate output level, differences in the relative capital productivity growth between the two sectors are cancelled out by the relative prices growth. Any reallocation of labour between the two final goods sectors also cancels out given the condition on constant allocation for the ICT-producing sector. Therefore, aggregate output growth is just a fraction of the ICT-production growth. The same reasoning works for aggregate capital.

The restriction on the preferences is required for constant aggregate consumption growth. In the case of an intratemporal elasticity which is higher than one, the consumers would allocate an increasing share of their expenditures to the ICT-using good over time given its falling relative price. The higher the substitutability of the two goods, the higher would be the rate at which this share would be increasing over time. Ceteris paribus, the interest rate in consumption units would be decreasing over time as consumers gain from consuming more of a good that becomes cheaper over time. For constant aggregate consumption growth, the real return on assets would need to increase over time to revert the incentives for reduced savings. However, the substitutability of labour and capital in the final goods production, and of the two types of intermediates in the composite intermediate good production, is different than the substitutability of the two consumption goods. As a result, the rate at which the ICT-using absorbs labour resources to match the increasing demand of its product cannot deliver the sufficient rate of return of assets in the economy for the consumption growth to be constant and equal to the production growth. The opposite dynamics would take place for an intratemporal elasticity of substitution, which is lower than one.

The unit intratemporal elasticity of substitution is the only case that there exists a CGP for the economy that satisfies static efficiency, i.e. the marginal rate of substitution needs to equal the marginal rate of transformation, and the resource constraints within every period and over time. This is feasible as long as the substitution patterns in consumption that are driven by relative consumption goods prices are matched by the substitution patterns of factors. It implies constant expenditure shares, and therefore through the static efficiency conditions implies constant labour allocations for the two final good sectors[6].

[6]The conditions for a CGP here are similar to the ones in the structural change literature, e.g. Ngai and Pissarides (2004). Their aim is to explain labour reallocations,

3.2 Features of the Steady-State

Given Proposition 1, the steady-state of the decentralized equilibrium is derived by imposing unit intratemporal elasticity of substitution and constant labour shares on the model. The details are given in Proposition 2. The most interesting static equilibrium results are[7]:

$$\begin{aligned} p_1 &= \left(\frac{A}{N}\right)^{1-\alpha} && (17)\\ p_H &= Bp_1^{1-\beta} && (18)\\ \hat{p}_0 &= \hat{p}_1 = \frac{p_H}{\alpha} && (19)\\ p_c &= \Theta p_1^{1-\theta} && (20)\\ \frac{u_0}{u_1} &= \frac{(1-\alpha^2)\theta + \alpha^2\beta}{1-(1-\alpha^2)\theta - \alpha^2\beta} && (21) \end{aligned}$$

Condition (17) shows that the relative price of the ICT-using good is falling over time at a rate which is proportional to the growth rate of the ICT-production. The factor of proportionality is equal to the labour share in final goods production, given the labour augmenting nature of the productivity embodied in the ICT-capital.

As condition (18) shows, the price of the composite intermediate good will follow the changes of the ICT-using good relative price, if the output of the relative more productive ICT-using good is used for its production. The extent to which the relative price of the composite intermediate good reflects the changes in the relative price of the ICT-using good depends on the contribution of the latter in its production.

Given that the composite intermediate good is used for the production of all capital varieties in the economy, their relative price will be a mark-up over its price. Over time, condition (19) shows that the relative prices of both types of capital goods will be falling, following the relative price declines of the composite intermediate good. Therefore, the productivity gain of the non-ICT-using sector comes only indirectly. This sector is using a fixed number of capital varieties, but these varieties become cheaper and cheaper relative to the non-ICT-using final good. The falling prices generate increased demand for the existing capital varieties. Capital deepening is

across manufacturing and services industries. These shifts are explained through different exogenous TFP growth rates of sectors and an elasticity of intratemporal substitution less than one. As noted in the introduction, such labour reallocations are not present in the ICT context.

[7] $B = B(\beta)$ and $\Theta = \Theta(\theta)$.

the only source of growth in this sector. At the same time, the ICT-using sector benefits from more varieties of capital becoming available. The benefits from more varieties complement those from cheaper varieties delivering faster growth for this sector relative to the non-ICT-using sector.

Investigating the consumption side, condition (20) shows that consumers gain utility from the falling relative price of their composite consumption good over time. The falling price of consumption is driven by the falling relative price of the ICT-using consumption good. This benefit accrues to the consumers as part of the interest rate in consumption units and provides the incentives for savings over time that sustain endogenously the growth mechanism.

Finally, condition (21) comes from equating the marginal rate of substitution to the marginal rate of transformation and using the market clearing conditions. It gives an expression for the relative labour shares in the two final goods sectors. This ratio depends on the expenditure share of the non-ICT-using good, θ, as long as it affects the marginal utility of consumption. It also depends on the output elasticity of capital, α, since that affects the capital-labour substitution. The same parameter also specifies the size of the mark-up that the capital producers enjoy. Finally, it depends on the output elasticity of the non-ICT-using intermediate in the production of the composite intermediate good, β, which affects the substitution of the two types of capital.

Proposition 2 *For preferences that satisfy $\epsilon = 0$, along the CGP the following are true*[8]*:*

The growth rate of every sector and of the aggregate economy is proportional to the endogenous growth rate of the ICT-producing sector, g_N^d:

$$\begin{aligned}
\frac{\dot{Y}_0}{Y_0} &= \frac{\dot{c}_0}{c_0} = \frac{\dot{h}_0}{h_0} = \frac{\dot{C}}{C} = \frac{\dot{Y}}{Y} = \frac{\dot{K}}{K} = \alpha\left(1 - \alpha\beta\right) g_N^d \\
\frac{\dot{Y}_1}{Y_1} &= \frac{\dot{c}_1}{c_1} = \frac{\dot{h}_1}{h_1} = \left(1 - \alpha\beta\right) g_N^d \\
\frac{\dot{K}_1}{K_1} &= \frac{\dot{K}_0}{K_0} = \frac{\dot{H}}{H} = (1 - \beta) g_N^d
\end{aligned}$$

The labour allocations are constant and depend on all parameters of the model and the aggregate labour stock:

$$u_z^d = u_z^d(\theta, \rho, \sigma, \alpha, \lambda; L); z = \{0, 1, N\}$$

Given the static optimization conditions described above, the features of the dynamic optimization conditions follow immediately. In particular, the ICT-producing sector is the engine of growth and exhibits the fastest growth in the economy. Its growth is driven entirely from the externalities present in its production. The ICT-using sector benefits from any advances in the ICT-production, in terms of capital deepening. Its capital has high productivity because more varieties become available over time. Its growth would coincide with the growth rate of the ICT-producing sector, only if this sector would be the only capital producing sector in the economy. The use of the non-ICT-using good for the production of capital slows down the relative price growth of capital and therefore capital deepening for all sectors. The non-ICT-using sector exhibits the lowest growth. It grows because of capital deepening, which is only driven by the fact that non-ICT-capital is becoming cheaper over time. Therefore, the growth rate for the non-ICT-using sector is only a fraction of the ICT-production growth, with the fraction being equal to the product of the capital share in final good production and the ICT-using good share in the production of intermediates.

At the aggregate level, the differences in output growth between the two final good sectors are cancelled out by the growth rate of relative prices. The

[8]The sufficient conditions for an interior solution are an endogenously determined lower bound for labour stock, $\bar{L}(\theta, \alpha, \lambda, \rho)$.

economy is along a constant growth path, where the consumption to output and capital to output ratios are constant within every sector, but different across sectors. The growth rate of the economy is a function of the preference and production parameters and the available labour stock.

