BANCA D'ITALIA

Temi di discussione

del Servizio Studi

ICT Accumulation and Productivity Growth in the United States: an Analysis Based on Industry Data

by Paola Caselli and Francesco Paternò

Number 419 - October 2001

This paper is part of a research project on "Technological Innovation, Productivity, Growth: Towards a New Economy?" carried out at the Economic Research Department of the Bank of Italy. Like others that are part of the project, it was presented and discussed in a seminar.

ICT ACCUMULATION AND PRODUCTIVITY GROWTH IN THE UNITED STATES: AN ANALYSIS BASED ON INDUSTRY DATA

by Paola Caselli* and Francesco Paternò*

Abstract

The paper analyses labour productivity (LP) and total factor productivity (TFP) dynamics in the United States using new data at the industry level on information and communications technology (ICT) capital stock in both manufacturing and the services sector.

In manufacturing, a growth accounting exercise confirms that the contribution to LP of ICT accumulation in most industries has been higher in the second half of the nineties than in 1973-1995. TFP has also been accelerating, even controlling for cyclical output fluctuations, especially in ICT-intensive industries. We have also found evidence of a recent direct positive effect on TFP growth of ICT intensity, though only in ICT-intensive industries.

In the services sector a direct effect of ICT accumulation on the acceleration of LP could be detected through both a growth accounting exercise and estimating a value added function. Moreover, we also have found evidence of a significant TFP acceleration after 1996, even controlling for cyclical effects. Econometric evidence supporting a positive effect of ICT capital accumulation on TFP growth is still rather weak, though some signs have emerged that computers accumulation has positively affected TFP dynamics in recent years.

JEL classification: L6, L8, L9, O3, O4, O5.

Keywords: information and communications technology, growth accounting.

Contents

* Banca d'Italia, Economic Research Department.

1. Where do we stand with growth-accounting results at the aggregate level?[1]

Since mid-1990's the U.S. economy has experienced an extraordinary and largely unexpected resurgence of growth, especially of productivity growth. According to the recent data released by the BEA at the end of July 2001, between 1995 and 2000, the rate of increase of GDP in the private non farm business sector averaged 4.7 per cent and hourly labour productivity 2.5 per cent; these figures compare with 3 and 1.4 per cent, respectively, recorded in the period 1973-1995. Another peculiar feature has been the concomitant sharp acceleration of accumulation in information and communications technology (ICT) capital goods, which has been accompanied by widespread application of new technologies to production processes, both in the manufacturing and in the service industries.

These two features have come to be perceived as intrinsically related to each other and to be commonly 'labeled' as the 'New Economy'.[2] Though the acceleration of average labour productivity (ALP) and the striking increase of ICT investment have been clearly 'highly correlated', until fairly recently there was little evidence, at least at the macro level, of either a significant ex-post direct contribution of ICT accumulation to productivity growth or of a causal relationship between the former and the latter (ex-ante effect).[3] For instance, only a couple of years ago, Sichel (1999) calculated that, in the period 1996-98, the contribution of the accumulation of computer hardware was less than one tenth of GDP

[1] We wish to thank James Kahn, Daniel Sichel and Kevin Stiroh for the very useful discussions we had during our visit at the Federal Reserve of New York and Washington and Francesco Lippi, Patrizio Pagano and Salvatore Rossi for helpful comments. We have also benefited from discussions with seminar participants at the Bank of Italy. Kevin Stiroh and Fabiano Schivardi gave us several suggestions leading to a substantial improvement of a previous version of the paper. Daniel Sichel kindly provided us the latest version of his growth accounting exercise updated to 2000. Any remaining errors are our own. The opinions expressed do not necessarily reflect those of the Bank of Italy. E-mail: caselli.paola@insedia.interbusiness.it ; paterno.francesco@insedia.interbusiness.it .

[2] The term 'New Economy' is not uncontroversial; according to the last Economic Report of the President (2001) a 'New Economy' paradigm for the US economy can be justified by the coexistence of the following four features: i) the acceleration of productivity growth; ii) low levels of unemployment and inflation; iii) the disappearance of the Federal budget deficits; iv) the strength of the U.S. economy's performance relative to the other industrial countries.

[3] The ex-post contribution is usually calculated within a 'growth accounting' framework; the ex-ante effect requires econometric analysis.

growth and less than 25 per cent of ALP growth; though this contribution had increased with respect to the previous period (1970-1995), it was nonetheless still rather limited.

After major changes were introduced in the US national accounts system at the end of 1999, several studies applied the standard neo-classical growth-accounting framework to the new updated data.[4] The results of the most important contributions are reported in Table 1; though these exercises differ slightly for the aggregate considered, their results are broadly comparable.[5] It emerges that, in the period 1995-99 (2000 in some cases), the average rate of increase of ALP on hourly basis - ranging from 2.3 to 3 per cent - can be equally attributed to the capital deepening effect and to total factor productivity (TFP) growth. In this respect the second half of the 1990's fundamentally differ from the previous period (1973-1995) when the contribution to ALP growth came essentially from capital deepening. This feature emerges especially in the exercises by the Council of Economic Advisors presented in the Report of the President (2000 and 2001), the BLS (2000b) and Oliner and Sichel (2000). All these exercises show a significant increase of TFP growth in the second half of the 1990's. According to the CEA (2001), in the period 1995-2000, the average rate of TFP growth reached 1.59 per cent, four times higher than that recorded during the phase of the so-called "productivity slowdown" (1973-1995).[6]

What is the role played by ICT in this remarkable performance? Two channels have to be distinguished: the first stems from ICT as capital input (that is from the *use* of ICT capital goods), the second from TFP growth in the ICT producing industries (that is from the *production* of ICT goods).[7] In this respect, not all the exercises are strictly comparable. CEA (2000) and Gordon (2000a) do not quantify explicitly the first channel, the BLS (2000) does

---

[4] For a description of the definitional and classificational changes introduced in the National Income and Product Accounts, see BEA (1999 e 2000).

[5] Oliner and Sichel (2000 and 2001), CEA (2000 and 2001) and Gordon (2000a) refer to output and productivity in the private non farm business sector, while Jorgenson and Stiroh (2000) add to this aggregate the service flow from consumers' durables and owner-occupied housing.

[6] Similar results have been obtained by Oliner and Sichel (2001) in a recent unpublished update of their previous paper. It is worth stressing that these results covering also 2000 are still provisional since the capital stock has been estimated.

[7] The size of the former depends on the strength of ICT accumulation, as compared to the accumulation of other inputs, and on the share of ICT capital in total income; the size of the latter depends on the strength of

not quantify the second. It is worth noting that according to Oliner and Sichel (2000 and 2001), BLS (2000b) and CEA (2001) the accumulation of ICT capital accounts for almost all of the total capital deepening effect in the second half of the nineties, while for Jorgenson and Stiroh (2000) it only accounts for less than a half. All the exercises indicate that the contribution to ALP growth directly attributable to ICT accumulation has doubled or more than doubled in the second half of the 1990's with respect to the previous period. In sum, a general consensus has emerged that the massive accumulation of ICT capital has significantly contributed to the recent labour productivity revival. More controversial is the role of the production of ICT goods. For Oliner and Sichel (2000 and 2001) and Jorgenson and Stiroh (2000), in the same period, about 50 per cent of TFP growth is directly related to the production of ICT goods; for Gordon (2000a) 70 per cent; for CEA (2000 and 2001) 37 and 23 per cent, respectively.[8] These differences are not negligible at all and they have different implications in term of growth perspectives and potential.

If TFP gains are mainly concentrated in ICT producing industries, productivity increases for the economy as a whole will depend only on the rate of technical progress in those industries. Thus, there are no spillovers from production of ICT goods to production in the ICT using industries. This position has been put forward forcefully by Gordon (2000a). Also Stiroh (2001a) argues that the recent US experience "*appears to be largely a neo-classical story of relative price decline and input substitution. Technical change in the production of information technology assets lowers their relative price, induces massive high-tech investment, and is ultimately responsible for the recent productivity revival. These benefits, however, accrue primarily to the producers and users of ICT goods, with little evidence of large spillovers. That is, we see TFP growth in ICT producing industries and capital deepening elsewhere*". Should this be the case, only the continuation of the extraordinary path of expansion of technical progress experienced in recent years in ICT

technological progress in the ICT producing industries and on their weights in total value added. In Section 2.2 the underlying analytical framework will be made explicit.

[8] Oliner and Sichel (2000 and 2001) consider the production of computers and semiconductors, Jorgenson and Stiroh (2000) add to this aggregate the production of software and communications. It is not clear which definition has been adopted by the CEA (2000 and 2001). Gordon uses the results obtained by Oliner and Sichel (2000).

producing industries would assure high rates of growth for the whole economy also in the future.

It seems to us that this interpretation neglects a rather interesting result emerging from all the recent growth accounting exercises – with the notable exception of Gordon (2000a) -, that is the acceleration of TFP occurred also in the non ICT producing sectors in the second half of the nineties. These increases range from 0.4 percentage points in Oliner and Sichel (2000) and Jorgenson and Stiroh (2000) to 1 percentage point in the latest exercise by CEA (2001); they are quite relevant, considering that in the period 1973-1995 TFP growth in the non-ICT industries was estimated only 0.2 per cent or even below that. Is there any link between this acceleration and ICT accumulation? Is it mainly attributable to cyclical factors, as argued by Gordon (1999 and 2000a)?[9] Have other factors been relevant, apart from ICT accumulation, in the TFP revival of the nineties outside the ICT producing sector?

The aim of the paper is to offer some preliminary evidences on these issues by examining the productivity performance of the US economy at industry level in a long term perspective. The cross-sectoral perspective is, in fact, very important in order to assess the existence of possible spillovers throughout the economy; moreover, the BLS has recently made available a very complete and powerful data base for manufacturing industries. The analysis has been split between manufacturing and services essentially because of methodological problems (see Section 2.1 and 3.1); it is also worth mentioning that the former 'used' less than 20 per cent of the total ICT capital stock of the non farm business sector in 1999, against the 70 per cent of the latter.[10]

The paper is organized as follows. We first present an analysis of productivity trends in the manufacturing sector by using the new data-base by BLS; this data-base is coherent with the new national accounts and contains very detailed information on ICT capital stock for all industries at the SIC 2 digit level (Section 2). After comparing recent productivity trends

---

[9] Very recently Gordon (Gordon, 2001) has updated his estimates of the impact of the cycle on productivity growth; according to these more recent calculations the acceleration of trend labour productivity in the period 1995-2000 has been 1.04 percentage points each year; long term TFP growth outside the ICT producing industries has also increased by 0.22 percentage points, nearly doubling with respect to the previous period.

[10] The sectors not explicitly considered in our analysis are: agriculture, forestry, and fishing, mining and construction.

with those characterizing the so-called ‘Golden-Age’, we present the results of a growth-accounting exercise at the industry level which quantifies the ex-post effect of ICT accumulation in each industry. Then we show some preliminary results of an econometric analysis aiming at quantify the ex-ante effects of ICT accumulation on ALP and TFP growth. In Section 3 we analyze in a similar fashion ALP and TFP trends in the service industries.

2. Productivity growth and ICT accumulation in the manufacturing sector

2.1 Productivity trends in the nineties and in the ‘Golden Age’

To what extent is the recent productivity revival comparable to the extraordinary performance recorded in the ‘Golden Age’? We will try to get some insights by exploring productivity trends in the manufacturing sector in the period 1952-1999.[11] Unfortunately, because of lack of data, we cannot perform such a long-term comparative analysis also for the service sector (see Section 3.1).

We first consider ALP, which is calculated by the BLS on hourly basis.[12] It is worth noting that hours worked are treated as homogeneous and additive, with no distinction made between hours of different groups of employees;[13] then, at industry level, ALP is affected by changes in labor composition (by sex, age, skills and so on), the so-called labor quality effect. The BLS does correct for labour composition only at aggregate level, for the private business and the private non farm business sector (BLS, 2000b).

Table 2a shows the average rates of ALP growth in four different sub-periods in the 20 manufacturing industries classified according to the Standard Industrial Classification at the 2 digit level. In total manufacturing the acceleration recorded last decade and especially between 1995 and 1999, has been quite remarkable, to 3.95 and 4.41 per cent, respectively from 2.46 in the period 1973-1991; it has been striking in the durable goods industries,

[11] According to Gordon (2000b) the American ‘Golden Age’ began much earlier, around the time of World War I. Unfortunately 1952 is the first year for which data are available at industry level.

[12] The BLS measures labour productivity on the basis of gross output, which includes intermediate inputs. Thus, this ALP measure is different from that used in Section 3 for services, based instead on value added.

[13] For industries in which the self-employed are important hours of all persons are considered, which

where ALP growth has increased from 2.65 per cent, between 1952 and 1991, to more than 6 per cent in 1995-99.[14]

In the non durable goods sector, 7 out of 10 industries recorded an increase of ALP growth in the nineties with respect to the period 1973-1991, 9 out of 10 in the durable goods sectors. Quite interestingly, in the two more intensive ICT producing industries (industrial and commercial machineries - SIC35 - and electric and electronic equipment – SIC36) ALP growth had already significantly increased in the period 1973-1991 with respect to the 'Golden Age'.[15] In these two industries the further acceleration recorded in the nineties has been dramatic, up to 10 and 13.5 per cent, respectively.[16]

In sum, though the increase of ALP growth has been widespread, involving 16 out of 20 industries, it is nonetheless true that the revival of the nineties has been largely concentrated in the durable goods sector, and in particular in SIC35 and SIC36 industries. This phenomenon is reflected in a sharp increase of the variability of ALP growth across industries that has reached 3.25 in the nineties, against values below one in the 'Golden Age' or just above one in the period 1973-1991.

Let's now turn to TFP, the other crucial measure of productivity. We avoid at this stage to discuss the issue about which is the most correct measure for welfare analysis. This issue is analyzed, among others, by Nordhaus (2001a) and by Steindel and Stiroh (2000).

TFP is calculated by the BLS as the 'Solow residual' from a constant return to scale Cobb-Douglas production function including capital, labor, energy, materials, and business services inputs. The features emerged for ALP are confirmed (Table 2b). In the nineties a

---

include paid employees, partners, proprietors, and unpaid family workers.

[14] One striking feature is that, in the manufacturing sector, the productivity slowdown after 1973 has been extremely limited and entirely confined to the non-durable goods industries.

[15] Computers, calculating machines and equipment are included in SIC35; semiconductors, electron tubes and communications equipment in SIC36; some high tech instruments are included in SIC38. Nordhaus (2001c) provides a complete list of information technology industries, including also services; in 1998 they represented about 8 per cent of total GDP, equally shared between goods and services.

[16] Caution is needed when comparing labor productivity trends across different periods. In fact, outsourcing of production activities imply an increase of labors productivity (other things equal) defined in terms of gross output. In the nineties the sharp restructuring of the manufacturing sector has been accomplished also through

large number of industries have experienced an increase of TFP growth (14 out of 20), which has been stronger for those of the durable goods sector, especially for SIC35 and SIC36, whose rate of TFP growth exceeded the extraordinary value of 6 per cent per year during last decade. Also in this case the variability across industries did rise quite sharply in the nineties.