The current framework does not allow for transition dynamics. The reason for that is the existence of a unique state stock variable, which has constant rate of return along the CGP. The latter is due to the type of externalities present in the production function of this sector. As a result, following a structural change in one of the key parameters, this economy will only exhibit discrete shifts from the original CGP to the new one, without an intermediate phase of smooth transition path[9].

3.3 Comparative Statics

Proposition 3 *The growth rate of the economy is higher and the labour shares in the two final goods' sectors are lower, the more patient the agents in the economy are (the lower ρ is), the higher the intratemporal elasticity of substitution (the lower σ is) is and the more productive the ICT-producing sector is (the higher λ is). The effect of a higher output elasticity of capital (α), a higher intermediate output elasticity of the non-ICT-using good (β), or the expenditure share of the non-ICT-using good (θ) is ambiguous and depends on the values of different parameters of the model.*

Patient agents would be more willing to substitute current with future consumption. The additional savings direct resources to the ICT-producing sector. This is because as asset holdings increase, they drive interest rates down and patent prices up. This enables higher growth in the long run, since it provides incentives for higher ICT-production growth. An increased productivity in the ICT-producing sector would have the same effect. It would increase the marginal product of the labour in this sector, and thus would attract more labour. The incentives to produce more ICT would come from higher patent prices, that would result both from the increased productivity and the reduced interest rate.

The comparative statics following an increased preference towards the non-ICT-using consumption good show two opposite effects. On the one

[9] Transition dynamics can be delivered by a slowly depreciating physical capital. That would make the model highly nonlinear and requires the use of numerical solution methods. This case has been explored for an simpler version of this model and its results are available by the author upon request.

hand, since the marginal utility of consumption goes up in this sector, there are forces to increase resources in its production, that are being driven out of the other two sectors. On the other hand, reducing the resources from the ICT-producing sector implies that the rate at which the price of the non-ICT-using good increases relative to the ICT-using good falls as well. Hence, the rate of consumption growth of the economy would fall, which reduces incentives to direct resources to the non-ICT-using sector depending on how willing the consumers are to substitute present with future consumption. For unit intertemporal elasticity of substitution, this second effect is eliminated. Hence, stronger preference for non-ICT-using goods implies lower growth rate and a diversion of resources out of the ICT-using and producing sector and into the non-ICT-using sector.

The effect of higher importance of the non-ICT-using good in the production of intermediates is similar. Given that it increases the relative productivity of the non-ICT-using intermediate good, more resources would be driven towards the production of the non-ICT-using good, which has a negative effect on growth. At the same time, the relative prices growth is lower, which implies a lower interest rate in consumption units. The second effect is eliminated for unit intertemporal elasticity of substitution. Resources would be driven out of both the ICT-using and ICT-producing sector.

Finally, the case of higher output elasticity of capital is more complex. On the one hand, this reduces the mark-up that the capital producers enjoy, and thus increases the production of capital and output. The effect of capital accumulation upon growth becomes stronger. On the other hand, since the labour share in output falls, this reduces the incentive for growth as it mitigates the gap between the interest rate in consumption units and the subjective discount rate. That also depends on the way that the ICT-using and the non-ICT-using good are substituted in the production of consumption and intermediates. For unit intertemporal elasticity of substitution, the positive effect on growth dominates. Resources would be driven out of the non-ICT-using sector and into the ICT-producing and ICT-using sectors, if the share of the non-ICT-using output in consumption is higher than its share in the production of intermediates.

4 Supportive Evidence

As in the theoretical model, the industries are grouped into three major sectors: ICT-producing, ICT-using and non-ICT-using. See Appendix B for precise sources and definitions of the data and details regarding the industries in each major sector and the aggregation method used[10].

In the benchmark model the ICT-using sector and the non-ICT-using sectors are the sectors that are assumed to provide consumption and intermediate goods for the economy. In order to check whether the resulting grouping of sectors supports this, the Bureau of Economic Analysis (BEA) "Use Table" of the "Benchmark 1997 Input-Output Table" was used to calculate the use shares of the commodities of the ICT-producing, ICT-using and non-ICT-using sector. The uses considered are "total intermediates" and "personal consumption". The results are shown in Table 2. The ICT-using and the non-ICT-using sectors deliver together 99 per cent of the total consumption good and 96 per cent of the total intermediate good.

Table 2

Shares of commodities' use	Intermediates	Consumption
ICT-producing	4.4	0.9
ICT-using	35.8	22.3
non-ICT-using	59.8	76.8

Source: BEA, Benchmark Input Output Table, 1997

According to the model, the requirement for growth to be transmitted to the non-ICT-using sector is that the ICT-using sector is providing with intermediates the non-ICT-using sector. Table 3 shows the interindustry transactions of intermediates for the two final good sectors. The two sectors do exchange the intermediate goods that they produce. What is relevant for the existence of benefits for the non-ICT-using sector in terms of falling intermediate good prices, is that it receives intermediates from the ICT-using sector. When controlling for the overall share of intermediates use of the sectors, the non-ICT-using sector receives 29 per cent of its intermediates from the ICT-using sector, while the ICT-using sector receives 41 per cent of its intermediates from the non-ICT-using sector[11].

[10] Note that given the choice of the numeraire in the theoretical model, the growth of the final good is pinned down by the output growth of the non-ICT-using sector. In practice, the final good value added growth is a weighted average of the value added growth rates of the individual sectors, with the weights given by the sectors' shares in value added. That rate would be constant on the CGP with constant growth rates and value added shares irrespective of the choice of the numeraire. Aggregate value added deflator is constructed in a similar way.

[11] These numbers come from Table 3 by dividing the respective entries of the matrix by each sector's aggregate share in use.

Table 3

Shares of intermediates	used by: ICT-using	non-ICT-using	aggregate share in production
produced by:			
ICT-using	15.9	20.9	36.8
non-ICT-using	10.8	52.4	63.2
aggregate share in use	26.7	73.3	100

Source: BEA, Benchmark Input Output Table, 1997

The model introduces the composite intermediate good production that combines the intermediates produced by the non-ICT-using and non-ICT-using sectors. Its production structure implies that the composite intermediate's output elasticity with respect to the ICT-using sector's intermediate good, β, is equal to the output share of that good in total intermediates' production. Table 3 shows that β is equal to 63 per cent. According to the model, $\frac{\dot{p}_H}{p_H} = (1-\beta)\frac{\dot{p}_1}{p_1}$. Hence, only 37 per cent of the growth of the ICT-using good relative price would show up as growth of the composite intermediate good relative price, so that the incentives for capital accumulation are dampened.

Table 3 shows that the share of the total intermediates that is used by the ICT-using sector is 73 per cent. Comparing this to its share in the production of intermediates suggests that the non-ICT-using is a sector that is more intensive in using rather than in producing intermediates. The model shows that in steady-state, $\frac{p_H K_1}{p_1 h_1} = \alpha^2 + (1-\theta)(1-\alpha^2)$, while $\frac{p_H K_0}{h_0} = \alpha^2 + \frac{\theta}{\beta}(1-\alpha^2)$. This implies that $\frac{p_H K_1}{p_1 h_1} < \frac{p_H K_0}{h_0}$, if $\theta - \beta > -\beta\theta$. Parameter θ may be recovered by the non-ICT-using good consumption expenditure share. It is equal to 78 per cent from the BEA I-O data. Hence, the data imply parameters' values that deliver results for the model that are consistent with the data.

Regarding the intensity of each final good sector in producing consumption and intermediates, Table 4 shows the share of use of the ICT-using and non-ICT-using sectors. The ICT-using sector appears to be more intensive in producing intermediate goods as opposed to the non-ICT-using sector. In the steady-state of the model, $\frac{c_1}{h_1} = \frac{(1-\theta)(1-\alpha^2)}{\alpha^2(1-\beta)}$ and $\frac{c_0}{h_0} = \frac{\theta(1-\alpha^2)}{\alpha^2\beta}$. This suggest that $\frac{c_1}{h_1} < \frac{c_0}{h_0}$, if $\theta > \beta$. This condition is supported by the parameters' values that are recovered from the data.

Table 4

Shares of commodities' use	Intermediates	Consumption
ICT-using	66.1	33.9
non-ICT-using	49.3	50.7

Source: BEA, Benchmark Input Output Table, 1997

One implication of the model is that along the CGP the labour shares will be constant across the three sectors. As appears in Figure 1, the hours shares of the three sectors are virtually constant over the period 1979-2001. The share of the ICT-producing sector is around 2%, that of ICT-using changes from a minimum of 24% to a maximum of 26% and that of non-ICT-using changes from 74% to 71%[12]. The static equilibrium condition that equates the marginal rate of transformation to the marginal rate of substitution implies that the relative labour shares of the two final good sectors is $\frac{u_1}{u_0} = \frac{1-\alpha^2\beta-\theta(1-\alpha^2)}{\alpha^2\beta+\theta(1-\alpha^2)}$. Using the calibrated parameters as discussed above and a capital output elasticity α=0.33 the model predicts a ratio $\frac{u_1}{u_0}$ of 0.32. This is very close to the average ratio over the 1979-2001 period, which equals 0.36.

Moreover, the model implies that the value added, hours and intermediates used share for each of the final good sectors should be equal along the CGP. For the non-ICT-using sector, this suggests $\frac{u_0}{u_0+u_1} = \frac{K_0}{K} = \frac{Y_0}{Y}$. For the period 1979-2001, the data indicate 74 per cent average hours share and 71 per cent average value added share, and 73 per cent share in intermediates use for 1997[13].

As a final note, Table 1 showed the striking growth accounting finding that only the ICT-producing sector has positive TFP growth. This is consistent with the model under the assumption that all the productivity embodied

[12]For the decomposition of the aggregate private economy favoured by the structural change literature (e.g. Ngai and Pissarides, 2004), the data reveal considerably stronger trends. Over the period 1979-2001, the share of Agriculture (ISIC:01-05) in total hours worked is falls from 4% to 2.5%, while that of Services (ISIC: 50-95) increases from 66% to 76% and Manufacturing (ISIC: 10-45) falls from 30% to 22%.

[13]The model implies that $\frac{u_0}{u_0+u_1} = \frac{K_0}{K} = \frac{Y_0}{Y} = \alpha^2\beta + \theta(1-\alpha^2)$. Given the calibrated parameters of the model, β and θ as discussed above, the hours, intermediates and value added shares that are taken from the data imply a capital output elasticity that ranges between 0.51 and 0.66, which is higher than 0.33. However, when the model is taken more literaly given that capital fully depreciates every period it may have the interpretation of intermediates. The BEA reports a share of intermediates in gross output around 0.64 for manufacturing.

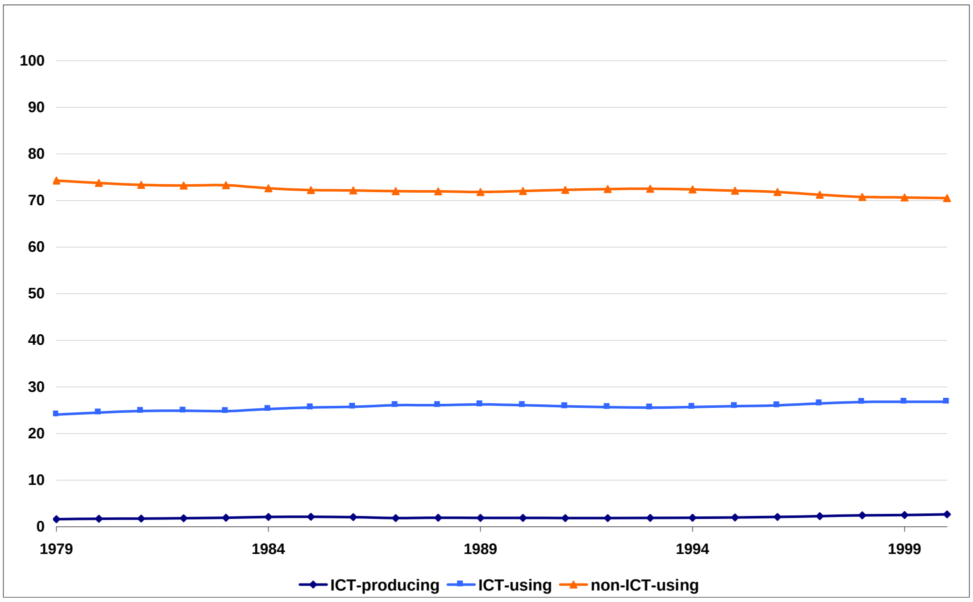

Figure 1: Shares in total hours.

in the capital is fully accounted in the data[14]. On the other hand, under the assumption that the productivity of the ICT-capital will not be fully captured, i.e. if only the accumulation of capital services is accounted, then the resulting TFP growth for the aggregate final good economy would appear positive and would be a fraction of the TFP growth of the ICT-producing sector[15]. This fraction depends on the output elasticity of labour and the value added share of the ICT-using sector. That poses an upper limit on what would be accounted as a Solow residual due to data limitations.

[14] Jorgenson et al (2005) report that the quality of capital accounts for 0.78 of the 1.74 percentage points of the capital's contribution to growth.

[15] Within the "Aggregate Production Possibility Frontier" aggregation method, real value added growth is a weighted average of the sectors' real output growth, $\frac{\dot{\tilde{Y}}}{\tilde{Y}}$, with the weights being the average value added shares of these sectors. $\frac{\dot{\tilde{Y}}}{\tilde{Y}}=\frac{p_{Y_0}Y_0}{p_{Y_0}Y_0+p_{Y_1}Y_1}\frac{\dot{Y}_0}{Y_0}+\left(1-\frac{p_{Y_0}Y_0}{p_{Y_0}Y_0+p_{Y_1}Y_1}\right)\frac{\dot{Y}_1}{Y_1}$. Using the results under Proposition 2, under the assumption that the expansion of the varieties of the ICT-capital is not accounted for: "Solow-Residual"$\equiv\frac{\dot{\tilde{Y}}}{\tilde{Y}}-$

$$\left\{\frac{p_{Y_1}Y_1}{p_{Y_0}Y_0+p_{Y_1}Y_1}\left[(1-\alpha)\left(\frac{\dot{\overline{u_1H}}}{u_1H}\right)+\alpha\frac{\dot{K}_1}{K_1}\right]-\left(1-\frac{p_{Y_1}Y_1}{p_{Y_0}Y_0+p_{Y_1}Y_1}\right)\left[(1-\alpha)\left(\frac{\dot{\overline{u_0H}}}{u_0H}\right)+\alpha\frac{\dot{K}_0}{K_0}\right]\right\}$$

$$=\frac{p_{Y_1}Y_1}{p_{Y_0}Y_0+p_{Y_1}Y_1}(1-\alpha)\frac{\dot{N}}{N}$$

5 Conclusions

This paper has developed a theoretical framework that accounts for growth in the ICT era. The source of growth are the externalities present in the ICT-production. It analyzes the mechanism through which growth is transmitted from the ICT-producing sector to the aggregate economy. The sector using ICT-capital goods benefits from the use of the new technologies, by experiencing accumulation of capital that embodies these advances. This results in falling capital prices, because the ICT-using good is used for the production of intermediates. The falling intermediate good prices drive capital deepening in the sector that does not use ICT-capital. Therefore, despite the fact that only one sector is using ICT-capital goods, the benefits from their use spread throughout the economy. These benefits are stronger, the more the ICT-using sector contributes to the production of intermediates.