However, some differences with respect to ALP trends deserve to be pointed out. In the non durable goods sector, the rate of growth of TFP remained, in the nineties, well below that recorded during the ‘Golden Age’ (about 0.6 per cent, against 1.31); in 2 industries (tobacco and printing and publishing) it was actually negative. In the durable goods sector, 4 industries (lumber and wood products, transportation equipment, miscellaneous manufacturing and, quite surprisingly, measuring and controlling instruments) recorded a rate of TFP growth well below that of the ‘Golden Age’.

One major criticism to this intertemporal comparison is that the nineties were a much shorter period than the ‘Golden Age’ (25 years) and, more importantly, they actually coincided with a phase of cyclical upswing, started in the first quarter of 1991. In order to overcome, at least partially, this second criticism, we have also compared the productivity performance in the nineties and in the expansionary phases of the ‘Golden Age’. The expansionary phases are the official ones, reported by the NBER. Because of lack of data we could not consider the 1949-1953 expansion (Haimovitz, 1998).

As regards ALP, it is still true that the variability across industries has been in the nineties the highest ever recorded (Table 3a). Moreover, only 4 industries have exhibited in the same period the highest rate of ALP growth (apparel and related products, leather products, SIC35 and SIC36). Again, it is worth stressing the extraordinary performance achieved by SIC35 and SIC36, whose ALP growth has been by far the highest ever recorded in any expansionary phase by any industry[17] TFP has exhibited similar patterns (Table 3b);

---

massive outsourcing (both in the US and abroad), so that the acceleration of labor productivity reported in Table 2 is likely to be overestimated.

[17] The only comparable figures are the 7.6 and 8.7 rates of growth recorded by ‘chemical and allied products’ and by ‘transportation equipment’ during the 1970-73 upswing.

also in this case apparel and related products as well as SIC35 and SIC36 have been the only three industries with the highest rate of growth ever recorded.

From this preliminary look at the data it appears also that in the nineties the performance of TFP growth was less good than that of ALP, in particular in the non durable sector. However, also some industries of the durable goods sector did not perform particularly well and substantial TFP growth was actually achieved only by 3 industries out of 10.[18] At least at first sight, Gordon's skepticism about the high concentration in high-tech industries of TFP gains in the nineties seems to have some validity.

2.2 A growth accounting exercise at the industry level

How much is the ALP revival of the nineties in the manufacturing sector directly related to the accumulation, that is to the *use*, of ICT capital in each industry? To get some preliminary insights we have performed a growth accounting exercise at industry level, in which we have explicitly computed the contribution of ICT capital stock.

Before presenting these results, it is helpful to have a glance at some indicators summarizing the main features of ICT capital accumulation across manufacturing industries. From this point onwards, the analysis focuses on the period 1973-1999. This is not because of lack of data; time series of ICT capital stock are, in fact, available at industry level since 1952. However, the weight of ICT capital did start to increase only at the beginning of the seventies, with an increasing role played by computers and, to lesser extent, by software.[19]

In 1999 less than 17 per cent of the ICT capital stock of the non-farm business sector was held by the manufacturing sector; this share had actually declined slightly since mid-eighties (Table 4).[20] Three industries (chemical and allied products, SIC35 and SIC36) held

---

[18] Apart from SIC35 and SIC36, also primary metal industries (SIC34).

[19] The BLS data base contains information on four types of ICT capital: computers (including also computer peripheral equipment), software, communication and 'other', which mainly includes office and accounting machinery, photocopy and related equipment.

[20] To compute these shares we have used data on 'productive' capital stock at 1996 prices. This concept is quite different from that of capital 'services', used in the growth accounting exercise and in the econometric analysis in Section 2.3. For a thorough description of the different concepts and measures of capital stock see Jorgenson and Stiroh (2000) and Stiroh (2001a); the methodology followed by the BLS in computing capital measures is described in BLS (2000a).

nearly 50 per cent; other 9 industries, all together, less than 8 per cent.[21] These shares are of course influenced by the size of each industry as well as by the degree of capital intensity. A more meaningful indicator of ICT intensity is the share of ICT with respect to equipment capital (Table 5).[22] These shares have increased dramatically in most industries from 1973 to 1987, starting from very low values. Note that 3 industries (chemical and allied products, SIC35 and SIC36) already exhibited in 1973 a share not very far from 10 per cent. As expected these shares rose significantly also in the 1990's, reaching 21 per cent in total manufacturing, 52 per cent in measuring and controlling instruments, 44 in printing and publishing, 30 in chemical and allied products, nearly 30 in SIC35 and SIC36. In 1999 only primary metal industries had a share close to 5 per cent.

The framework we have applied for the growth accounting exercise is the standard neo-classical one, which assumes a constant return-to-scale Cobb-Douglas production function and Hicks neutral technical progress (Oliner and Sichel (1994 and 2000) and Jorgenson and Stiroh (2000)):

$$Y_t = A_t K_{NICT,t}^{\alpha} K_{ICT,t}^{\beta} INT_t^{\gamma} H_t^{(1-\alpha-\beta-\gamma)} \qquad (1)$$

where Y is gross output, K_{NICT} is non ICT capital input, K_{ICT} is ICT capital input, INT[23] are intermediate inputs and H is labor input measured as hours worked and A is the exogenous technical progress (TFP). α, β, γ represent the coefficients of the production function. Under the assumption of competitive product and factor markets, it can be easily shown that the production coefficients equal the respective share of nominal income. By taking log of (1), differencing with respect to time, and rearranging we get the following expression for the rate of growth of ALP, (Y/H):

---

[21] In 1999, nine industries had a share below 2 per cent. They were: tobacco, textile mills products, apparel and related products, rubber and plastic products, leather products, lumber and wood products, furniture and fixtures, stone, class, clay and miscellaneous manufacturing.

[22] The share of gross ICT investment over gross equipment investment is an upward biased indicator of ICT intensity, since ICT capital goods have a depreciation rate much higher than 'traditional' equipment capital goods. Stiroh (2001b and 2001c) uses as indicators of ICT intensity: the ICT capital stock as share of total capital, of value added and of (full time equivalent) employment.

[23] The intermediate inputs considered in the exercise are actually three: energy, non-energy materials and business services.

$$\Delta \log ALP_t = \Delta \log TFP_t + \alpha \Delta \log(K_{NICT,t} / H_t) + \beta \Delta \log(K_{ICT,t} / H_t) + \gamma \Delta \log(INT_t / H_t) \quad (2)$$

Equation (2) decomposes ALP growth, at industry level, into four different components: the first is TFP growth, the second is the capital deepening due to accumulation of non ICT capital, the third is the capital deepening due to the accumulation of ICT capital and the fourth is the intermediate inputs contribution. In the growth accounting exercises at the aggregate level, which use value added instead of gross output, the fourth component is obviously absent.

We have applied equation (2) in different subperiods. Here, for brevity, we restrict the comparison to the two most relevant for our purpose: 1973-1995 and 1995-99.[24] The contribution to ALP growth from ICT accumulation has increased substantially in all industries with only one exception (measuring and controlling instruments). In other industries it has become impressive (printing and publishing, chemical and allied products plus, and, obviously SIC35 and SIC36). However, apart a few cases, also the contribution of non ICT accumulation has been relevant. This result contrasts to a certain extent with those obtained at the aggregate level. Another interesting feature is the increasing role of computers (last column): in the period 1995-98, in 16 industries out of 20, computers represented more than a half of ICT contribution to productivity growth.

A final point worth mentioning is that, at least in the manufacturing sector, the contribution to ALP growth due to capital deepening (ICT and non ICT) does not seem to be so impressive; in the period 1995-99 it represented 30 per cent of ALP growth only in three industries and less than 10 per cent in 8 industries. A major role, at industry level, has been played by the accumulation of intermediate inputs: 13 industries out of 20 recorded an increase of intermediate inputs contribution from the first to second period; in some cases the increase has been substantial: tobacco, apparel and related products, leather products and transportation equipment.

[24] This has been chosen to be comparable with most of the aggregate growth accounting exercises in spite of the fact that, in doing so, we include, in the first period five years of the last expansionary phase.

2.3 A preliminary econometric analysis

We start our empirical investigation by carrying out some simple tests of the acceleration of ALP and TFP growth in the nineties, very much in line with the strategy proposed by Stiroh (2001b). In our regressions we have, however, explicitly controlled for cyclical effects, in order to verify to what extent the recent US productivity revival is a structural phenomenon, as recently claimed by CEA (2001). To this aim we have run the following regressions:

$$\Delta \log ALP_{t,i} = \alpha_0 + \alpha_1 D92 + \alpha_2 CYCLEMF_t + \varepsilon_{i,t} \tag{3}$$

$$\Delta \log TFP_{t,i} = \beta_0 + \beta_1 D94 + \beta_2 CYCLEMF_t + \nu_{i,t} \tag{3'}$$

where $D92$ and $D94$ are two dummy variables equal 1 after 1991 and 1993, respectively, and 0 before. The two years were chosen after running a set of regressions like (3) and (3') and by changing, each time, the year dummy from 1987 to 1996. It turns out that 1992 for ALP and 1994 for TFP are the two years in which the R^2 of the regression is the highest. $CYCLEMF_t = \Delta \log(Y)_{t,MF} - \frac{1}{10}\sum_{j=1}^{10} \Delta \log(Y)_{t-j,MF}$ is the deviation of the contemporaneous growth rate of manufacturing gross output from its ten years average;[25] $CYCLEMF_t$ represents that part of the cycle which can be thought as common to all sectors and can be associated with macroeconomic, rather than industry specific factors.[26] (3) and (3') have been estimated both with OLS and Fixed Effects, to allow for different average rates of productivity growth across industries. Tables 7a-b show that α_1 and β_1 are positive and highly significant; though their values decrease when we introduce the cyclical variable, they remain quite high (1.5 per cent for ALP and 0.7 for TFP in the Fixed Effects regressions). Our estimated break in the trend of ALP growth is similar to that calculated by

---

[25] The length of the cycle was chosen so long, because the period considered in our empirical analysis was characterized by two very long cycles, in the eighties and in the nineties.

[26] The cyclical correlation within the industries of the manufacturing sector is very high; only in few industries (food and kindred products, tobacco and leather products) output fluctuations are weakly correlated with those of aggregate manufacturing output.

CEA (2001) for the non private business sector (Table 1), while that of TFP growth is lower and closer to the estimates of Oliner and Sichel (2000) and of Jorgenson and Stiroh (2000). Finally, one percentage point of aggregate output growth above trend translates into an increase of 0.25 percentage point of ALP and TFP growth.

Has this acceleration of productivity been particularly robust in the most ICT-intensive industries? This thesis has been put forward by CEA (2001) on the basis of a simple correlation between the increases of ALP growth in the period 1995-98 with respect to 1989-1995 in 19 manufacturing and service industries and the intensity with which they use information technologies.[27] Some preliminary insights can be drawn by modifying equations (3) and (3'), by allowing the break of the coefficient after 1995 to be different for ICT and non ICT-intensive industries. So we have added an ICT-intensity dummy, defined ordering the 20 manufacturing industries according to the ratio of ICT to equipment capital or to equipment capital income and assigning the values 1 to the industries above the median industry and 0 to the others:[28]

$$\Delta \log ALP_{t,i} = \alpha_0 + \alpha_1 D92 + \alpha_2 CYCLEMF_t + \alpha_3 DUICT,J + \alpha_4 DUICT92 + \varepsilon_{i,t} \quad (4)$$

$$\Delta \log TFP_{t,i} = \beta_0 + \beta_1 D94 + \beta_2 CYCLEMF_t + \beta_3 DUICT,J + \beta_4 DUICT94 + v_{i,t} \quad (4')$$

with $J = 1,2,3,4$. We have calculated the ICT-intensity dummy on the basis of the shares of ICT on equipment capital stock in 1995 $(DUICT1)$, in 1973 $(DUICT3)$, in the average of the period 1973-1985 $(DUICT4)$, or of the share of ICT income relative to equipment income in 1995 $(DUICT2)$.[29] Then they have been multiplied by $DU92$ and by $DU94$. The results are not particularly sensitive to the choice of the ICT-intensity indicator, especially as far as TFP growth is concerned (Tables 8a-b). In three cases, out of four, α_3 is positive and highly significant, indicating that, even before 1992, ICT intensive industries

---

[27] See Economic Report of the President (January 2001), p. 31.

[28] Stiroh's data base includes 57 industries at the SIC 2 - digit level; his analysis is, however, limited to ALP.

[29] The ICT share on equipment capital have been computed using the data on productive capital stock at 1996 prices. The ordering of the industries would have been the same using the shares computed with data on capital services, as done by Stiroh (2001b).

did exhibit a trend of ALP productivity growth higher than the average (in fact α_0 is now lower than reported in Table 7a); β_3, instead, is not significantly different from zero in three cases out of four, indicating that before 1994 long-run TFP growth was the same in ICT and non ICT intensive industries; moreover, in two cases, β_0 is not significantly different from 0 either. α_1 remains positive and significant in most cases, while β_1 is never significant, indicating that the acceleration of TFP growth after 1994 has been confined to ICT-intensive industries. Note also that the effect of $CYCLEMF_t$ is virtually unchanged in all our estimates.

In order to test, in a more structured framework, whether ICT accumulation and intensity have had directs effects on productivity growth we have estimated the following equation:

$$\begin{aligned}\Delta\log(ALP)_{i,t} &= \gamma_1\Delta\log(KICT/H)_{i,t} + \gamma_2\Delta\log(KNICT/H)_{i,t} + \gamma_3\Delta\log(INT/H)_{i,t} \\ &+ \gamma_4 QICT_{i,t-3} + \gamma_5 CYCLEMF_{i,t} + g_i + \varepsilon_{i,t}\end{aligned} \quad (5).$$

(5) is derived from a production function similar to (1) where we have implicitly imposed the first degree homogeneity restriction. In (5) it has been assumed that the rate of TFP growth can be split into an industry specific exogenous rate of technical progress (g_i) and a component depending on the degree of ICT-intensity, measured as the share of ICT on equipment capital stock ($QICT$). This variable has been computed using the data on capital services rather than productive capital in order to be consistent with the other measures of capital stock used in this equation. $KNICT_t$ is total non-ICT capital input, INT_t are intermediate inputs and $CYCLEMF_t$ is the same variable described before. The problems in estimating equation (5) are very well known and will be addressed more extensively in Section 3.2.1. Because of the simultaneity between g_i and the error term, using fixed effects gives inconsistent estimates; however, since the time span is considerably long in our case (t

= 27, for the period 1973-1999 or 19 for 1973-1991), the bias should not be too serious.[30] Note that we have not included period dummies in our regressions because we have used $CYCLEMF_t$ that is aimed to capture shocks common to all sectors. (5) has been estimated over two different time spans: 1973-1999 and 1973-1991, that is in the period preceding the break in ALP growth detected in the previous analysis. In the first case (column [1] of Table 9) γ_1 is positive and significant; its value is actually higher than average ICT income share across all manufacturing sectors in the estimated period (1.2 per cent); both γ_2 and γ_3 are positive and highly significant and are lower than the effective average income shares, equal to 12.2 per cent for non-ICT capital and to 53.5 per cent for intermediate inputs. The effect of ICT intensity is also positive and significant. When we exclude the nineties (column [2] of Table 9), both $KICT_t$ and $QICT$ are no longer significant. Also the other coefficients change substantially: that of $KNICT_t$ more than doubles, while that of INT_t becomes lower. This result confirms previous findings indicating that, before the nineties, the effect of ICT capital on productivity growth was very hard to detect (Berndt and Morrison, 1995).