At the same time the mechanism that drives growth in this model, i.e. the falling capital prices, may explain growth caused by any technologies that expand the production possibility frontier of the capital-producing industries in an economy. In that sense, the model is more general than its selected application in this paper (i.e. to account for growth in the ICT context). On more general grounds, this paper provides insight into how multiple sectors of different growth potentials interact within an economy in a way that allows for a CGP at the aggregate level, where growth is sustained endogenously.

Along the steady-state growth path, there is no reallocation of labour across sectors. The ICT-producing sector is the fastest growing sector. The ICT-using sector does not grow as fast as the ICT-producing sector, despite the fact that it uses capital varieties that follow the growth of the ICT-production stock. This is because the use of the low productivity non-ICT-using good in the production of intermediates implies lower growth for the capital prices and therefore weaker incentives for capital accumulation. The non-ICT-using sector is the slowest growing sector in the economy, growing only due to capital deepening. The aggregate growth rate is driven by the advances in the ICT-production. It is endogenously determined as a function of the preference and production parameters of the model and the size of the labour stock. The aggregate consumption to capital and output to capital ratios are constant over time. The real interest rate is also constant over time. The main implications of the model are consistent with data of the United States economy.

6 Appendix A: Analytical Proofs

Proof of Proposition 1

Production side: The final good producers take prices as given in input and output markets. Therefore, their demand for capital comes by equating the value of marginal product of every capital variety to its price:

$$\frac{\partial Y_0}{\partial x_0(i)} = \alpha(u_0 L)^{1-\alpha} x_0^{\alpha}(i) = \hat{p}_0(i), \forall i \tag{22}$$
$$p_1 \frac{\partial Y_1}{\partial x_1(j)} = p_1 \alpha(u_1 L)^{1-\alpha} x_1^{\alpha}(i) = \hat{p}_1(j), \forall j \tag{23}$$

The intermediate output producer also takes prices as given in input and output markets. The demand for the intermediates produced by the two final-good sectors is:

$$p_H \frac{\partial H}{\partial h_0} = \beta p_H h_0^{\beta-1} h_1^{1-\beta} = 1 \tag{24}$$
$$p_H \frac{\partial H}{\partial h_1} = (1-\beta) p_H h_0^{\beta} h_1^{-\beta} = p_1 \tag{25}$$

The implied relative demands and price for the intermediate goods:

$$\frac{\beta}{1-\beta}\frac{h_1}{h_0} = \frac{1}{p_1} \tag{26}$$
$$p_H = B p_1^{1-\beta} \tag{27}$$

,where $B = \left[\beta^{\beta}(1-\beta)^{1-\beta}\right]^{-1}$.

The producers of the capital varieties function under monopolistic competition. In the absence of dynamic decision variables, they maximize their profits by choosing their price and production in every period:

$$\pi_0(i) = \max_{\hat{p}_0(i), x_0(i)} \{\hat{p}_0(i) x_0(i) - p_H x_0(i); s.t.(22)\}$$
$$\pi_1(j) = \max_{\hat{p}_1(i), x_1(i)} \{\hat{p}_1(i) x_1(j) - p_H x_1(j); s.t.(23)\}$$

The solutions to these programs are:

$$x_0 = \alpha^{\frac{2}{1-\alpha}} \left(\frac{1}{p_H}\right)^{\frac{1}{1-\alpha}} (u_0 L) \tag{28}$$
$$x_1 = \alpha^{\frac{2}{1-\alpha}} \left(\frac{p_1}{p_H}\right)^{\frac{1}{1-\alpha}} (u_1 L) \tag{29}$$
$$\hat{p}_0 = \hat{p}_1 = \frac{p_H}{\alpha} \tag{30}$$

The model delivers symmetry across the varieties of each type of capital goods.

The implied profit flows for every period is:

$$\pi_0 = \tfrac{1-\alpha}{\alpha}\alpha^{\frac{2}{1-\alpha}}\left(\tfrac{1}{p_H}\right)^{\frac{\alpha}{1-\alpha}}(u_0L) \tag{31}$$

$$\pi_1 = \tfrac{1-\alpha}{\alpha}\alpha^{\frac{2}{1-\alpha}}p_1^{\frac{1}{1-\alpha}}\left(\tfrac{1}{p_H}\right)^{\frac{\alpha}{1-\alpha}}(u_1L) \tag{32}$$

Aggregate per-period profits are defined as $\Pi = A\pi_0 + N\pi_1$.

The producers of capital varieties enter the market upon getting a "blueprint" that allows them to produce the new varieties that are available at every point in time, $\dot{N}$. The old varieties are fixed in number, hence no new firms enter the market producing non-ICT-capital varieties. With well defined property rights, the cost that each ICT-capital variety producer needs to assume in order to acquire a blueprint is equal to the present discounted value of his entire stream of future profits, $V_1(t)$. The firm considers the real interest rate and the price index of the composite good as given:

$$\frac{V_1(t)}{p_c(t)} = \int_t^\infty e^{-\int_t^\tau r(s)ds}\frac{\pi_1(j)(\tau)}{p_c(\tau)}d\tau \tag{33}$$

Since the labour market is perfectly competitive, there exists a wage,w_L, that clears out the market. This wage is equal to the value of marginal product of labour in all three sectors, where p_N is the value of a patent paid for a new variety:

$$\tfrac{\partial Y_0}{\partial(u_0L)} = (1-\alpha)\left(\tfrac{1}{p_H}\right)^{\frac{\alpha}{1-\alpha}}A\alpha^{\frac{2\alpha}{1-\alpha}} = w_L \tag{34}$$

$$p_1\tfrac{\partial Y_1}{\partial(u_1L)} = (1-\alpha)N\alpha^{\frac{2\alpha}{1-\alpha}}p_1^{\frac{1}{1-\alpha}}\left(\tfrac{1}{p_H}\right)^{\frac{\alpha}{1-\alpha}} = w_L \tag{35}$$

$$p_N\tfrac{\partial \dot{N}}{\partial(u_NL)} = V_1\lambda N = w_L \tag{36}$$

Equating (34) and (35):

$$p_1 = \left(\tfrac{A}{N}\right)^{1-\alpha} \tag{37}$$

Equating (35) and (36):

$$V_1\lambda = (1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}}p_1^{\frac{1}{1-\alpha}}\left(\tfrac{1}{p_H}\right)^{\frac{\alpha}{1-\alpha}} \tag{38}$$

Consumer side: The households solve the following dynamic problem by choosing $\{c_0, c_1\}$ taking all prices as given:

$$\mathcal{H} = e^{-\rho t}\tfrac{\left[\theta c_0^\epsilon + (1-\theta)c_1^\epsilon\right)\right]^{1-\sigma}-1}{1-\sigma} + \lambda\left[rS + \tfrac{w_LL+\Pi-c_0-p_1c_1}{p_c}\right]$$

The solution to this problem gives the standard conditions:

$$\frac{c_1}{c_0} = \left(\frac{1-\theta}{\theta}\frac{1}{p_1}\right)^{\frac{1}{1-\epsilon}} \tag{39}$$

$$-\frac{\dot{\lambda}}{\lambda} = r \tag{40}$$

The price index of the composite consumption good is given by the inverse of the shadow price to the per-period consumption expenditures allocation problem: $\max\limits_{c_0,c_1}\{c_0^{\theta}c_1^{1-\theta}; s.t. E = c_0 - p_1 c_1\}$:

$$p_c = \left[\theta^{\frac{1}{1-\epsilon}} + (1-\theta)^{\frac{1}{1-\epsilon}} p_1^{\frac{-\epsilon}{1-\epsilon}}\right]^{-\frac{1-\epsilon}{\epsilon}} \tag{41}$$

The above imply:

$$\frac{\dot{C}}{C} = \frac{1}{\sigma}\left[r + \sigma(1-\gamma(t))\frac{\dot{p}_1}{p_1} - \rho\right] \tag{42}$$

, where $\gamma(t) = \frac{c_0}{c_0+p_1c_1} = \frac{\theta c_0^{\epsilon}}{\theta c_0^{\epsilon}+(1-\theta)\theta c_1^{\epsilon}} = \frac{1}{1+\left(\frac{1-\theta}{\theta}\right)^{\frac{1}{1-\epsilon}} p_1^{\frac{-\epsilon}{1-\epsilon}}}$ from the equilibrium conditions above.