Imposing the same values for γ_1 and γ_4 to all industries seems, however, a too strong assumption; so we have allowed these two coefficients, which are the most relevant in our investigation, to be different between ICT-intensive and non ICT-intensive industries. To do that we have multiplied $\Delta\log(KICT)_t$ and $QICT_{t-3}$ by $DUICT4$ and by $(1-DUICT4)$. We have chosen $DUICT4$ for two distinct reasons: first, since it has been computed on averages of the period 1973-1995, this should diminish potential endogeneity problem, second because it was associated with the smallest increase of TFP growth after 1994 (Table 8b). As expected γ_1 is higher for ICT-intensive industries, since they have a higher ICT capital income share; γ_4, however, is higher for non ICT-intensive industries. The other coefficients remain broadly unchanged. Running this regression in the sub-period 1973-1991 implies that γ_1 and γ_4 become not significant both for non ICT and ICT-intensive industries. In columns [5]-[8] of Table 9 we have reported the results obtained excluding

[30] It would have been preferable to estimate (5) with other econometric methods, such as those proposed by Arellano and Bond (1991) which also permits a certain degree of endogeneity of the other regressors, as it is rather likely in our case.

from the sample the two heavily ICT producing industries (SIC35 and SIC36). In this case it is harder to find both a direct and indirect effect of ICT accumulation on labour productivity growth. In fact, the relevant coefficients, though positive, are never significantly different from zero, even when the equation is estimated on the whole sample. Once we split the coefficients between ICT and non ICT intensive industries, we get however, a positive and significant effect of $QICT$ for the former when we consider the whole sample.

As a final part of our empirical investigation we have estimated directly the effects on TFP growth of ICT intensity. We have started from this very simple specification:

$$\Delta \log TFP_{t,i} = \delta_i + \delta_1 \Delta \log(QINT)_{t-3,i} + \delta_2 QINT_{t-3,i} + \delta_3 CYCLEMF_{t,i} + \varepsilon_{i,t} \quad (6)$$

where $QINT$ is a measure of ICT intensity. We have chosen three different measures: the share of ICT on equipment capital ($QICT$) as we have already done in equation (5), the share of computers on equipment capital ($QCOM$) and on ICT capital ($QCOMICT$). In order to limit the problem of simultaneity between TFP growth and ICT accumulation, the ICT intensity variables have been introduced in the equation (6) with a three years lag.[31] The results are reported in Table 10a. While the degree of ICT intensity is positive and significant in five out of six cases, its rate of change is never significant. When we split between ICT-intensive and non ICT-intensive industries the effects of ICT intensity are still positive and significant only for the ICT- intensive ones (Table 10b). We have then estimated equation (6) by allowing the coefficients to differ between 1973-1993 and 1994-99. The results (Table 10c) show that before 1994 it is never possible to detect a significant effect of any measure of ICT intensity on TFP growth. However, the coefficient turns out to be positive and significant in the period 1994-99 in all but one cases. Note that the effect of the cycle tends to be higher in the second period. Finally, we have repeated the exercise by allowing the coefficients to differ also between ICT-intensive and non ICT-intensive industries. The first two columns of Table 10d report the results obtained with $QICT$ as ICT intensity variable, the second two with $QCOM$ and the last two when $QCOMICT$ is used. The previous findings are fully

[31] We have tried different time lag, starting from 3 to 5. The results are almost identical to those reported here.

confirmed: all the ICT intensity measures are positive and significant only for ICT-intensive industries and only for the second period.

Summing up, some evidence, though still preliminary, is emerging of a positive ex-ante effect of ICT accumulation on TFP growth in the manufacturing sector, even controlling for cyclical fluctuations. This is however limited to the second half of the nineties. This suggests the existence of some 'threshold' that was reached only in that period. Moreover, even though the effect of ICT accumulation on TFP growth is detectable in the average of all manufacturing industries, it is concentrated in the ICT-intensive ones.

3. Productivity growth and ICT accumulation in the service sector

3.1 Data description and growth accounting

The BLS data-set for the service industries is as much detailed as that for the manufacturing ones as regards total capital and ICT capital stock. The key difference between the two data-sets is the lack of productivity data measures for the service industries; in fact, neither the BLS nor the BEA calculate official ALP or TFP measures. The BEA makes available, however, a database covering the period 1977-1999, reporting a breakdown at SIC 2-digit level of several variables including both value added and full-time equivalent employment; BEA has also made separately available to us also data on hours worked by industry. Unfortunately this database does not include an output measure analogous to the one calculated by the BLS for the manufacturing industries, i.e. *industry gross output excluding transactions between establishments within the same industry*.

Instead of using the available gross output measure (which includes transactions between establishments within the same industry) making some arbitrary assumptions, we have preferred to use value added. So value added per hour is our measure of ALP for industries in the service sector; this amounts to assume a value added function at industry level. This approach represents a shortcut with respect to the more rigorous one adopted by Jorgenson, Gollop and Fraumeni (1987) who show that, in order to assume an industry value added function, a few restrictions on a trans-log production function should be tested first; since these restrictions are usually not satisfied, they conclude that at industry level it is more preferable to assume a gross output production function. Note, however, that value added functions have been adopted in the past by many authors, such as Kahn and Lim (1998).

In order to have an idea of the relevance of ICT capital in the service sector we have calculated the following three indicators: (i) the share of non farm business sector ICT capital used in each of the service industries; (ii) the share of ICT capital on total capital in each industry and (iii) the share of ICT capital on equipment capital in each industry.[32]

The share of non farm business sector ICT capital in the service sector, derived including in the calculation of the service sector 27 SIC 2 digit industries, was equal to 82.7 per cent in 1972; it then decreased gradually to 74.4 per cent in 1987, reaching 73.3 in 1999 (Table 11). The decline of the ratio was almost entirely concentrated in Telephone and Telegraph and Real Estate. The ICT capital ‘used’ in the former represented 45 per cent of the non farm business sector ICT capital in 1972; this share dropped drastically and in 1999 it was only 17.9 per cent. Most of the other service industries raised their share of non farm business sector ICT capital. The performance of Wholesale Trade has been quite striking in this respect (from 2.5 per cent in 1972 to 11.3 in 1999); remarkable was also the increase of Non-Depository Institutions, from 0.1 per cent in 1972 to 3.0 in 1987 and 8.2 in 1999. The shares of Depository Institutions and Retail Trade rose from 1.8 and 1.1 per cent in 1972 to 4.6 and 3.8 per cent in 1999, respectively.

The substitution between ICT capital and other capital has been quite strong in most service industries in the period (Table 12a). The share of ICT to total capital rose from 2.5 per cent in 1972 to 5.9 in 1992 and reached 10.2 in 1999. It rose from 0.5 per cent in 1972 to 17.0 in 1999 in Transportation by Air, from 0.6 to 33.2 in Transportation Service, from 1.2 per cent to 16.4 in the Wholesale Trade, from 0.1 per cent to 35.7 per cent in Non Depository Institutions. Telephone and Telegraph already started with a huge share in 1972 (33.8 per cent) which rose only moderately (39.4 per cent in 1999). Only 4 industries out of 27 recorded marginal declines of the weight of ICT capital.

[32] All the shares are calculated using the data on productive capital stock at 1996 prices.

The increase of ICT share with respect to equipment capital was even more impressive (Table 13). In Wholesale Trade it rose from 7.1 per cent in 1972 to 54.1 in 1999; in Non Depository Institutions from 1.0 per cent to 43.2. The performance of Pipelines, except natural gas was equally striking and occurred mostly in the nineties, from 13.3 per cent in 1987 to 50.5 per cent in 1999.

The service sector has always been more ICT intensive than manufacturing. In 1999 the share of ICT on equipment capital was equal to 37.8 in the former (Table 12b) and to 20.5 in the latter (Table 5).[33]

The dynamics of ALP across the service industries is depicted in Tables 13a-c. The whole period covered by the data-set is divided into two sub-periods, 1977-1992 and 1992-99; the second half of the nineties (1995-99) is also shown.

By comparing ALP growth rates in the two periods 1977-1992 and 1992-99 it is evident that there is no uniform acceleration across the 26 service industries.[34] A strong acceleration was registered in both Wholesale and Retail Trade; other two industries recorded disruptive ALP growth rates (Pipelines, except natural gas, and Security and Commodity Brokers), while in others (Telephone and Telegraph, Railroad Transportation) ALP did actually decelerate.

The ALP growth rates in most industries classified between SIC70 and SIC82 are the most difficult to interpret, because they are negative in both the sub-periods. While a negative ALP growth could be rationalised invoking a fall over time of the capital/labor ratio, this interpretation is not supported by the data, as it will be shown below.

Data reported in Tables 13a and 13b show that the process of capital deepening[35] involved most service industries, while only five industries exhibited in the nineties a decline

[33] The higher ICT intensity of services with respect to manufacturing is confirmed also taking as indicator productive capital per worked hour.

[34] Business services (SIC73) was excluded from the analysis because the value added data start only in 1987.

[35] Capital deepening is the difference between the delta log of capital input and the delta log of hours worked by full time and part time employees. As in Section 2.2 we have used here a measure of capital stock based on the concept of capital services. Capital deepening contributions are defined as capital deepening times

of the capital/labour ratio; in the second part of the nineties only three industries (Local and Interurban Passenger Transit, Real Estate and Auto repair, services and parking) recorded negative capital contributions. With these few exceptions the nineties witnessed a widespread process of capital deepening mainly concentrated in the second half of the decade. Wholesale Trade was the leading industry in the process of accumulation of capital per worked hour, but this process was strong also in Depository and Non-Depository Institutions. Telephone and Telegraph registered a substantial deceleration of capital accumulation per worked hour in the nineties with respect to previous decade.

In almost all the industries classified between SIC70 and SIC82 capital deepening contributions in the nineties were positive, leading us to exclude that the negative ALP growth rates were due to continuously falling capital stock per hour worked. This evidence suggests that measurement problems are probably very serious for these industries.

The contribution to ALP growth of ICT accumulation has been remarkably strong in the whole period, generally rising during the nineties and reaching the highest levels, frequently exceeding one percentage point, in the second part of the 1990's (Table 13c).

As regards TFP dynamics, there was no uniform acceleration in the 1990's with respect to the 1977-1992 period. The industries showing significant increases of TFP growth are the same that registered also substantial ALP acceleration; i.e. Wholesale Trade and Retail Trade, as well as Pipelines, except natural gas and Security and Commodities Brokers. In Telephone and Telegraph, TFP kept growing at around 3.0 per cent; the TFP dynamics in this sector is consistent with a period of strong innovation in the eighties, a slowing down in the first part of the nineties and a new wave of innovation in the most recent years.

---

capital income shares. We have used the capital income data reported by the BEA in the Gross Product Originating database. They differ from the BLS capital income data. This inconsistency cannot be solved. We thank Kevin Stiroh for having suggested us this solution.

The negative TFP growth rates for many industries between SIC70 and SIC82 in both the sub-periods confirm the existence of serious measurement problems. The difficulty to justify persistent negative TFP growth rates has induced us to run the econometric analysis on a restricted sample, made of 18 out of 26 industries, excluding those registering persistently negative TFP growth rates.[36] Among the excluded industries are Insurance Carriers and Insurance Agents, Brokers and Services; their strongly negative ALP growth rates are likely to reflect a failure by national accounts to treat the complex issue of risk (Diewert, 1999). Negative TFP growth rates of Health and Educational Services can be instead related to the measurement problems of complex multi-product industries (Diewert, 1999).

3.2 A preliminary econometric analysis

3.2.1 Estimating a value added function

In this paragraph we have checked the results obtained with the growth accounting exercise. This reduces to test how the income shares perform as parameters of a value added function that has been estimated in a panel context. The panel is not balanced; it covers the period 1977-1999 for 16 industries, 1987-1999 for two industries.[37] In these regressions, we use two alternative measures of capital stock: productive capital and capital services. The break down of productive capital stock at 1996 prices into ICT and non-ICT capital is directly available in the BLS database; the break down of capital services is not directly available; we have then used the same procedure described in Section 2.3.

As it is well known, the main problem with value added estimation (a problem shared with production function estimation) is simultaneity, i.e. the contemporaneous choice by the producer of the output level and the variable input (typically labour). Griliches and Mairesse (1995) treated extensively this issue; one solution they proposed is recurring to first differences. In this case, keeping the breakdown of capital into ICT and non-ICT capital ($KICT$ and $KNICT$, respectively), we end up with:

[36] For instance Harper (1999) has calculated aggregate TFP growth setting to zero the rates of those industries registering persistent negative values.

[37] These are Depository Institutions and Non Depository Institutions.

$$\Delta\log(Y)_{i,t} = \beta_1\Delta\log(KICT)_{i,t} + \beta_2\Delta\log(KNICT)_{i,t} + \beta_3\Delta\log(Labor)_{i,t} + \varepsilon_{i,t} \quad (7)$$

which can be estimated with OLS. However, if one assumes that the industry specific component of TFP follows a process, such as:

$a_{i,t} = a_i + g_i * t$, then taking first difference leads to the following equation:

$$\Delta\log(Y)_{i,t} = \beta_1\Delta\log(KICT)_{i,t} + \beta_2\Delta\log(KNICT)_{i,t} + \beta_3\Delta\log(Labor)_{i,t} + g_i + \varepsilon_{i,t}$$

(8)

reintroducing a simultaneity problem, i.e. the lack of orthogonality between g_i and $\varepsilon_{i,t}$. A possible way to overcome this problem is to take the difference from the mean of the delta log variations for each industry, i.e. performing a within transformation on the panel of first (log) differences.

The regressions reported in Table 14 impose a first degree homogeneity condition which has not been rejected by a standard F-test. The estimated coefficient for ICT productive capital stock is 0.061 and that of non ICT productive capital stock is 0.418 for equation (7) (pooled estimates OLS). Note that the estimated coefficient for labour input is 0.52.

Estimating equation (8) with fixed effects is very costly since the two coefficients on capital stock become negative and are non significantly different from zero. These results parallel those by Griliches and Mairesse (1995) on a data-set of micro-data. Replacing Hours with Full Time Equivalent Workers does not alter significantly the previous results.

Re-estimating equation (7) replacing productive capital stock with capital services leads to a somewhat lower coefficient on ICT capital.

If the growth accounting exercises captures correctly the ICT contribution to productivity growth, the production function exhibits constant return to scale and factors are paid at their marginal products, β_1 should equal ICT income share; actually the average ICT income share for the 18 industries in our sample rose from 3.8 in 1977 to 7.2 per cent in

1999, averaging 5.4 per cent over the period. Thus the estimated value of β_1 is indeed very close to the average ICT income share.

These results give support to those obtained with growth accounting and confirm that ICT capital has had a significant role in the service industries. This conclusion has, however, to be considered with caution, keeping in mind that, because of simultaneity problems involved in the estimation of equation (7) the estimated elasticities of the value added function can be biased.

3.2.2 Testing for direct effects of ICT capital on TFP growth

Our second step is to test whether ICT accumulation has also had an effect on TFP dynamics (see Section 2.3). This analysis has been developed in a framework similar to that proposed by Bartelsman et al. (1994) to analyse customer and supplier driven externalities. Their set-up is useful because it allows to distinguish long-run from short-run effects in a panel context. We start from the following equation:

$$\Delta \log(Y)_{i,t} = \beta_1 \Delta \log(K)_{i,t} + \beta_2 \Delta \log(Labour)_{i,t} + \upsilon_{i,t} \qquad (9)$$

where $\upsilon_{i,t}$ represents the rate of growth of technical progress or TFP in industry i. The error term can be broken into a constant (θ), a sector specific term (θ_i) and an effect linked to the difference between the growth rate of ICT capital and that of total capital $(difictk_i)$; we assume that (θ_i) depends linearly on the average of $difictk_i$ $(\overline{difictk_i})$. So we end up with the following equations for TFP growth:

$$\Delta \log(TFP)_{i,t} = \upsilon_{i,t} = \theta + \theta_1 \overline{difictk_i} + \theta_2 difictk_{i,t} + \varepsilon_{i,t} \qquad (10)$$

that can be rearranged as:

$$\Delta \log(TFP)_{i,t} = \upsilon_{i,t} = \theta + \theta_2 (difictk_{i,t} - \overline{difictk}_i) + \theta_3 difictk_{i,t} + \varepsilon_{i,t} \qquad (11)$$

where $\theta_3 = \theta_2 + \theta_1$.

The short-run effects on TFP growth of ICT accumulation relative to that of total capital are caught by the “within regression” :

$$[\Delta \log(TFP)_{i,t} - \overline{\Delta \log(TFP)}_{i,t}] = \theta_2 (difftctk_{i,t} - \overline{difftctk}_i) + error \qquad (12).$$

Through a stepwise procedure taking into account the contemporaneous and the lagged values up to lag 5 of $difftctk$, we have chosen $difftctk_{t-3}$; θ_2 is positive and significant at the 10, but not at 5 per cent level (Table 15). The long run effects are caught from the “between regression”:

$$\overline{\Delta \log(TFP)}_{i,t} = \theta + \theta_3 (\overline{difftctk}_i) + error \qquad (13).$$

In this case θ_3 is negative and not significant, but the number of observations (only 18) is very small. Estimation of equation (11) confirms the results obtained with the “within” regression and the “between” regression (the inclusion of a time trend does not alter the results).

3.2.3 Testing for acceleration in the second half of the nineties and threshold effects

In this paragraph we present some tests of the hypothesis that TFP and ALP did accelerate in the second half of the nineties. This analysis parallels that of Section 2.3 for manufacturing. Table 16a reports evidence consistent with a TFP acceleration dated somewhere between 1995 and 1996 (line 1 and 2).[38] The TFP acceleration is significant even including among the regressors a variable (*cycle9*) capturing the aggregate cycle, defined as: $cycle9_t = \Delta \log(Y)_t - \frac{1}{9}\sum_{j=0}^{8} \Delta \log(Y)_{t-j}$, where Y is the non-farm private business sector output. The effect of this variable on TFP dynamics is positive, as expected, but never significant at 10 per cent. This result contrasts sharply with those obtained in Section 2.3 confirming that the service sector is much less cyclical than the manufacturing one. The estimates reported in Table 14a (line 1 and 2) however raise two problems.

[38] Dummypost95 equals 1 for t ≥ 1995; dummypost96 equals 1 for t ≥ 1996.

The first relates to the possibility that the period 1995-99 witnessed actually a rise in the cyclical sensitivity of TFP, rather than an acceleration of long term TFP growth. This hypothesis is tested introducing a variable (*cycle9-post95)* defined as *cycle9-post95 = cycle9 * dummy post 95*; the results look consistent with this hypothesis. However testing in the same regression (line 4) both the break of the constant and that of the sensitivity to the cycle leads to the loss of significance of both, probably because of serious multicollinearity problems and to the small number of observations available to estimate the two coefficients. All in all the hypothesis of TFP acceleration looks more reasonable than that of a striking increase of TFP sensitivity to the cycle; but the evidence does not rule out completely this possibility.

The second objection regards the size of the TFP acceleration. An acceleration of two percentage points after 1996 appears really huge given the historical very low rate of TFP growth in the service sector. Consequently we have tested for the influence of possible outliers on the estimated acceleration. Dropping two industries (Non depository institutions and Security and commodity brokers) lowers the estimated TFP acceleration to 1.5 per cent (with a p-value at 6 percent); while dropping four industries (Non depository institutions, Security and commodity brokers, Pipelines except natural gas, and Railroad transportation) lowers it to 1.1 per cent (with a p-value at 11 per cent). Hence the size of the estimated TFP acceleration appears now more reasonable and still significant.

We will now try to test, also for the service sector, the hypothesis that acceleration regarded mainly ICT intensive industries. First, we have introduced an ICT intensity dummy (*DUICT*) that splits the 18 industries according to whether the share of ICT on total capital was higher or lower than the median industry in 1992, three years before the acceleration took place. This should limit, but not eliminate simultaneity problems. In principle we would like to be able to split industries according to a variable which is highly correlated with ICT intensity, but exogenous to TFP (see Stiroh (2001a) for a discussion on this point). Note, however, that this ranking is rather stable over time; given 1992 values, the median value, which represents our breakpoint between ICT intensive and non–ICT intensive industries, is 0.04. Second, we have introduced an interaction dummy (*DUICT95*) equals 1 in the period 1995-99 only for the ICT-intensive industries previously identified ($DUICT95 = DUICT * DU95$). Then the equation becomes:

$$\Delta \log(TFP)_{i,t} = \beta_0 + \beta_1 DU95 + \beta_2 DUICT + \beta_3 DUICT95 + \varepsilon_{i,t} \qquad (14).$$

The results reported in the last line of Table 16a show that $DUICT$ and $DUICT95$ are not significant. While the lack of significance of $DUICT$ [39] shows that there was not a positive gap between ICT and non-ICT intensive industries over the entire period under scrutiny, the lack of significance of $DUICT95$ indicates that TFP has not accelerated in the second part of the 90s , not even in ICT intensive industries. Replicating the same analysis for ALP leads to very similar results (Table 16b).

We have also tried to detect whether there were differences of the impact of ICT intensity on TFP growth over time. In other words, in each industry, ICT intensity may affect TFP growth only when it hits an unknown industry specific value. So even an industry constantly below the median value may experience, after a certain point, positive TFP gains if its ICT intensity has increased enough. This hypothesis is investigated by estimating the following equation:

$$\Delta \log(TFP)_{i,t} = \alpha_i + \sum_j \delta_j diffictk_{i,t-j} + \varepsilon_{i,t} \qquad j = 0,1,2....5 \qquad (15)$$

in the two sub-periods 1987-1999 and 1990-99 and in the whole period covered by the data (1977-1999). We have used a stepwise procedure testing for the relevance of $diffictk$ up to lag 5.[40] The results (Table 17a) show that the effect on TFP growth of ICT accumulation relative to total capital increases as we shorten the estimated period; the coefficient is equal to 0.0522 over the entire period, rises to 0.142 in 1987-1999, and reaches 0.2213 in the nineties. However $diffictk$ is never significant at the 5 per cent level; it is almost significant at the 10 per cent level only over the entire period and in the nineties. Furthermore, the hypothesis that the value of the coefficient estimated over the shorter time horizon is equal to that estimated over the whole period can never be rejected at the 5 per cent level of significance. The estimates do not change including among the regressors *cycle9*. Overall the evidence is only very weakly consistent with an hypothesis of an increasing influence of ICT

[39] $DUICT$ was not significant also when omitting $DUICT95$.

[40] We have fixed the *enter* significance level at 0.20, and the *stay* significance level at 0.10.

capital accumulation on TFP growth in the nineties, i.e. with the idea that the relationship between ICT accumulation and TFP growth is non linear.

These results might partially depend on the fact that the BLS definition of ICT capital is too wide and that TFP growth is affected only by really innovative technologies; this would suggest to replace ICT capital with computers. Computers are clearly the most relevant new component of ICT capital; their share, in terms of capital stock, was generally close to zero at the beginning of the seventies, but thereafter their dynamics really exploded. The results (Table 17b) are encouraging: the estimated effect of relative computer capital accumulation (*diffpc*) on TFP growth is now significant at the 5 per cent. Moreover, the Hansen (1991) parameter instability test supports the hypothesis of an increase of δ in the nineties.

Our preliminary econometric evidence can be summarised as follows: i) accumulation of ICT capital did play a role with a significant capital deepening contribution to ALP growth in the service sector; ii) the service industries (more precisely the 18 included in our restricted sample) did register an acceleration of ALP after 1995; iii) the acceleration of TFP can be dated in 1996; iii) there is not a strong evidence in favour of a direct positive effect of ICT accumulation on TFP growth; the latter could be partially found only in the most recent period, possibly after a ‘threshold’ level of ICT intensity has been reached. Computer accumulation does seem to have a greater explanatory power with respect to aggregate ICT capital. However, the evidence supporting the hypothesis of a ‘threshold’ effect for the service sector remains still weak.

4. Concluding remarks and future developments of the research

For the manufacturing sector, a growth accounting exercise at the industry level has confirmed an increasing contribution to ALP dynamics of ICT accumulation (capital deepening) in the second half of the nineties with respect to the period 1973-1995. The higher ‘use’ of ICT capital is, however, only a part of the story. In the second part of last decade, also TFP acceleration has been significant, even controlling for cyclical output fluctuations, especially in ICT-intensive industries. Preliminary econometric evidence shows that, in the same period, TFP growth in the manufacturing sector has been positively correlated with some measures of ICT intensity (the share of ICT on equipment capital, that of computers on equipment and ICT capital); this correlation, however, seems to have been limited to ICT-intensive industries. This evidence is consistent with the idea that ICT accumulation may affect TFP growth only after a certain ‘threshold’ has been reached in terms of ICT intensity. We have, however, to be cautious in interpreting these results. First of all, simultaneity among the variables here considered is likely to be strong. Secondly, the acceleration we detect after 1994 might be due to some ‘omitted’ variables that have been highly correlated with the increase of ICT intensity; we may think, first of all, of labor quality effects.

As far as the service sector is concerned, the direct influence of ICT accumulation on the acceleration of ALP can be detected both through a growth accounting exercise and by the estimation of a value added function. Moreover, we have found evidence also of a significant TFP acceleration after 1996, even controlling for cyclical effects. Econometric evidence supporting a positive effect of ICT intensity on TFP growth is still rather weak, though some signs are emerging that computers accumulation has positively affected TFP dynamics in the most recent years.

However, apart from ICT accumulation, other channels need to be investigated. The existence of network externalities, making TFP growth in a given industry to influence that of other industries through intermediate inputs purchases, the interaction of ICT capital with other factors such as human capital, that between ICT accumulation and greater competition in the nineties are other factors worth investigating. It is our aim to include at least some of them in the future developments of this research.

Tables

Table 1

Sources of Growth of the US economy: 1973-1999

(annual percentage rates of change)

	Oliner - Sichel (2000) (1)		Jorgenson - Stiroh (2000)		Council of Economic Advisors (2000)		Bureau of Labor Statistics (2000)		Gordon (2000)		Council of Economic Advisors (2001)	
	1973/95	1995/99	1973/95	1995/99	1973/95	1995/99	1973/95	1995/98	1972/95	1995/99	1973/95	1995/2000
Output (y)	3,06	4,90	3,04	4,76	n.a.	n.a.	3,03	4,90	2,75	4,90	n.a.	n.a.
Labor Hours (h)	1,58	2,24	1,62	2,18	n.a.	n.a.	1,64	2,60	1,71	2,25	n.a.	n.a.
Labor Productivity (y/h)	1,48	2,66 (2,86)	1,42	2,58	1,43	2,90	1,39	2,30	1,04	2,65	1,39	3,01
Trend of Labor Productivity	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1,47	2,28	1,39	2,97
Contribution of:												
Capital Deepening	0,76	1,09 (1,06)	0,85	1,34	1,06	1,53	0,70	0,80	0,76	1,09	0,70	1,09
ICT Capital	0,45	0,94 (1,04)	0,22	0,58	n.a.	n.a.	0,42	0,80	n.a.	n.a.	0,41	1,03
Other Capital	0,31	0,16 (0,02)	0,63	0,76	n.a.	n.a.	0,29	0,00	n.a.	n.a.	0,30	0,06
Labor Quality	0,27	0,31 (0,28)	0,24	0,25	0,26	0,31	0,24	0,30	0,27	0,31	0,27	0,27
TFP	0,44	1,25 (1,52)	0,34	0,99	0,11	1,06	0,40	1,30	0,44	0,88	0,40	1,59
Production of ICT	0,22	0,63 (0,70)	0,20	0,44	0,16	0,39	n.a.	n.a.	0,22	0,63	0,18	0,36
Other Sectors	0,22	0,62 (0,82)	0,14	0,55	-0,06	0,65	n.a.	n.a.	0,22	0,25	0,22	1,22
R & D	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0,17	0,20	n.a.	n.a.	n.a.	n.a.

Source : Based on data published in the mentioned papers and publications. - (1) In brakets are reported recent unpublished estimates for the period 1995-2000.

Table 2a

United States : Manufacturing Sector

Labour Productivity by Industry

(average growth rates in selected periods)

Industry	1952-73	1973-91	1991-99	1995-99
Total Manufacturing	2.68	2.46	3.95	4.41
Non durable goods	2.91	1.93	2.59	2.75
Food and kindred products (SIC20)	2.91	2.38	1.54	1.12
Tobacco (SIC21)	2.72	1.79	1.29	-2.81
Textile mill products (SIC22)	4.28	3.82	4.12	3.74
Apparel and related products (SIC23)	2.26	2.50	6.79	7.55
Paper and allied products (SIC26)	3.16	2.09	1.95	1.63
Printing and publishing (SIC27)	2.31	0.18	0.67	1.27
Chemicals and allied products (SIC28)	4.50	1.50	2.65	2.45
Petroleum refining and related industries (SIC29)	4.45	1.85	3.52	3.18
Rubber and plastics products (SIC30)	2.86	1.59	3.61	3.56
Leather and leather products (SIC31)	2.17	1.46	3.48	6.27
Durable goods	2.68	2.63	5.45	6.14
Lumber and wood products (SIC24)	3.50	1.93	-0.61	0.33
Furniture and fixtures (SIC25)	1.99	1.56	3.14	3.54
Stone, clay and glass products (SIC32)	2.18	1.21	2.50	3.31
Primary metal industries (SIC33)	1.96	1.04	2.83	2.46
Fabricated metal products (SIC34)	2.12	0.93	2.52	2.15
Industrial and commercial machinery (1) (SIC35)	2.19	3.81	9.86	10.18
Electrical and electronic equipment (SIC36)	3.06	4.77	13.54	14.30
Transportation equipment (SIC37)	3.51	0.96	5.40	5.69
Measuring and controlling instruments (SIC38)	3.39	4.25	3.54	2.76
Miscellaneous manufacturing (SIC39)	3.88	1.10	1.73	1.49
Standard Deviation	*0.84*	*1.24*	*3.25*	*3.75*

Source: based on BLS data (2001). - Includes computer equipment.