In order to complete the static equilibrium results, note that the production side requires: $\frac{p_1 Y_1}{Y_0} = \frac{u_1}{u_0}$. Given the demand for capital varieties, it follows, $p_H K_0 = \alpha^2 Y_0$ and $p_H K_1 = \alpha^2 p_1 Y_1$ and therefore: $\frac{K_1}{K_0} = \frac{u_1}{u_0}$. Combining these with the market clearing condition for intermediate goods, $H = h_0^{\beta}h_1^{1-\beta} = K_0 + K_1$, (24), and the market clearing for non-ICT-using good, $Y_0 = c_0 + h_0$ it follows:

$$\alpha^2\beta\left(1+\frac{u_1}{u_0}\right) = \frac{h_0}{h_0+c_0} \tag{43}$$

Also, combining the static equilibrium conditions for intermediates and consumption goods: $\frac{h_1}{h_0}\frac{\beta}{1-\beta} = \frac{c_1}{c_0}\frac{\theta}{1-\theta}$. It then follows by combing the results above together with the market clearing conditions for the non-ICT-using and the ICT-using good, $Y_1 = c_1 + h_1$ that:

$$\frac{u_1}{u_0}\left(1+\frac{c_1}{c_0}\right) = \frac{1-\theta}{\theta}\frac{c_0}{h_0} + \frac{1-\beta}{\beta} \tag{44}$$

Combining (43) and (44) allows to solve for the consumption to intermediates shares in the two final goods sectors and relative labour allocations:

$$\frac{c_0}{h_0} = \frac{\gamma(t)(1-\alpha^2)}{\alpha^2\beta} \tag{45}$$

$$\frac{c_1}{h_1} = \frac{(1-\gamma(t))(1-\alpha^2)}{\alpha^2(1-\beta)} \tag{46}$$

$$\frac{u_1}{u_0} = \frac{1-\alpha^2\beta-\gamma(t)(1-\alpha^2)}{\alpha^2\beta+\gamma(t)(1-\alpha^2)} \tag{47}$$

The shares to be positive if: $\frac{1-\alpha^2\beta}{1-\alpha^2} > \gamma(t)$.

Along the CGP, for constant growth rate for the varieties stock, $\frac{\dot{N}}{N}$, the labour allocation in the ICT-producing sector needs to be constant, $\dot{u}_N = 0$. That implies $\dot{u}_1 = \dot{u}_0$. Given (30), (27), (41) and (37), this implies constant growth for the relative prices of capital varieties, $\frac{\dot{\hat{p}}_1}{\hat{p}_1} = \frac{\dot{\hat{p}}_0}{\hat{p}_0} = \frac{\dot{p}_1}{p_1}$, intermediates $\frac{\dot{p}_H}{p_H} = (1-\beta)\frac{\dot{p}_1}{p_1}$, composite consumption good, $\frac{\dot{p}_c}{p_c} = (1-\gamma(t))\frac{\dot{p}_1}{p_1}$, and ICT-using final good, $\frac{\dot{p}_1}{p_1} = -(1-\alpha)\frac{\dot{N}}{N}$.

Regarding the dynamic equilibrium results, given the demand for capital varieties (28), (29) and the growth rates of relative prices, the implied growth rates for the two final-good sectors are constant as well. The growth of aggregate output is constant as well and equal to the growth of the non-ICT-using good. Note that, for the growth of the aggregate output to be constant, it is sufficient that $\dot{u}_N = 0$, because the output growth differences are cancelled out by the relative price differences of the two final-good sectors and any labour reallocations between the two sectors aggregate to zero:

$$\frac{\dot{Y}_0}{Y_0} = \alpha(1-\beta)\frac{\dot{N}}{N} + \frac{\dot{u}_0}{u_0} \tag{48}$$

$$\frac{\dot{Y}_1}{Y_1} = (1-\alpha\beta)\frac{\dot{N}}{N} + \frac{\dot{u}_1}{u_1} \tag{49}$$

$$\frac{\dot{Y}}{Y} = \alpha(1-\beta)\frac{\dot{N}}{N} \tag{50}$$

Given the demand for capital varieties, it follows, $p_H K_0 = \alpha^2 Y_0$ and $p_H K_1 = \alpha^2 p_1 Y_1$. For capital as for output, it is sufficient for constant growth that $\dot{u}_N = 0$. It follows that along the CGP:

$$\frac{\dot{K}_1}{K_1} = \frac{\dot{K}_0}{K_0} = (1-\beta)\frac{\dot{N}}{N} \tag{51}$$

$$\frac{\dot{K}}{K} = \alpha(1-\beta)\frac{\dot{N}}{N} \tag{52}$$

The market clearing condition for intermediate goods, $H = h_0^{\beta} h_1^{1-\beta} = K_0 + K_1$, (26) and the relative prices' growth on CGP, imply:

$$\frac{\dot{h}_0}{h_0} = \alpha(1-\beta)\frac{\dot{N}}{N} \tag{53}$$

$$\frac{\dot{h}_1}{h_1} = (1-\alpha\beta)\frac{\dot{N}}{N} \tag{54}$$

Finally, the market clearing conditions for the two final-good products together with (48), (49) and (51) :

$$\frac{\dot{c}_0}{c_0} = \alpha(1-\beta)\frac{\dot{N}}{N} \tag{55}$$

$$\frac{\dot{c}_1}{c_1} = (1-\alpha\beta)\frac{\dot{N}}{N} \tag{56}$$

From (33), it follows that: $\frac{\dot{V}_1}{V_1} = \left[r(t) + (1-\gamma(t))\frac{\dot{p}_1}{p_1}\right] - \frac{\pi_1}{V_1}$, and from (38): $\frac{\dot{V}_1}{V_1} = \frac{1-\alpha(1-\beta)}{1-\alpha}\frac{\dot{p}_1}{p_1}$. Hence, the implied real interest rate from the production side is:

$$r(t) = \left[\frac{1-\alpha(1-\beta)}{1-\alpha} - (1-\gamma(t))\right]\frac{\dot{p}_1}{p_1} + \frac{\pi_1}{V_1}$$

, where again (38) implies that: $\frac{\pi_1}{V_1} = \lambda\alpha u_1 L$.