Table 2b

United States : Manufacturing Sector
Total Factor Productivity by Industry
(average growth rates in selected periods)

Industry	1952-73	1973-91	1991-99	1995-99
Total Manufacturing	1.43	0.41	2.13	2.48
Non durable goods	1.31	-0.06	0.55	0.47
Food and kindred products (SIC20)	0.58	0.34	0.17	-0.31
Tobacco (SIC21)	-0.28	-4.70	-1.86	-8.92
Textile mill products (SIC22)	2.49	2.40	2.05	2.07
Apparel and related products (SIC23)	0.59	0.87	1.38	1.63
Paper and allied products (SIC26)	1.52	-0.34	0.63	1.27
Printing and publishing (SIC27)	0.58	-0.94	-0.85	-0.78
Chemicals and allied products (SIC28)	2.61	-0.61	0.73	0.95
Petroleum refining and related industries (SIC29)	0.74	-0.24	0.56	0.82
Rubber and plastics products (SIC30)	0.82	0.26	1.29	1.40
Leather and leather products (SIC31)	0.19	0.46	0.68	2.41
Durable goods	1.32	0.83	3.33	3.96
Lumber and wood products (SIC24)	1.89	1.67	-1.63	-1.17
Furniture and fixtures (SIC25)	0.42	0.49	1.06	1.18
Stone, clay and glass products (SIC32)	0.78	0.30	1.24	1.04
Primary metal industries (SIC33)	0.15	-0.56	1.39	1.99
Fabricated metal products (SIC34)	0.47	-0.16	0.80	-0.07
Industrial and commercial machinery (1) (SIC35)	0.51	1.84	5.74	6.94
Electrical and electronic equipment (SIC36)	1.83	2.32	7.39	8.14
Transportation equipment (SIC37)	1.49	-0.15	1.08	1.28
Measuring and controlling instruments (SIC38)	1.73	1.26	0.53	0.97
Miscellaneous manufacturing (SIC39)	1.57	0.08	0.66	0.67
Standard Deviation	*0.80*	*1.51*	*2.16*	*3.31*

Source: based on BLS data (2001). - (1) Includes computer equipment.

Table 3a

United States: Manufacturing Sector

Labour Productivity by Industry during the expansionary phases of the 'Golden Age'

(average rate of growth in selected periods)

Industry	1954-57	1961-69	1970-73	1991-99
Total Manufacturing	1.82	2.87	**4.26**	3.95
Non durable goods	**3.53**	2.65	3.26	2.59
Food and kindred products (SIC20)	**4.47**	2.82	2.70	1.54
Tobacco (SIC21)	3.30	2.44	**4.60**	1.29
Textile mill products (SIC22)	**4.86**	4.36	3.10	4.12
Apparel and related products (SIC23)	**3.45**	2.28	3.13	***6.79***
Paper and allied products (SIC26)	0.80	3.68	**5.46**	1.95
Printing and publishing (SIC27)	1.34	2.14	**4.36**	0.67
Chemicals and allied products (SIC28)	4.59	4.55	**7.60**	2.65
Petroleum refining and related industries (SIC29)	**5.86**	5.23	3.22	3.52
Rubber and plastics products (SIC30)	-1.38	3.06	**4.69**	3.61
Leather and leather products (SIC31)	2.38	2.64	2.47	**3.48**
Durable goods	0.44	3.45	**5.69**	5.45
Lumber and wood products (SIC24)	**3.85**	3.56	1.33	-0.61
Furniture and fixtures (SIC25)	1.55	1.36	**4.23**	3.14
Stone, clay and glass products (SIC32)	1.90	2.14	**2.99**	2.50
Primary metal industries (SIC33)	1.87	2.19	**5.85**	2.83
Fabricated metal products (SIC34)	1.77	**2.72**	2.63	2.52
Industrial and commercial machinery (1) (SIC35)	-0.91	3.06	**6.39**	***9.86***
Electrical and electronic equipment (SIC36)	-0.61	4.97	**6.48**	***13.54***
Transportation equipment (SIC37)	-0.93	3.83	**8.69**	5.40
Measuring and controlling instruments (SIC38)	2.91	3.53	**3.93**	3.54
Miscellaneous manufacturing (SIC39)	3.69	3.66	**4.41**	1.73
Standard Deviation	*2.09*	*1.03*	*1.87*	*3.25*

Source: based on BLS data (2001). - (1) Includes computer equipment.

Table 3b

United States: Manufacturing Sector

Total Factor Productivity by Industry during the expansionary phases of the 'Golden Age'

(average rate of growth in selected periods)

Industry	1954-57	1961-69	1970-73	1991-99
Total Manufacturing	0.76	1.96	**2.74**	2.13
Non durable goods	1.11	1.48	**1.78**	0.55
Food and kindred products (SIC20)	**1.26**	.97	-.10	0.17
Tobacco (SIC21)	-2.01	-0.30	**1.98**	-1.86
Textile mill products (SIC22)	2.55	**2.77**	0.86	2.05
Apparel and related products (SIC23)	0.64	0.75	1.01	**1.38**
Paper and allied products (SIC26)	-1.36	1.70	**4.12**	0.63
Printing and publishing (SIC27)	0.65	0.72	**1.35**	-0.85
Chemicals and allied products (SIC28)	2.79	2.04	**4.27**	0.73
Petroleum refining and related industries (SIC29)	0.83	0.68	**0.89**	0.56
Rubber and plastics products (SIC30)	-2.98	1.19	**2.76**	1.29
Leather and leather products (SIC31)	0.66	**0.91**	-0.18	0.68
Durable goods	0.23	2.12	**3.07**	***3.33***
Lumber and wood products (SIC24)	**2.67**	1.74	-0.52	-1.63
Furniture and fixtures (SIC25)	0.33	0.87	**2.42**	1.06
Stone, clay and glass products (SIC32)	-.13	1.21	**1.66**	1.24
Primary metal industries (SIC33)	0.63	0.99	**2.62**	1.39
Fabricated metal products (SIC34)	0.15	0.66	**1.17**	0.80
Industrial and commercial machinery (1) (SIC35)	-1.40	0.87	**2.96**	***5.74***
Electrical and electronic equipment (SIC36)	0.82	3.10	**3.87**	***7.39***
Transportation equipment (SIC37)	-0.39	2.15	**2.84**	1.08
Measuring and controlling instruments (SIC38)	0.24	**2.41**	2.12	0.53
Miscellaneous manufacturing (SIC39)	**1.92**	1.82	1.55	0.66
Standard Deviation	*1.52*	*0.83*	*1.38*	*2.16*

Source: based on BLS data (2001). - (1) Includes computer equipment.

Table 4

United States: Manufacturing Sector

Composition of ICT capital stock by Industry (1)

(percentage values)

Industry	1973	1986	1991	1999
Total Manufacturing (2)	12.4	17.8	17.4	16.7
Non durable goods				
Food and kindred products (SIC20)	11.5	6.8	6.4	5.5
Tobacco (SIC21)	0.4	0.6	0.6	0.5
Textile mill products (SIC22)	1.8	1.0	1.1	1.1
Apparel and related products (SIC23)	1.0	0.6	0.6	0.6
Paper and allied products (SIC26)	1.0	3.7	4.6	3.6
Printing and publishing (SIC27)	2.2	6.0	8.0	9.3
Chemicals and allied products (SIC28)	27.4	21.4	21.3	20.9
Petroleum refining and related industry (SIC29)	4.3	4.1	4.3	4.6
Rubber and plastics products (SIC30)	1.5	1.0	1.2	1.9
Leather and leather products (SIC31)	0.4	0.1	0.1	0.1
Durable goods				
Lumber and wood products (SIC24)	0.6	0.7	0.7	0.8
Furniture and fixtures (SIC25)	0.3	0.3	0.4	0.6
Stone, clay and glass products (SIC32)	0.9	2.4	2.1	1.5
Primary metal industries (SIC33)	8.5	6.1	3.8	2.1
Fabricated metal products (SIC34)	1.7	2.2	2.4	3.1
Industrial and commercial machinery (3) (SIC35)	15.5	11.8	11.2	12.6
Electrical and electronic equipment (SIC36)	12.8	16.5	14.0	14.2
Transportation equipment (SIC37)	5.8	7.9	8.1	7.8
Measuring and controlling instruments (SIC38)	1.5	6.2	8.4	8.4
Miscellaneous manufacturing (SIC39)	0.9	0.6	0.6	0.7

Source: based on BLS data (2001). – (1) Based on data on productive capital stock at 1996 prices. - (2) As percentage of ICT capital stock of the non-farm business sector. - (3) Includes computer equipment.

Table 5

United States: Manufacturing Sector

ICT capital stock shares on equipment capital stock (1)

(percentage values)

Industry	1973	1987	1991	1999
Total Manufacturing	3.3	11.1	13.1	20.5
Food and kindred products (SIC20)	3.9	8.5	9.4	12.6
Tobacco (SIC21)	3.5	10.7	11.7	20.8
Textile mill products (SIC22)	1.3	4.0	5.3	10.0
Apparel and related products (SIC23)	3.3	8.6	11.4	20.9
Paper and allied products (SIC26)	0.5	5.4	6.9	9.6
Printing and publishing (SIC27)	2.1	18.5	24.9	43.7
Chemicals and allied products (SIC28)	7.3	17.5	20.6	30.0
Petroleum refining and related industries (SIC29)	4.7	10.1	13.5	22.2
Rubber and plastics products (SIC30)	1.4	3.7	4.7	9.4
Leather and leather products (SIC31)	4.8	4.6	6.9	22.0
Lumber and wood products (SIC24)	0.8	3.7	5.5	11.4
Furniture and fixtures (SIC25)	1.4	6.5	8.8	18.1
Stone, clay and glass products (SIC32)	0.6	7.4	8.2	10.2
Primary metal industries (SIC33)	1.9	5.5	4.9	5.4
Fabricated metal products (SIC34)	0.9	4.0	5.0	10.6
Industrial and commercial machinery (2) (SIC35)	7.0	14.0	15.8	27.0
Electrical and electronic equipment (SIC36)	9.2	23.9	22.9	28.7
Transportation equipment (SIC37)	1.8	9.1	10.9	15.9
Measuring and controlling instruments (SIC38)	2.7	28.4	36.1	52.0
Miscellaneous manufacturing (SIC39)	3.3	8.0	10.8	18.9

Source: based on BLS data (2001). – (1) Based on data on productive capital stock at 1996 prices. - (2) Includes computer equipment.

Tab. 6a

United States: Manufacturing Sector

Sources of Productivity Growth by Industry in the period 1973-1995

(average rate of growth and contributions)

Industry	Y/h	Tfp	Input/h	K/h	*Kict/h*	*Kcom/h*
Non durable goods						
Food and kindred products (SIC20)	2.30	0.40	1.67	0.22	*0.06*	*0.03*
Tobacco (SIC21)	2.47	-2.87	4.22	1.23	*0.14*	*n.a.*
Textile mill products (SIC22)	3.94	2.34	1.30	0.26	*0.07*	*0.04*
Apparel and related products (SIC23)	3.14	0.91	1.90	0.30	*0.07*	*0.04*
Paper and allied products (SIC26)	2.13	-0.28	1.88	0.53	*0.15*	*0.05*
Printing and publishing (SIC27)	0.16	-0.94	0.78	0.33	*0.31*	*0.15*
Chemicals and allied products (SIC28)	1.75	-0.41	1.40	0.76	*0.32*	*0.09*
Petroleum refining and related industries (SIC29)	1.85	-0.14	1.44	0.54	*0.07*	*0.02*
Rubber and plastics products (SIC30)	1.97	0.42	1.38	0.16	*0.06*	*0.04*
Leather and leather products (SIC31)	1.33	0.19	0.48	0.65	*0.06*	*n.a.*
Durable goods						
Lumber and wood products (SIC24)	1.29	0.97	0.16	0.16	*0.07*	*n.a.*
Furniture and fixtures (SIC25)	1.77	0.57	1.02	0.17	*0.06*	*n.a.*
Stone, clay and glass products (SIC32)	1.29	0.51	0.55	0.22	*0.15*	*0.08*
Primary metal industries (SIC33)	1.43	-0.32	1.51	0.24	*0.07*	*0.03*
Fabricated metal products (SIC34)	1.28	0.18	0.78	0.32	*0.09*	*0.06*
Industrial and commercial machinery (1) (SIC35)	4.83	2.33	1.86	0.57	*0.28*	*0.18*
Electrical and electronic equipment (SIC36)	6.19	3.09	1.99	1.00	*0.44*	*0.24*
Transportation equipment (SIC37)	1.70	0.04	1.50	0.16	*0.12*	*0.07*
Measuring and controlling instruments (SIC38)	4.27	1.05	2.88	0.30	*0.13*	*0.06*
Miscellaneous manufacturing (SIC39)	1.25	0.18	0.75	0.32	*0.09*	*0.05*

Source: based on BLS data (2001). - (1) Includes computer equipment.

Legenda: Y/h: labour productivity; Tfp: total factor productivity (Solow’s residual); Input/h: contribution of intermediate inputs; K/h: contribution of total capital; Kict/h: contribution of ICT capital; Kcom/h: contribution of computers. TFP, Input/h and K/h sum up to Y/h.

Tab. 6b

United States: Manufacturing Sector

Sources of Productivity Growth by Industry in the period 1995-99

(average rate of growth and contributions)

Industry	Y/h	Tfp	Input/h	K/h	*Kict/h*	*Kcom/h*
Non durable goods						
Food and kindred products (SIC20)	1.12	-0.31	1.09	0.34	*0.12*	*0.07*
Tobacco (SIC21)	-2.81	-8.92	6.03	0.64	*0.23*	*0.23*
Textile mill products (SIC22)	3.74	2.07	0.93	0.70	*0.28*	*0.18*
Apparel and related products (SIC23)	7.55	1.63	5.21	0.58	*0.16*	*0.09*
Paper and allied products (SIC26)	1.63	1.27	-0.11	0.47	*0.18*	*0.10*
Printing and publishing (SIC27)	1.27	-0.78	1.14	0.92	*0.75*	*0.45*
Chemicals and allied products (SIC28)	2.45	0.95	0.26	1.22	*0.61*	*0.25*
Petroleum refining and related industries (SIC29)	3.18	0.82	2.04	0.29	*0.08*	*0.02*
Rubber and plastics products (SIC30)	3.56	1.40	1.55	0.57	*0.19*	*0.12*
Leather and leather products (SIC31)	6.27	2.41	3.73	0.04	*0.40*	*0.40*
Durable goods						
Lumber and wood products (SIC24)	0.33	-1.17	1.50	0.02	*0.12*	*0.12*
Furniture and fixtures (SIC25)	3.54	1.18	2.20	0.13	*0.13*	*0.13*
Stone, clay and glass products (SIC32)	3.31	1.04	1.72	0.52	*0.23*	*0.14*
Primary metal industries (SIC33)	2.46	1.99	0.31	0.15	*0.12*	*0.09*
Fabricated metal products (SIC34)	2.15	-0.07	1.95	0.27	*0.21*	*0.13*
Industrial and commercial machinery (1) (SIC35)	10.18	6.94	2.20	0.81	*0.56*	*0.36*
Electrical and electronic equipment (SIC36)	14.30	8.14	3.43	2.19	*0.93*	*0.56*
Transportation equipment (SIC37)	5.69	1.28	4.04	0.30	*0.19*	*0.11*
Measuring and controlling instruments (SIC38)	2.76	0.97	1.56	0.21	*0.13*	*0.07*
Miscellaneous manufacturing (SIC39)	1.49	0.67	0.57	0.24	*0.24*	*0.14*

Source: based on BLS data (2001). - (1) Includes computer equipment.

Legenda: Y/h: labour productivity; Tfp: total factor productivity (Solow's residual); Input/h: contribution of intermediate inputs; K/h: contribution of total capital input; Kict/h: contribution of ICT capital input; Kcom/h: contribution of computers. TFP, Input/h and K/h sum up to Y/h.

Table 7a

Tests of acceleration of hourly labour productivity after 1992

	OLS			FE		
	[1]	[2]	[3]	[1]	[2]	[3]
DU92	0.0159 (0.0039)	0.0241 (0.0036)	0.0194 (0.0035)	0.0159 (0.0034)	0.0197 (0.0030)	0.0150 (0.0030)
Constant	0.0200 (0.0019)	0.0194 (0.0020)	0.0204 (0.0021)			
Cycle-mf_t			0.2455 (0.0437)			0.2451 (0.0375)
Weights	No	Yes (Output)	Yes (Output)	No	Yes (Output)	Yes (Output)
Number of Industries	20	20	20	20	20	20
Number of Observations	540	540	540	540	540	540

Notes: Dependent variable is the delta log of hourly labour productivity in each industry. Cycle-mf is an indicator of the cycle in the manufacturing sector; DU92 is a dummy variable equal 1 if $t \geq 1992$ and 0 otherwise. Standards errors are in parentheses. All estimates are corrected for heterosckedasticity. Estimated period: 1973-1999.

Tests of acceleration of total factor productivity after 1994

	OLS			FE		
	[1]	[2]	[3]	[1]	[2]	[3]
DU94	0.0091 (0.0039)	0.0152 (0.0031)	0.0106 (0.0030)	0.0091 (0.0032)	0.0115 (0.0026)	0.0069 (0.0025)
Constant	0.0033 (0.0015)	0.0035 (0.0015)	0.0041 (0.0014)			
Cycle-mf_t			0.2511 (0.0037)			0.2501 (0.0291)
Weights	No	Yes (Output)	Yes (Output)	No	Yes (Output)	Yes (Output)
Number of Industries	20	20	20	20	20	20
Number of Observations	540	540	540	540	540	540

Notes: Dependent variable is the delta log of total factor productivity in each industry. Cycle-mf is an indicator of the cycle in the manufacturing sector; DU94 is a dummy variable equal 1 if t ≥ 1994 and 0 otherwise. Standards errors are in parentheses. All estimates are corrected for heterosckedasticity. Estimated period: 1973-1999. Coefficients in bold are not significant at the 10% level.

Table 8a

Tests of acceleration of hourly labour productivity for ITC - intensive industries after 1992

	[1]	[2]	[3]	[3]
Cycle-mf_t	0.2457	0.2449	0.2465	0.2463
	(0.0437)	(0.0438)	(0.0430)	(0.0439)
DU92	0.0085	**-0.0004**	0.0129	0.0161
	(0.0033)	**(0.0037)**	(0.0037)	(0.0041)
DUICT1	0.0073			
	(0.0039)			
DUICT2		**0.0058**		
		(0.0038)		
DUICT3			0.0128	
			(0.0037)	
DUICT4				0.0074
				(0.0038)
DUICT92	0.0223	0.0322	**0.0109**	**0.0052**
	(0.0069)	(0.0061)	**(0.0066)**	**(0.0066)**
Constant	0.0172	0.0173	0.0139	0.0161
	(0.0022)	(0.0027)	(0.0023)	(0.0027)
Number of Industries	20	20	20	20
Number of Observations	540	540	540	540

Notes: Dependent variable is the delta log of hourly labour productivity in each industry. Cycle-mf is an indicator of the cycle in the manufacturing sector; DUICT1,2,3,4 are alternative dummies used to identify ICT-intensive industries; DU92 is a dummy variable equal 1 if $t \geq 1992$ and 0 otherwise; DUICT92 is a dummy equal to DU92*DUICT1,2,3,4. Standards errors are in parentheses. All estimates are corrected for heterosckedasticity and are weighted with output. Estimated period: 1973-1999. Coefficients in bold are not significant at the 10% level.

Table 8b

Tests of acceleration of total factor productivity for ITC - intensive industries after 1994

	[1]	[2]	[3]	[4]
$Cycle\text{-}mf_t$	0.2512 (0.0375)	0.2505 (0.0375)	0.2514 (0.0375)	0.2511 (0.0374)
DU94	**-0.0011** **(0.0028)**	**-0.0020** **(0.0042)**	**0.0001** **(0.0026)**	**0.0004** **(0.0027)**
DUICT1	**0.0014** **(0.0028)**			
DUICT2		0.0056 (0.0028)		
DUICT3			**0.0039** **(0.0027)**	
DUICT4				**-0.0026** **(0.0027)**
DUICT94	0.0243 (0.0058)	0.0199 (0.0057)	0.0191 (0.0055)	0.0169 (0.0053)
Constant	0.0035 (0.0017)	**0.0011** **(0.0020)**	**0.0022** **(0.0016)**	0.0043 (0.0018)
Number of Industries	20	20	20	20
Number of observations	540	540	540	540

Notes: Dependent variable is the delta log of Total Factor Productivity in each industry. Cycle-mf is an indicator of the cycle in the manufacturing sector; DUICT1,2,3,4 are alternative dummies to identify ICT-intensive industries; DU94 is a dummy variable equal 1 if $t \geq 1994$ and 0 otherwise; DUICT94 is a dummy equal to DU94*DUICT1,2,3,4. Standards errors are in parentheses. All estimates are corrected for heterosckedasticity and weighted with output. Estimated period: 1973-1999. Coefficients in bold are not significant at the 10% level.

Table 9

Equation (5) : Estimation results

(dependent variable is delta log of hourly labour productivity in each industry)

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
$\Delta\log(KICT)_t$	0.0307	**-0.0254**			**0.0030**	**-0.0281**		
	(0.0151)	**(0.0187)**			**(0.0155)**	**(0.0195)**		
$\Delta\log(KICTL)_t$			**0.0266**	**-0.0011**			**0.0159**	**-0.0172**
			(0.0183)	**(0.0221)**			**(0.0177)**	**(0.0230)**
$\Delta\log(KICTH)_t$			0.0394	**-0.0628**			**-0.0157**	**-0.0472**
			(0.0210)	**(0.0261)**			**(0.0237)**	**(0.0290)**
$\Delta\log(KNICT)_t$	0.0889	0.1846	0.0874	0.1867	0.1003	0.2657	0.0973	0.2615
	(0.0389)	(0.0466)	(0.0390)	(0.0465)	(0.0389)	(0.0525)	(0.0389)	(0.0528)
$\Delta\log(INT)_t$	0.4762	0.4080	0.4744	0.4004	0.4631	0.3943	0.4537	0.3926
	(0.0264)	(0.0312)	(0.0268)	(0.0314)	(0.0271)	(0.0329)	(0.0275)	(0.0331)
$QICT_{t-3}$	0.0793	**0.0287**			**0.0270**	**0.0261**		
	(0.0220)	**(0.0298)**			**(0.0225)**	**(0.0296)**		
$QICTL_{t-3}$			0.1115	**0.0533**			**0.0027**	**0.0170**
			(0.0553)	**(0.0870)**			**(0.0252)**	**(0.0322)**
$QICTH_{t-3}$			0.0754	**0.0122**			0.1192	**0.0468**
			(0.0240)	**(0.0322)**			(0.0529)	**(0.0888)**
Cycle-mf_t	0.2894	0.2345	0.2890	0.2324	0.2429	0.2422	0.2405	0.2398
	(0.0385)	(0.0411)	(0.0386)	(0.0410)	(0.0383)	(0.0424)	(0.0382)	(0.0426)
Number of Industries	20	20	20	20	18	18	18	18
Number of observations	540	380	540	380	486	342	486	342

Notes: Panel regressions with fixed effects. All estimates are corrected for heteroskedasticity. Estimates are weighted with output. Estimated periods: 1973-1999 (540 or 486 observations) and 1973-1991 (380 or 342 observations). Coefficients in bold are not significant at the 10% level.

TFP growth and ICT intensity: Estimation results of equation (6)
(dependent variable is delta log of total factor productivity in each industry)

	[1]	[2]	[3]	[4]	[5]	[6]
Δlog $QICT_{t-3}$		**0.0139** **(0.0187)**				
Δlog $QCOM_{t-3}$				**0.7993** **(2.0974)**		
Δlog $QCOMICT_{t-3}$						**-0.0080** **(0.0179)**
$QICT_{t-3}$	0.0476 (0.0210)	0.0533 (0.0224)				
$QCOM_{t-3}$			0.5484 (0.1776)	**0.4623** **(0.2876)**		
$QCOMICT_{t-3}$					0.08551 (0.0317)	0.08845 (0.0324)
Cycle-mf_t	0.2574 (0.0288)	0.2596 (0.0290)	0.2557 (0.0286)	0.2563 (0.0287)	0.2548 (0.0288)	0.2563 (0.0290)
Number of Industries	20	20	20	20	20	20
Number of observations	540	540	540	540	540	540

Notes: Panel regressions with fixed effects. All estimates are corrected for heteroskedasticity. Estimates are weighted with output. Coefficients in bold are not significant at the 10% level.

TFP growth and ICT intensity: Estimation results of equation (6)
(dependent variable is delta log of total factor productivity in each industry)

	[1]	[2]	[3]
$QICTL_{t-3}$	**0.0156** **(0.0526)**		
$QCOML_{t-3}$		**0.0322** **(0.4175)**	
$QCOMICTL_{t-3}$			**0.0007** **(0.0404)**
$QICTH_{t-3}$	0.0535 (0.0228)		
$QCOMH_{t-3}$		0.6592 (0.1951)	
$QCOMICTH_{t-3}$			0.2098 (0.0488)
Cycle-mf_t	0.2583 (0.0289)	0.2573 (0.0286)	0.2520 (0.0286)
Number of Industries	20	20	20
Number of observations	540	540	540

Notes: Panel regressions with fixed effects. All estimates are corrected for heteroskedasticity. Estimates are weighted with output. Coefficients in bold are not significant at the 10% level.

Table 10c

TFP growth and ICT intensity: Estimation results of equation (6)
(dependent variable is delta log of total factor productivity in each industry)

	[1]	[2]	[3]	[4]	[5]	[6]
$QICT73_{t-3}$	**-0.0143**	**-0.0135**				
	(0.0332)	**(0.0333)**				
$QICT94_{t-3}$	0.0424	**0.0337**				
	(0.0210)	**(0.0246)**				
$QCOM73_{t-3}$			**-0.3108**	**-0.3057**		
			(0.3481)	**(0.3486)**		
$QCOM94_{t-3}$			0.5527	0.5123		
			(0.1764)	(0.2048)		
$QCOMICT73_{t-3}$					**0.0137**	**0.0138**
					(0.0431)	**(0.0431)**
$QCOMICT94_{t-3}$					0.0963	0.0902
					(0.0318)	(0.0396)
$Cycle\text{-}mf_{t}$	0.2510		0.2493		0.2476	
	(0.0288)		(0.0285)		(0.0288)	
$Cycle\text{-}mf73_{t}$		0.2473		0.2470		0.2462
		(0.0293)		(0.0292)		(0.0293)
$Cycle\text{-}mf94_{t}$		0.3632		0.3065		0.2912
		(0.1652)		(0.1496)		(0.1714)
Number of Industries	20	20	20	20	20	20
Number of observations	540	540	540	540	540	540

Notes: Panel regressions with fixed effects. All estimates are corrected for heteroskedasticity. Estimates are weighted with output. Coefficients in bold are not significant at the 10% level.

Table 10d

TFP growth and ICT intensity: Estimation results of equation (6)
(dependent variable is delta log of Total Factor Productivity in each industry)

	[1]	[2]	[3]	[4]	[5]	[6]
Q*INTL*73$_{t-3}$	**-0.0092**	**-0.0078**	**-0.4114**	**-0.3962**	**-0.0046**	**-0.0046**
	(0.0897)	**(0.0897)**	**(0.7708)**	**(0.7714)**	**(0.0526)**	**(0.0527)**
Q*INTL*94$_{t-3}$	**0.01720**	**-0.0110**	**0.0834**	**-0.0742**	**0.0033**	**0.0027**
	(0.05243)	**(0.0598)**	**(0.4202)**	**(0.4683)**	**(0.0413)**	**(0.0467)**
Q*INTH*73$_{t-3}$	**-0.0127**	**-0.0100**	**-0.2667**	**-0.2545**	**0.0493**	**0.0492**
	(0.0360)	**(0.0361)**	**(0.3906)**	**(0.3911)**	**(0.0723)**	**(0.0724)**
Q*INTH*94$_{t-3}$	0.0465	0.0357	0.6448	0.5767	0.2059	0.2052
	(0.0229)	(0.0254)	(0.1941)	(0.2137)	(0.0485)	(0.0548)
Cycle-mf$_t$	0.2523		0.2514		0.2458	
	(0.0289)		(0.0286)		(0.0285)	
Cycle-mf73$_t$		0.2472		0.2470		0.2457
		(0.0294)		(0.0291)		(0.0290)
Cycle-mf94$_t$		0.4240		0.3682		**0.2505**
		(0.1770)		(0.1557)		**(0.1698)**
Number of Industries	20	20	20	20	20	20
Number of observations	540	540	540	540	540	540

Notes: Panel regressions with fixed effects. All estimates are corrected for heteroskedasticity. Estimates are weighted with output. Coefficients in bold are not significant at the 10% level.