Finally, the market clearing conditions imply that $\frac{\dot{C}}{C} = \frac{\dot{Y}}{Y} = \alpha(1-\beta)g_N$, where $g_N \equiv \frac{\dot{N}}{N} = \lambda L\left(1 - \frac{u_1}{1-\gamma(t)(1-\alpha^2)-\alpha^2\beta}\right)$. Using this condition, substituting for the real interest rate and rearranging terms:

$$\rho + [1-\alpha(1-\beta)+\sigma\alpha(1-\beta)]\, g_N = \lambda\alpha u_1 L + (1-\sigma)(1-\alpha)(1-\gamma(t))g_N.$$

Along the CGP, all the units in the LHS of this expression are constant over time. Hence, the relation will hold only if the RHS is constant as well, which requires: $\frac{\dot{u}_1}{\dot{\gamma}} = \frac{(1-\alpha)(1-\sigma)g_N}{\lambda\alpha L}$. This needs to comply with $\frac{\dot{u}_1}{\dot{\gamma}} = -(1-\alpha^2)\frac{g_N}{\lambda L}$, that comes from (47) under the CGP requirements. These suggest the following requirement on the intratemporal elasticity of substitution: $\sigma = 1 + \alpha(1+\alpha)$. Hence, the condition is used to solve for the steady-state labour allocations. It follows that:

$$u_N = \frac{\alpha\left[1-\gamma(t)(1-\alpha^2)-\alpha^2\beta\right] - \frac{\rho}{\lambda L}}{\alpha[1-\gamma(t)(1-\alpha^2)-\alpha^2\beta]+1+\alpha(1+\alpha)[\alpha(1-\beta)+(1-\alpha)(1-\gamma(t)]}$$

This shows however that the equilibrium allocation is a function of time. The necessary condition for the steady-state requirement $\dot{u}_N = 0$, is either $\dot{\gamma} = 0$, which implies that $\epsilon = 0$, or $\rho = -\frac{\lambda L\left[1+\alpha^2(1-\beta)\right]}{2} < 0$. The latter cannot be the case for a well defined problem. Therefore, this implies that restriction on the intertemporal elasticity of substitution is not a sufficient condition for the existence of a CGP. The necessary condition for this is that there is unit intratemporal elasticity of substitution, i.e. $\epsilon = 0$. The argument for this proof is completed in Proposition 2, where it is shown that the condition on $\epsilon = 0$, is not only necessary, but also sufficient condition for a CGP, since one can solve for the constant allocations of labour and constant growth rates along the CGP, without any further requirements on the intertemporal elasticity of substitution. *Q.E.D.*

Proof of Proposition 2

For unit intratemporal elasticity of substitution: $u(c_0, c_1) = \frac{\left(c_0^{\theta}c_1^{1-\theta}\right)^{1-\sigma}-1}{1-\sigma}$. The FOCs of Proposition1 above are altered as follows:

$$\frac{c_1}{c_0} = \frac{1-\theta}{\theta}\frac{1}{p_1} \tag{57}$$

$$-\frac{\dot{\lambda}}{\lambda} = r \tag{58}$$

The price index of the composite consumption good is:

$$p_c = \Theta p_1^{1-\theta} \tag{59}$$

,where $\Theta = \left[\theta^\theta (1-\theta)^{1-\theta}\right]^{-1}$. The above imply:

$$\frac{\dot{C}}{C} = \frac{\dot{c}_0}{c_0} = \frac{1}{\sigma}\left[r + \sigma(1-\theta)\frac{\dot{p}_1}{p_1} - \rho\right] \tag{60}$$

Production side: The solution of the dynamic programs of the final good producers, composite intermediate good and the capital varieties firms remains as described in Proposition 1, and described by (22) through (38).

Along the CGP, for constant growth rate for the varieties stock, $\frac{\dot{N}}{N}$, the labour allocation in the ICT-producing sector needs to be constant, $\dot{u}_N = 0$. Given (30), (27), (59) and (37), this implies constant growth for the relative prices of capital varieties, $\frac{\dot{\hat{p}}_1}{\hat{p}_1} = \frac{\dot{\hat{p}}_0}{\hat{p}_0} = \frac{\dot{p}_1}{p_1}$, intermediates $\frac{\dot{p}_H}{p_H} = (1-\beta)\frac{\dot{p}_1}{p_1}$, composite consumption good, $\frac{\dot{p}_c}{p_c} = (1-\theta)\frac{\dot{p}_1}{p_1}$, and ICT-using final good, $\frac{\dot{p}_1}{p_1} = -(1-\alpha)\frac{\dot{N}}{N}$.

The guess to be verified later, is that along the CGP real interest rate, r and the labour allocations in the two final good sectors will be constant. Under these assumptions and together with the constant growth of relative prices, it follows from equating (35) and (36) that there is a negative relationship between the real interest rate and the ICT-production growth:

$$\alpha\lambda u_1 L = r + \frac{\dot{N}}{N}\left[\theta(1-\alpha) + \alpha\beta\right] \tag{61}$$

Completing the static equilibrium results, the consumption to intermediates shares in the two final goods sectors and relative labour allocations are now modified as follows:

$$\frac{c_0}{h_0} = \frac{\theta(1-\alpha^2)}{\alpha^2\beta} \tag{62}$$

$$\frac{c_1}{h_1} = \frac{(1-\theta)(1-\alpha^2)}{\alpha^2(1-\beta)} \tag{63}$$

$$\frac{u_1}{u_0} = \frac{1-\alpha^2\beta-\theta(1-\alpha^2)}{\alpha^2\beta+\theta(1-\alpha^2)} \tag{64}$$

In order that the shares to be positive: $\frac{1-\theta(1-\alpha^2)}{\alpha^2} > \beta$.

Regarding the dynamic equilibrium results, given the demand for capital varieties (28), (29) and the growth rates of relative prices, the implied growth rates for the two final-good sectors are constant as well. The growth of aggregate output is constant as well and equal to the growth of the non-ICT-using good. Note that, for the growth of the aggregate output to be constant,a it is sufficient that $\dot{u}_N = 0$, as long as the relative output growth differences are cancelled out by the relative price differences of the two final-good sectors and any labour reallocations between the two sectors should aggregate to zero:

$$\frac{\dot{Y}}{Y} = \frac{\dot{Y}_0}{Y_0} = \alpha(1-\beta)\frac{\dot{N}}{N} \tag{65}$$

$$\frac{\dot{Y}_1}{Y_1} = (1-\alpha\beta)\frac{\dot{N}}{N} \tag{66}$$

Given the demand for capital varieties, it follows, $p_H K_0 = \alpha^2 Y_0$ and $p_H K_1 = \alpha^2 p_1 Y_1$. For capital as for output, it is sufficient for constant growth that $\dot{u}_N = 0$. It follows that along the CGP:

$$\frac{\dot{K}_1}{K_1} = \frac{\dot{K}_0}{K_0} = (1-\beta)\frac{\dot{N}}{N} \tag{67}$$

$$\frac{\dot{K}}{K} = \alpha(1-\beta)\frac{\dot{N}}{N} \tag{68}$$

The market clearing condition for intermediate goods, $H = h_0^{\beta} h_1^{1-\beta} = K_0 + K_1$, (26) and the relative prices' growth on CGP, imply:

$$\frac{\dot{h}_0}{h_0} = \alpha(1-\beta)\frac{\dot{N}}{N} \tag{69}$$

$$\frac{\dot{h}_1}{h_1} = (1-\alpha\beta)\frac{\dot{N}}{N} \tag{70}$$

Finally, the market clearing conditions for the two final-good products together with (65), (66) and (67) :

$$\frac{\dot{c}_0}{c_0} = \alpha(1-\beta)\frac{\dot{N}}{N} \tag{71}$$

$$\frac{\dot{c}_1}{c_1} = (1-\alpha\beta)\frac{\dot{N}}{N} \tag{72}$$

In order to solve for the constant interest rate, allocations and growth of ICT-production, (60) is used together with (71), (61), (64) and $\frac{\dot{N}}{N} = \lambda L\,(1-u_1-u_0)$:

$$u_1^d = \frac{\left[1-\theta(1-\alpha^2)-\alpha^2\beta\right]\left(\frac{\rho}{\lambda L}+\Phi\right)}{\alpha[1-\theta(1-\alpha^2)-\alpha^2\beta]+\Phi} \tag{73}$$

$$u_0^d = \frac{\left[\theta(1-\alpha^2)+\alpha^2\beta\right]\left(\frac{\rho}{\lambda L}+\Phi\right)}{\alpha[1-\theta(1-\alpha^2)-\alpha^2\beta]+\Phi} \tag{74}$$

$$g_N^d \equiv \frac{\dot{N}}{N}^d = \lambda L \frac{\alpha\left[1-\theta(1-\alpha^2)-\alpha^2\beta\right]-\frac{\rho}{\lambda L}}{\alpha[1-\theta(1-\alpha^2)-\alpha^2\beta]+\Phi} \tag{75}$$

, where $\Phi = \sigma + (1-\sigma)\left[\alpha\beta + \theta(1-\alpha)\right]$.

In order to check the conditions for an interior solution, it is sufficient to check that $u_1^d > 0$ and $g_N^d > 0$. Note that for $\frac{1-\theta(1-\alpha^2)}{\alpha^2} > \beta$ it is sufficient to search conditions for $\Phi \geq 0$. If $\sigma \leq 1$, it follows that $\Phi \geq 0$ and $u_1^d > 0$.

If instead $\sigma > 1$, then the condition for $\Phi \geq 0$ is that either $\frac{1-\theta(1-\alpha)}{\alpha} > \beta$, or $\frac{1-\theta(1-\alpha)}{\alpha} < \beta < \frac{1-\theta(1-\alpha^2)}{\alpha^2}$ with $\sigma \leq \frac{\alpha\beta+\theta(1-\alpha)}{\alpha\beta+\theta(1-\alpha)-1}$. Therefore, a sufficient condition for interior solution is that $\frac{1-\theta(1-\alpha)}{\alpha} > \beta$. This imposes no further requirement on the intertemporal elasticity of substitution. However, that restriction is always satisfied itself always given that $\theta, \beta \in (0,1)$. Hence the only condition required on the parameters is that $L > \frac{\rho}{\lambda\alpha[1-\theta(1-\alpha^2)-\alpha^2\beta]}$. *Q.E.D.*

Proof of Proposition 3

Let $\Delta = \alpha\left[1-\theta(1-\alpha^2)-\alpha^2\beta\right]+\Phi$. The comparative statics are for parameters that satisfy $\frac{1-\theta(1-\alpha)}{\alpha} > \beta$ and $L > \frac{\rho}{\lambda\alpha[1-\theta(1-\alpha^2)-\alpha^2\beta]}$. The effect of a change in λ is:

$$\begin{aligned}
\frac{\partial g_N^d}{\partial \lambda} &= \frac{\alpha\left[1-\theta(1-\alpha^2)-\alpha^2\beta\right]L}{\Delta} > 0 \\
\frac{\partial\left(u_1^d/u_0^d\right)}{\partial \lambda} &= 0
\end{aligned}$$

A change in ρ implies:

$$\begin{aligned}
\frac{\partial g_N^d}{\partial \rho} &= -\frac{1}{\Delta} < 0 \\
\frac{\partial\left(u_1^d/u_0^d\right)}{\partial \lambda} &= 0
\end{aligned}$$

A change in σ implies:

$$\begin{aligned}
\frac{\partial g_N^d}{\partial \sigma} &= -\frac{1}{\Delta^2}\left[1-\theta(1-\alpha)-\alpha\beta\right]\left(\lambda L\alpha\left[1-\theta(1-\alpha^2)-\alpha^2\beta\right]-\rho\right) < 0 \\
\frac{\partial\left(u_1^d/u_0^d\right)}{\partial \lambda} &= 0
\end{aligned}$$

A change in θ implies:

$$\begin{aligned}
\frac{\partial g_N^d}{\partial \theta} &= \frac{1}{\Delta^2}\left\{-\alpha(1-\alpha^2)\left(\lambda L\Phi+\rho\right)\right. \\
&\quad \left.-(1-\sigma)(1-\alpha)\left(\lambda L\alpha\left[1-\theta(1-\alpha^2)-\alpha^2\beta\right]-\rho\right)\right\} \\
\frac{\partial\left(u_1^d/u_0^d\right)}{\partial \theta} &= \frac{-(1-\alpha^2)}{\left[\theta(1-\alpha^2)+\alpha^2\beta\right]^2} < 0
\end{aligned}$$

For $\sigma \leq 1$, the effect on the growth rate is definitely negative.
A change in α implies:

$$\begin{aligned}
\frac{\partial g_N^d}{\partial \alpha} &= \frac{1}{\Delta^2}\left\{\left[1-\theta(1-\alpha^2)-\alpha^2\beta+2\alpha^2\left(\theta-\beta\right)\right]\left(\lambda L\Phi+\rho\right)\right. \\
&\quad \left.-\left(1-\sigma\right)\left(\theta-\beta\right)\left(\lambda L\alpha\left[1-\theta(1-\alpha^2)-\alpha^2\beta\right]-\rho\right)\right\} \\
\frac{\partial\left(u_1^d/u_0^d\right)}{\partial \alpha} &= \frac{2\alpha(\theta-\beta)}{\left[\theta(1-\alpha^2)+\alpha^2\beta\right]^2}
\end{aligned}$$

The results depend critically on θ, β and σ. For $\theta > \beta$ the effect on the growth rate and the relative labour allocations is positive if $\sigma \geq 1$.
A change in β implies:

$$\begin{aligned}\frac{\partial g_N^d}{\partial \beta} &= \frac{1}{\Delta^2}\left\{-\alpha^3\left(\lambda L\Phi+\rho\right)\right.\\ &\quad \left.-(1-\sigma)\alpha\left(\lambda L\alpha\left[1-\theta(1-\alpha^2)-\alpha^2\beta\right]-\rho\right)\right\}\\ \frac{\partial\left(u_1^d/u_0^d\right)}{\partial\beta} &= \frac{-2\alpha^2}{\left[\theta(1-\alpha^2)+\alpha^2\beta\right]^2}<0\end{aligned}$$

The effect on growth would be negative for $\sigma \leq 1$. *Q.E.D.*

7 Appendix B: Data Summary

Data Sources:

The data on average value added and Domar shares, value added and TFP growth for the 1977-2000 period for 44 industries, are taken from Table 8.6 in Jorgenson et al. (2005). Table 7.1 provides with the decomposition of the output growth for these 44 industries into the contribution of capital, labor, intermediate materials and TFP for the 1977-2000 period. ICT-capital intensity in 1995 for each of the 44 industries is coming from Table 4.2. All data are based the three-digit SIC 1987 industry classification. Details on the sources and methodology for the detailed industry growth accounting are found in Jorgenson (2005), Chapter 4.

The data on employment, value added and value added deflators for 57 industries of the United States economy are taken from the "60-Industry Database", which is constructed by the Groningen Growth and Development Centre (GGDC). The data cover the period 1979-2001 (version Oct. 2003) and are based on the three-digit ISIC Rev.3 industry classification. The dataset is constructed based on the information available in the OECD STructural ANalysis Database (STAN) and official United States Statistical Offices: the Bureau of Economic Analysis (BEA) and Bureau of Labour Statistics (BLS).

The data on the use shares of the commodities are from the "Use Table" of the "Benchmark 1997 Input-Output Table" (after redefinitions) available from BEA. The 1997 benchmark I-O accounts use the classification system that is based on the North American Industry Classification System (NAICS).

The data on "Personal Consumption Expenditures by Type of Product" are taken from NIPA Table 2.4.5. available from BEA, in accordance with

NIPA Table 2.5.5 on "Personal Consumption Expenditures by Type of Expenditures". NIPA Tables from BEA are consistent with the NAICS basis used in their I-O Tables.