Table 11

United States: Service Sector

Composition of ICT capital stock by Industry (1)

(percentage values)

Industry	1972	1977	1982	1987	1992	1999
Service sector (2)	*82.7*	*78.9*	*73.9*	*74.4*	*73.1*	*73.3*
Railroad transportation (SIC 40)	0.7	0.4	0.7	0.6	0.5	0.4
Local and interurban passenger transit (SIC 41)	0.3	0.2	0.2	0.2	0.2	0.1
Trucking and warehousing (SIC 42)	0.1	0.0	0.2	0.4	0.5	0.6
Water transportation (SIC 44)	0.1	0.0	0.1	0.1	0.1	0.1
Transportation by air (SIC 45)	0.2	0.1	0.5	0.8	1.0	1.8
Pipelines, except natural gas (SIC 46)	0.1	0.0	0.1	0.1	0.1	0.2
Transportation services (SIC 47)	0.1	0.1	0.2	0.5	0.6	1.2
- Telephone and telegraph (SIC 481, 482, 489)	45.0	42.2	36.1	28.5	24.5	17.9
Electric , gas and sanitary services (SIC 49)	2.8	4.1	6.4	8.5	8.0	4.5
Wholesale trade (SIC 50-51)	2.5	4.2	7.0	9.3	8.4	11.3
Retail trade (SIC 52-59)	1.1	2.2	2.5	3.0	3.2	3.8
Depository institutions (SIC 60)	1.8	3.7	4.3	4.2	5.0	4.6
Non depository institutions (SIC 61)	0.1	0.2	0.7	3.0	4.4	8.2
Security and commodity brokers (SIC 62)	0.2	0.2	0.3	0.8	1.0	1.3
Insurance carriers (SIC 63)	0.7	0.9	1.3	1.9	2.4	3.1
Insurance agents, brokers, and services (SIC 64)	0.3	0.4	0.3	0.2	0.2	0.3
Real estate (SIC 65)	13.2	7.6	3.6	1.9	1.2	0.5
Hotels and other lodging places (SIC 70)	0.1	0.1	0.2	0.3	0.3	0.3
Personal services (SIC 72)	1.9	1.4	0.7	0.4	0.4	0.3
Business services (SIC 73)	3.4	2.8	2.7	4.6	5.2	6.9
Auto repair, services and parking (SIC 75)	0.1	0.1	0.3	0.3	0.3	0.2
Miscellaneous repair services (SIC 76)	0.0	0.0	0.1	0.1	0.1	0.3
Motion pictures (SIC 78)	1.3	1.3	0.8	0.6	0.7	1.0
Amusement and recreation services (SIC 79)	1.4	1.3	0.7	0.3	0.2	0.1
Health services (SIC 80)	4.9	4.9	3.5	3.3	3.8	3.5
Legal services (SIC 81)	0.3	0.1	0.3	0.5	0.7	0.6
Educational services (SIC 82)	0.2	0.2	0.1	0.1	0.1	0.1

Source: based on BLS (2001) data. - (1) Data on productive capital stock at 1996 prices. - (2) As percentage of ICT capital stock of the non-farm business sector. The service sector includes the 27 2-digit SIC industries listed in the table.

Table 12a

United States: Service Sector

ICT capital stock shares on total capital stock (1)

(percentage values)

Industry	1972	1977	1982	1987	1992	1999
Service sector (2)	*2.5*	*3.1*	*4.1*	*5.1*	*5.9*	*10.2*
Railroad transportation (SIC 40)	0.2	0.2	0.5	0.8	0.9	1.3
Local and interurban passenger transit (SIC 41)	1.2	1.4	2.1	3.9	5.3	5.7
Trucking and warehousing (SIC 42)	0.2	0.1	0.9	2.1	3.3	5.8
Water transportation (SIC 44)	0.3	0.2	0.7	1.4	1.7	2.9
Transportation by air (SIC 45)	0.5	0.5	2.1	4.6	7.1	17.0
Pipelines, except natural gas (SIC 46)	0.2	0.1	0.5	0.6	1.0	3.7
Transportation services (SIC 47)	0.6	0.7	3.0	7.9	13.3	33.2
- Telephone and telegraph (SIC 481, 482, 489)	33.8	36.7	39.0	36.8	35.9	39.4
Electric , gas and sanitary services (SIC 49)	0.6	1.1	2.7	4.6	5.2	5.4
Wholesale trade (SIC 50-51)	1.2	2.4	5.1	8.4	8.5	16.4
Retail trade (SIC 52-59)	0.3	0.8	1.3	1.9	2.2	4.1
Depository institutions (SIC 60)	1.9	4.3	6.2	7.2	9.5	15.9
Non depository institutions (SIC 61)	0.1	0.4	1.7	8.3	16.7	35.7
Security and commodity brokers (SIC 62)	4.7	7.4	13.0	15.9	14.7	21.0
Insurance carriers (SIC 63)	4.2	5.1	8.8	10.8	12.8	21.9
Insurance agents, brokers, and services (SIC 64)	4.8	6.5	7.0	6.7	9.4	19.1
Real estate (SIC 65)	1.4	1.1	0.8	0.6	0.4	0.3
Hotels and other lodging places (SIC 70)	0.1	0.1	0.5	0.8	0.9	1.2
Personal services (SIC 72)	8.6	9.1	6.7	5.3	6.5	8.3
Business services (SIC 73)	6.8	6.5	9.1	20.2	24.8	37.0
Auto repair, services and parking (SIC 75)	0.2	0.2	1.4	1.8	1.7	2.3
Miscellaneous repair services (SIC 76)	0.4	0.6	1.4	2.3	5.2	16.4
Motion pictures (SIC 78)	8.9	11.8	11.3	10.1	11.9	20.2
Amusement and recreation services (SIC 79)	3.4	4.1	3.8	2.5	1.4	1.6
Health services (SIC 80)	13.7	15.7	14.6	15.2	17.9	24.1
Legal services (SIC 81)	4.0	2.5	6.5	13.2	18.5	29.1
Educational services (SIC 82)	8.9	5.4	4.0	4.0	4.3	7.0

Source: based on BLS (2001) data. - (1) Based on data on productive capital stock at 1996 prices. - (2) The Service sector includes the 27 2-digit SIC industries listed in the table.

United States: Service Sector

ICT capital stock shares on equipment capital stock (1)

(percentage values)

Industry	1972	1977	1982	1987	1992	1999
Services sector (2)	*15.2*	*16.8*	*20.2*	*24.4*	*27.3*	*37.8*
Railroad transportation (SIC 40)	1.5	1.2	3.4	5.4	6.8	9.2
Local and interurban passenger transit (SIC 41)	7.4	7.2	9.1	14.8	18.4	13.9
Trucking and warehousing (SIC 42)	0.3	0.2	1.4	3.3	5.4	8.6
Water transportation (SIC 44)	0.4	0.2	0.8	1.5	2.0	3.5
Transportation by air (SIC 45)	0.5	0.5	2.4	5.6	8.8	20.1
Pipelines, except natural gas (SIC 46)	5.7	4.5	9.5	13.3	26.2	50.5
Transportation services (SIC 47)	0.6	0.7	3.2	8.7	15.2	37.9
-Telephone and telegraph (SIC 481, 482, 489)	82.7	85.6	86.8	86.2	82.6	78.6
Electric , gas and sanitary services (SIC 49)	3.1	5.3	11.1	16.9	18.4	19.3
Wholesale trade (SIC 50-51)	7.1	13.3	25.5	36.4	39.9	54.1
Retail trade (SIC 52-59)	2.4	5.7	9.2	13.7	16.3	26.6
Depository institutions (SIC 60)	16.1	20.3	21.3	23.4	30.2	49.3
Non depository institutions (SIC 61)	1.0	2.5	9.0	23.8	27.9	43.2
Security and commodity brokers (SIC 62)	43.8	53.5	59.6	64.5	47.7	44.9
Insurance carriers (SIC 63)	39.7	41.4	42.3	37.3	38.8	52.7
Insurance agents, brokers, and services (SIC 64)	35.1	21.5	21.0	26.3	34.4	40.6
Real estate (SIC 65)	36.0	35.6	31.8	20.8	15.0	13.4
Hotels and other lodging places (SIC 70)	1.1	1.7	6.0	10.2	11.2	15.0
Personal services (SIC 72)	33.6	30.1	24.8	21.9	28.7	39.6
Business services (SIC 73)	10.6	9.9	15.1	37.3	43.4	54.3
Auto repair, services and parking (SIC 75)	0.3	0.4	2.2	2.7	2.8	3.1
Miscellaneous repair services (SIC 76)	0.8	1.1	2.7	4.9	12.6	33.0
Motion pictures (SIC 78)	70.8	74.8	63.4	53.4	54.8	62.5
Amusement and recreation services (SIC 79)	17.2	17.2	15.4	13.8	10.4	10.2
Health services (SIC 80)	58.3	59.0	54.9	58.8	66.8	74.3
Legal services (SIC 81)	20.1	14.3	26.3	37.3	48.3	64.8
Educational services (SIC 82)	15.9	22.3	25.7	26.7	33.5	57.4

Source: based on BLS (2001) data. - (1) Based on data on productive capital stock at 1996 prices. - (2) The Service sector includes the 27 2-digit SIC industries listed in the table.

United States: Service Sector

Sources of Productivity Growth by Industry in the period 1977-92

(average rates of growth and contributions)

Industry	Va/h	Tfp	K/h	*Kict/h*
Railroad transportation (SIC 40)	7.7	6.8	0.9	*0.05*
Local and interurban passenger transit (SIC 41)	-2.6	-1.7	-0.9	*0.06*
Trucking and warehousing (SIC 42)	1.9	1.3	0.5	*0.14*
Water transportation (SIC 44)	1.0	0.9	0.1	*0.04*
Transportation by air (SIC 45)	1.3	1.6	-0.3	*0.14*
Pipelines, except natural gas (SIC 46)	-2.2	-2.4	0.1	*0.13*
Transportation services (SIC 47)	-0.6	0.9	-1.5	*0.50*
- Telephone and telegraph (SIC 481, 482, 489)	5.7	2.9	2.8	*1.55*
Electric , gas and sanitary services (SIC 49)	0.2	-0.6	0.8	*0.65*
Wholesale trade (SIC 50-51)	3.2	2.1	1.1	*0.88*
Retail trade (SIC 52-59)	1.3	0.6	0.7	*0.30*
Depository institutions (SIC 60)	Na	Na	Na	*Na*
Non depository institutions (SIC 61)	Na	Na	Na	*Na*
Security and commodity brokers (SIC 62)	2.9	0.3	2.6	*1.52*
Insurance carriers (SIC 63)	-3.6	-3.7	0.2	*0.02*
Insurance agents, brokers, and services (SIC 64)	-2.0	-1.1	-0.9	*0.05*
Real estate (SIC 65)	1.4	0.9	0.5	*-0.05*
Hotels and other lodging places (SIC 70)	-2.5	-2.6	0.1	*0.14*
Personal services (SIC 72)	-0.7	-0.5	-0.2	*0.06*
Auto repair, services and parking (SIC 75)	-0.9	-1.2	0.3	*0.33*
Miscellaneous repair services (SIC 76)	-0.6	-0.9	0.4	*0.52*
Motion pictures (SIC 78)	0.7	0.5	0.2	*0.14*
Amusement and recreation services (SIC 79)	2.4	2.9	-0.5	*-0.11*
Health services (SIC 80)	-1.7	-2.1	0.4	*0.24*
Legal services (SIC 81)	-3.4	-4.4	0.9	*1.43*
Educational services (SIC 82)	-0.3	-0.5	0.2	*0.03*

Source: based on BEA (2000) and BLS (2001) data.

Table 13b

United States: Service Sector

Sources of Productivity Growth by Industry in the period 1992-99

(average rates of growth and contributions)

Industry	Va/h	Tfp	K/h	*Kict/h*
Railroad transportation (SIC 40)	2.3	2.2	0.1	*0.07*
Local and interurban passenger transit (SIC 41)	0.3	1.3	-0.9	*-0.01*
Trucking and warehousing (SIC 42)	1.1	-0.2	1.3	*0.47*
Water transportation (SIC 44)	1.5	1.7	-0.2	*0.24*
Transportation by air (SIC 45)	1.6	1.8	-0.2	*0.42*
Pipelines, except natural gas (SIC 46)	7.5	3.1	4.4	*1.73*
Transportation services (SIC 47)	1.4	-0.6	2.1	*2.59*
- Telephone and telegraph (SIC 481, 482, 489)	4.4	3.3	1.1	*0.97*
Electric, gas and sanitary services (SIC 49)	2.9	1.4	1.5	*0.39*
Wholesale trade (SIC 50-51)	4.6	2.9	1.7	*1.46*
Retail trade (SIC 52-59)	3.4	2.9	0.5	*0.35*
Depository institutions (SIC 60)	1.3	-0.4	1.7	*2.04*
Non depository institutions (SIC 61)	0.3	-0.6	0.9	*1.09*
Security and commodity brokers (SIC 62)	13.0	12.7	0.4	*0.15*
Insurance carriers (SIC 63)	0.8	-1.0	1.8	*1.27*
Insurance agents, brokers, and services (SIC 64)	-3.9	-6.3	2.4	*1.27*
Real estate (SIC 65)	0.6	1.5	-0.9	*0.00*
Hotels and other lodging places (SIC 70)	0.4	-0.1	0.5	*0.19*
Personal services (SIC 72)	0.5	-1.3	1.7	*0.67*
Auto repair, services and parking (SIC 75)	-0.1	-0.9	0.7	*0.17*
Miscellaneous repair services (SIC 76)	-2.3	-4.0	1.7	*1.47*
Motion pictures (SIC 78)	-3.4	-3.8	0.5	*0.64*
Amusement and recreation services (SIC 79)	-0.6	-0.3	-0.3	*0.07*
Health services (SIC 80)	-2.0	-2.5	0.5	*0.46*
Legal services (SIC 81)	-0.9	-2.0	1.1	*1.76*
Educational services (SIC 82)	-1.0	-1.0	0.0	*0.07*

Source: based on BEA (2000) and BLS (2001) data.

Table 13c

United States: Service Sector

Sources of Productivity Growth by Industry in the period 1995-99

(average rates of growth and contributions)

Industry	Va/h	Tfp	K/h	*Kict/h*
Railroad transportation (SIC 40)	2.4	1.8	0.6	*0.11*
Local and interurban passenger transit (SIC 41)	2.7	3.7	-1.0	*0.05*
Trucking and warehousing (SIC 42)	-0.8	-1.9	1.0	*0.35*
Water transportation (SIC 44)	2.0	1.9	0.1	*0.34*
Transportation by air (SIC 45)	7.6	5.7	2.0	*0.98*
Pipelines, except natural gas (SIC 46)	13.5	9.0	4.5	*1.75*
Transportation services (SIC 47)	3.4	-0.3	3.7	*3.56*
- Telephone and telegraph (SIC 481, 482, 489)	5.2	3.9	1.3	*1.15*
Electric , gas and sanitary services (SIC 49)	2.5	1.1	1.5	*0.37*
Wholesale trade (SIC 50-51)	7.6	5.5	2.1	*1.76*
Retail trade (SIC 52-59)	5.3	4.7	0.6	*0.48*
Depository institutions (SIC 60)	0.9	-1.4	2.2	*2.57*
Non depository institutions (SIC 61)	0.7	-0.2	0.9	*1.12*
Security and commodity brokers (SIC 62)	17.5	16.9	0.6	*0.66*
Insurance carriers (SIC 63)	0.0	-1.7	1.8	*1.42*
Insurance agents, brokers, and services (SIC 64)	-2.0	-4.8	2.8	*1.49*
Real estate (SIC 65)	0.7	1.6	-0.9	*0.02*
Hotels and other lodging places (SIC 70)	-0.7	-1.6	0.8	*0.24*
Personal services (SIC 72)	0.9	0.2	0.7	*0.61*
Auto repair, services and parking (SIC 75)	0.2	0.6	-0.4	*0.20*
Miscellaneous repair services (SIC 76)	-3.2	-5.7	2.5	*1.76*
Motion pictures (SIC 78)	-2.5	-3.3	0.8	*0.63*
Amusement and recreation services (SIC 79)	2.3	2.1	0.1	*0.11*
Health services (SIC 80)	-1.1	-1.8	0.7	*0.55*
Legal services (SIC 81)	-0.5	-3.1	2.6	*2.79*
Educational services (SIC 82)	-2.2	-2.3	0.1	*0.10*

Source: based on BEA (2000) and BLS (2001) data.