Since different data sources rely on different systems of industry classification, the mapping of every industry is only approximate across the different databases. The original classification tables for NAICS 1997, NAICS 2002, SIC 1987, ISIC Rev. 3.1 and ISIC Rev. 3 were checked together with the correspondence tables provided by the United Nations (ISIC Rev. 3-ISIC Rev. 3.1, ISIC Rev. 3.1-NAICS 2002 (US)) and U.S. Census Bureau (NAICS 1997-SIC 1987, NAICS 1997-NAICS 2002).

To illustrate the consistency across the different data sources, the following Table B1 at the end of the appendix summarizes the main variables' values across the different sources, while Table B2 provides descriptive statistics of the main variables used.

Variables:

Value added is current gross value added measured at producer prices or at basic prices, depending on the valuation used in the national accounts. It represents the contribution of each industry to total GDP.
Value added deflator is the change in the value added deflator. It can be combined with current value added to derive quantity indices of real value added at industry level[16].
Hours refers to average annual hours worked per employee or per person engaged.
Personal consumption expenditures are the goods and services purchased by persons[17].

Aggregation Method:

In each dataset, the industries are grouped into three aggregate sectors: ICT-producing, ICT-using and non-ICT-using. Any transactions with abroad are not taken into consideration.

[16] The official data were readily adjusted into using a hedonic deflator system, so as to account better for the benefits arising from the ICT production and use. The deflators provided in the GGDC database come from official BEA data (harmonising of the deflators for other countries in the dataset does not affect USA data) and are based on the double deflation procedure for the ICT related industries. For an overview of the literature regarding hedonic deflators, see OECD "Handbook on Hedonic Indexes and Quality Adjustments in Price Indexes: Special Application to Information Technology Products", Triplett J. (2004).

[17] In the national income and product accounts (NIPAs), persons consist of individuals, nonprofit institutions that primarily serve individuals, private noninsured welfare funds, and private trust funds.

The Information and Communication Technology sector (ICT) producing sector is defined as in Jorgenson (2005) to include (SIC 1987 codes in parentheses) Computers and Office equipment (357), Electronic Components (367), Communications equipment (36 x 366-367) and Computer Services (737)[18].

Following Jorgenson et al. (2005), the criterion for classifying an industry as ICT using is its degree of ICT capital intensity in 1995. In particular, the share of the ICT capital out of total capital compensation for an industry in 1995 needs to exceed the 15%[19]. Details on the mapping of the GGDC data industries in each aggregate sector are provided below.

The aggregation is straightforward for the hours and consumption expenditures, intermediates and value added at current prices data. The direct aggregation across industries follows the "Aggregate Production Possibility Frontier" approach as first developed by Jorgenson (1966) and employed in recent growth accounting studies (Jorgenson et. al., 2005, van Ark et al., 2003). A Törnqvist index was applied to obtain value added deflators and value added growth rates for each of the three sectors[20]. The Domar weights were used for the aggregation of the contributions of capital, labor and TFP growth in aggregate value added.

[18] Compared to the OECD definition of the ICT sector that is followed in other studies (e.g. O' Mahony et. al, 2003, Van Ark et. al. 2003), Jorgenson's ICT-producing definition excludes the manufacturing industries ISIC Rev. 3. 1, (3312) and (3313), while it only includes the services industry ISIC rev. 3.1, (72).

[19] Alternative definitions for both the ICT-producing and ICT-using sectors were used, as well as the exclusion of the government sectors. The results presented in the paper are relatively robust to these alternative measures. The particular application was preferred because of its implied TFP data availability and its straightforward comparison to already found results.

[20] The Törnqvist aggregation method is based on weighting each industry's exponential annual growth rate with a two-period average of its share in aggregate value added. After computing the growth rate, the implied quantity index was derived, with the normalization that it is equal to 100 in 1995.

Aggregate Sectors in GGDC database:

ICT-producing sector[21]:
Office machinery (30), Insulated wire (313), Electronic valves and tubes (321), Telecommunication equipment (322), Radio and television receivers (323), Computer and related activities (72)

ICT-using sector:
Printing & publishing (22), Mechanical engineering (29), Other electrical machinery and apparatus nec (31-313), Scientific instruments (331), Other instruments (33-331), Building and repairing of ships and boats (351), Aircraft and spacecraft (353), Railroad equipment and transport equipment nec (352+359), Furniture, miscellaneous manufacturing; recycling (36-37), Wholesale trade and commission trade, except of motor vehicles and motorcycles (51), Communications (64), Financial intermediation, except insurance and pension funding (65), Insurance and pension funding, except compulsory social security (66), Activities auxiliary to financial intermediation (67), Renting of machinery and equipment (71), Research and development (73), Legal, technical and advertising (741-3), Other business activities, nec (749).

non-ICT-using:
Agriculture (01), Forestry (02), Fishing (05), Mining and quarrying (10-14), Food, drink & tobacco (15-16), Textiles (17), Clothing (18), Leather and footwear (19), Wood & products of wood and cork (20), Pulp, paper & paper products (21), Mineral oil refining, coke & nuclear fuel (23), Chemicals (24), Rubber & plastics (25), Non-metallic mineral products (26), Basic metals (27), Fabricated metal products (28), Motor vehicles (34), Electricity, gas and water supply (40-41), Construction (45), Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel (50), Retail trade, except of motor vehicles and motorcycles;repair of personal and household goods (52), Hotels & catering (55), Inland transport (60), Water transport (61), Air transport (62), Supporting and auxiliary transport activities; activities of travel agencies (63), Real estate activities (70), Public administration and defence; compulsory social security (75), Education (80), Health and social work (85), Other community, social and personal services (90-93), Private households with employed persons (95).

Table B1:

source:		Jorgenson (2005)	GGDC		BEA, I-O	BEA, NIPA
variable/ period of comparison:		1977-2000	1979-2000	1997	1997	1997
value added growth	Total Economy	3.08	3.03			
(in percent)	ICT-producing	20.09	20.48			
	ICT-using	3.89	2.98			
	non-ICT-using	2.31	2.11			
shares in value added	ICT-producing	2.1	2.9	3.7	3.5	
(in percent)	ICT-using	26.1	28.0	30.0	31.6	
	non-ICT-using	71.8	69.1	66.4	64.9	
expenditure shares	ICT-using				22.5	22.3
(in percent)	non-ICT-using				77.5	77.7

Table B2

		Average			**St. Deviation**		
		1979-01	1979-95	1995-01	1979-01	1979-95	1995-01
share of total hours worked	ICT-producing	2.0	1.9	2.4	0.29	0.13	0.25
(in percent)	ICT-using	25.7	25.5	26.4	0.73	0.63	0.40
	non-ICT-using	72.2	72.6	71.2	0.97	0.71	0.60
share of value added	ICT-producing	3.0	2.7	3.7	0.59	0.38	0.24
(in percent)	ICT-using	28.1	27.2	30.2	1.72	0.96	1.04
	non-ICT-using	69.0	70.1	66.1	2.29	1.30	1.27
real value added growth rate	ICT-producing	19.81	19.68	21.08	6.78	7.01	6.63
(in percent)	ICT-using	3.11	2.35	4.77	2.76	2.49	2.54
	non-ICT-using	2.09	2.06	2.16	1.84	2.06	1.13
value added deflator growth rate	ICT-producing	-10.22	-9.44	-12.72	3.63	3.60	2.96
(in percent)	ICT-using	4.02	4.88	2.10	2.24	1.98	1.28
	non-ICT-using	3.79	4.23	2.58	2.15	2.38	0.45
expenditure shares	ICT-using	20.7	20.0	22.4	1.61	1.32	0.50
(in percent)	non-ICT-using	79.3	80.0	77.6	1.61	1.32	0.50

Sources: All series from GGDC "60 Industry Database", 2003. Expenditure shares from the BEA NIPA Table on "Personal Consumption Expenditures by Type of Product", 2006

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