Value added function estimates

(each variable is expressed in delta log; standard errors within brackets)

Dependent variable is value added	Dependent variable	Hours	FTE	ICT capital	Non- ICT capital	Number of observations	R^2
Pooled estimates (1)	$\Delta \log (Y)_{it}$	0.52036 (0.0624)		0.06118 (0.0231)	0.41844 (0.0661)	376	0.0667
Within transformation (1)	$\Delta \log (Y)_{it} - av (\Delta \log (Y)_i)$	0.35416 (0.07072)		-0.00380 (0.03023)	-0.1859 (0.1144)	376	0.0657
Pooled estimates (1)	$\Delta \log (Y)_{it}$		0.57389 (0.0682)	0.05996 (0.02309)	0.36613 (0.07143)	376	0.0695
Within transformation (1)	$\Delta \log (Y)_{it} - av (\Delta \log (Y)_i)$		0.42583 (0.08122)	-0.01025 (0.03013)	-0.20373 (0.11453)	376	0.0714
Pooled estimates (2)	$\Delta \log (Y)_{it}$	0.5459 (0.0586)		0.04040 (0.02373)	0.4136 (0.0661)	376	0.0715
Pooled estimates (2)	$\Delta \log (Y)_{it}$		0.59758 (0.0640)	0.04125 (0.02373)	0.36115 (0.07124)	376	0.0727

Notes: (1) The concept of capital used is that of productive capital stock. - (2) The concept of capital used is that of capital services.

TFP growth rate and ICT capital accumulation relative to total capital

(standard errors within brackets)

	Within OLS	Between OLS	Mixed OLS
Dependent variable	$\Delta\ log\ (TFP)_{it} - av(\Delta\ log\ (TFP)_{it}$	$av(\Delta\ log\ (TFP)$	$\Delta\ log\ (TFP)_{it}$
Constant		0.0162 (0.0075)	0.01694 (0.0059)
diffictk $_{t-3}$ – av(diffictk)	0.05069 (0.03052)		0.05091 (0.03177)
av(diffictk)		-0.06339 (0.07831)	-0.06375 (0.06414)
Number of observations	376	18	376
R^2	0.007	0.0393	0.009

Table 16a

TFP acceleration and threshold effects

Dependent variable Δ log	Constant	Dummy post 1995	Dummy post 1996	Cycle9	Cycle9 Post95	ICT intensive sector dummy	Dummy post 95 * ICT intensive dummy	No. Obs.	Estimation period	R^2
TFP (pooled)	0.0084 (0.0038)	**0.01300 (0.0081)**		**0.1552 (0.1451)**				376	1977-99	0.013
TFP (pooled)	0.00766 (0.0037)		0.02066 (0.0087)	**0.1240 (0.1449)**				376	1977-99	0.020
TFP (pooled)	0.0084 (0.0037)			**0.1430 (0.1460)**	1.0073 (0.5722)			376	1977-99	0.014
TFP (pooled)	0.0084 (0.0038)	**0.0013 (0.0179)**		**0.14290 (0.1462)**	**0.9223 (1.2660)**			376	1977-99	0.014
TFP (fixed effects)		0.01399 (0.0080)		**0.1516 (0.1430)**				376	1977-99	0.086
TFP (fixed effects)			0.0216 (0.00868)	**0.1207 (0.1427)**				376	1977-99	0.094
TFP (fixed effects)				**0.1395 (0.1438)**	1.0705 (0.5664)			376	1977-99	0.087
TFP (fixed effects)		**0.0023 (0.0176)**		**0.1392 (0.1440)**	**0.9259 (1.2469)**			376	1977-99	0.087
TFP (pooled)	0.01120 (0.0055)	**0.00532 (0.01165)**				**-0.00582 (0.00767)**	**0.01829 (0.01573)**	376	1977-99	0.013

Notes: The ICT intensive dummy was defined by splitting the 18 industries according to whether the share of ICT on total capital was higher or lower than the median industry in 1992, and assigning value 1 to those above the median and value 0 to those below. Coefficients in bold are not significant at the 10% level.

Table 16b

ALP acceleration and threshold effects

Dependent variable Δ log	Constant	Dummy post 1995	Dummy post 1996	Cycle9	Cycle9 Post95	ICT intensive sector dummy	Dummy post 95 * ICT intensive dummy	No. Obs.	Estimation period	R^2
ALP (pooled)	0.0129 (0.0041)	0.0220 (0.0087)		**-0.0311** **(0.156)**				376	1977-99	0.017
ALP (pooled)	0.0125 (0.0039)		0.0296 (0.0094)	**-0.059** **(0.156)**				376	1977-99	0.026
ALP (pooled)	0.0134 (0.004)			**-0.039** **(0.157)**	1.541 (0.617)			376	1977-99	0.017
ALP (pooled)	0.012 (0.004)	**0.0127** **(0.019)**		**-0.041** **(0.157)**	**0.739** **(1.365)**			376	1977-99	0.018
ALP (fixed effects)		0.0223 (0.008)		**-0.032** **(0.152)**				376	1977-99	0.113
ALP (fixed effects)			0.0299 (0.009)	**-0.060** **(0.151)**				376	1977-99	0.122
ALP (fixed effects)				**-0.040** **(0.153)**	1.558 (0.603)			376	1977-99	0.113
ALP (fixed effects)		**0.0130** **(0.018)**		**-0.042** **(0.153)**	**0.741** **(1.326)**			376	1977-99	0.114
ALP (pooled)	0.0148 (0.005)	**0.009** **(0.010)**				**-0.003** **(0.007)**	**0.0285** **(0.016)**	376	1977-99	0.025

Notes: The ICT intensive dummy was defined by splitting the 18 industries according to whether the share of ICT on total capital was higher or lower than the median industry in 1992, and assigning value 1 to those above the median and value 0 to those below. Coefficients in bold are not significant at the 10% level.

Table 17a

Threshold effects

(dependent variable is Δ log TFP)

Estimation period	Diffictk [lag]	Cycle9	Test F on sector dummies, significance level	R^2	Number of observations
1977- 99	0.0522 [3] (0.0317)		0.033	0.079	376
1977 – 99	**0.0456 [3] (0.0321)**	**0.1872 (0.1397)**		0.083	376
1987 – 99	**0.1422 [2] (0.094)**		0.0231	0.140	216
1987 – 99	**0.1385 [2] (0.0948)**	**0.0742 (0.220)**		0.140	216
1991 – 99	**0.2213 [2] (0.1358)**		0.003	0.250	144
1991 – 99	**0.2185 [2] (0.1389)**	**0.0869 (0.8115)**		0.250	144

Notes: Coefficients in bold are not significant at the 10% level.

Table 17b

Threshold effects

(dependent variable is Δ log TFP)

Estimation period	Diffpc [lag]	Cycle9	Test F on sector dummies, significance level	R^2	Number of observations
1977- 99	NO				337
1977-99		**0.241** **(0.146)**		0.071	337
1987 – 99	0.0660 [0] (0.0282)		0.0113	0.153	216
1987 – 99	0.0664 [0] (0.0291)	**-0.0129** **(0.223)**		0.153	216
1991 – 99	0.0850 [0] (0.0449)		0.001	0.256	144
1991 - 99	0.0901 (0.0484)	**-0.2484** **(0.8521)**		0.256	144

Notes: Coefficients in bold are not significant at the 10% level.

References

Arellano, M. and S. R. Bond (1991), *Some Tests of Specifications for Panel Data: Monte Carlo Evidence and an Application to Employment Equations"*, in "Review of Economic Studies", Vol. 58, No. 2, pp. 277-97.

Bartelsman, E. J., R. J. Caballero and R. K. Lyons (1994), *Customer and Supplier Driven Externalities*, in "American Economic Review", Vol. 84, pp. 1075-84.

Berndt, E. R. and C. J. Morrison (1995), *High–Tech Capital Formation and Economic Performance in the U.S. Manufacturing Industries: an Exploratory Analysis,* in "Journal of Econometrics", Vol. 65, pp. 9-43.

Blundell, R. and S. Bond (2000), *GMM Estimation with Persistent Panel Data: an Application to Production Functions,* in "Econometric Review", Vol. 19, No. 3, pp. 321-40.

Bureau of Economic Analysis (1998), *Fixed Reproducible Tangible Wealth of the United States, 1925-96,* NCN-0136, May.

Bureau of Economic Analysis (1999), *A Preview of the 1999 Comprehensive Revision of the National Income and Product Accounts: Definitional and Classificational Changes,* in "Survey of Current Business", Vol. 79, No. 8, pp. 6-17.

Bureau of Economic Analysis (2000), *Improved NIPA Estimates for 1929*-99, in "Survey of Current Business", pp. 11-17.

Bureau of Labor Statistics (2000a), *Revisions to Capital Inputs for the BLS Multifactor Productivity Measures.*

Bureau of Labor Statistics (2000b), *Multifactor Productivity Trends,1998*, September.

Bureau of Labor Statistics (2000c), *Productivity and Costs, Fourth Quarter and Annual Averages*, March.

Diewert W. E. and K. Fox (1999), *Can Measurement Error Explain the Productivity Paradox?*, in "Canadian Journal of Economics", Vol. 32, No. 2.

Economic Report of the President (2000), Washington, United States Government Printing Office.

Economic Report of the President (2001), Washington, United States Government Printing Office.

Gordon, R. J. (2000a), *Does the 'New Economy' Measure up to the Great Inventions of the* P*ast?*, in "Journal of Economic Perspectives", Vol. 14, No. 4, Fall, pp. 49-74.

Gordon, R. J. (2000b), *Interpreting the "One Big Wave" in the U.S. Long Term Productivity Growth,* NBER Working Papers, No. 7752.

Gordon, R. J. (2000c), *Technology and Economic Performance in the American Economy,* Northwestern University, manuscript.

Griliches, Z. and J. Mairesse (1995), *Production Functions: the Search for Identification*, NBER Working Paper, No. 5067.

Gullickson, W. and M. J. Harper (2000), *Bias in Aggregate Productivity Trends Revisited*, Bureau of Labor Statistics, December.

Hansen, B. E. (1992), *Testing for Parameter Instability in Linear Models*, in "Journal of Policy Modeling", Vol. 14, No. 4, pp. 517-33.

Haimowitz, J. H. (1998), *The Longevity of Expansions*, in "Economic Review", Federal Reserve Bank of Kansas City, Vol. 83, pp. 13-34.

Jorgenson, D.W., F. M. Gollop and B. Fraumeni (1987), *Productivity and US Economic Growth*, Harvard University Press.

Jorgenson, D. W. and K. J. Stiroh (2000), *Raising the Speed Limit: US Economic Growth in the Information Age"*, in "Brookings Papers on Economic Activity", pp. 125-211.

Kahn, J. A. and Lim Jong-Soo (1998), *Skilled Labour Augmenting Technical Progress in US Manufacturing*, Federal Reserve Bank of New York.

Katz, A. J. and W. H. Shelby (1997), *Improved Estimates of Fixed Reproducibile Tangible Wealth, 1929-95,* in "Survey of Current Business", May, pp. 69-92.

Nordhaus, W. D. (2001a), *Alternative Methods for Measuring Productivity Growth;* NBER Working Papers, No. 8095.

Nordhaus, W. D. (2001b), *Productivity Growth and the New Economy*, NBER Working Papers, No. 8096.

Nordhaus, W. D. (2001c), *New Data and Output for Understanding Productivity Trends*, NBER Working Papers, No. 8097.

Oliner, S. D. and D. E. Sichel (1994), *Computers and Output Growth Revisited: How Big Is the Puzzle?*, in "Brookings Papers on Economic Activity", pp. 273-317.

Oliner, S. D. and D. E. Sichel (2000), *The Resurgence of Growth in the Late 1990's: Is Information Technology the Story?*, in "Journal of Economic Perspectives", Vol.14, No. 4, Fall, pp. 3-22.

Oliner, S. D. and D. E. Sichel (2001), *The Resurgence of Growth in the Late 1990's: Is Information Technology the Story?*, Federal Reserve Boards of Governors, manuscript, January.

Sichel, D. E. (1999), *Computers and Aggregate Economic Growth: an Update*, in "Business Economics", April, pp. 18-24.

Steindel, C. and K. J. Stiroh (2000), *Productivity: What Is It and Why do We Care about It?*, Federal Reserve Bank of New York, manuscript, September.

Stiroh, K. J. (2001a), *What Drives Productivity Growth?,* in "Economic Policy Review", Federal Reserve Bank of New York, (forthcoming).

Stiroh, K. J. (2001b), *Information Technology and the U.S. Productivity Revival: What do the Industry Data Say?,* Federal Reserve Bank of New York Staff Reports, No. 115, January.

Stiroh, K. J. (2001c), *Are ICT Spillovers Driving the New Economy?,* Federal Reserve Bank of New York, manuscript,

RECENTLY PUBLISHED "TEMI" (*)

No. 394 — *Firm Size Distribution and Growth,* by P. PAGANO and F. SCHIVARDI (February 2001).

No. 395 — *Macroeconomic Forecasting: Debunking a Few Old Wives' Tales,* by S. SIVIERO and D. TERLIZZESE (February 2001).

No. 396 — *Recovering the Probability Density Function of Asset Prices Using GARCH as Diffusion Approximations,* by F. FORNARI and A. MELE (February 2001).

No. 397 — *A Simple Approach to the Estimation of Continuous Time CEV Stochastic Volatility Models of the Short-Term Rate,* by F. FORNARI and A. MELE (February 2001).

No. 398 — *La convergenza dei salari manifatturieri in Europa,* by P. CIPOLLONE (February 2001).

No. 399 — *Labor Income and Risky Assets under Market Incompleteness: Evidence from Italian Data,* by G. GRANDE and L. VENTURA (March 2001).

No. 400 — *Is the Italian Labour Market Segmented?,* by P. CIPOLLONE (March 2001).

No. 401 — *Optimal Debt Maturity under EMU,* by R. GIORDANO (March 2001).

No. 402 — *Il modello di specializzazione internazionale dell'area dell'euro e dei principali paesi europei: omogeneità e convergenza,* by M. BUGAMELLI (March 2001).

No. 403 — *Seasonality and Capacity: an Application to Italy,* by G. DE BLASIO and F. MINI (June 2001).

No. 404 — *The Effects of Bank Consolidation and Market Entry on Small Business Lending,* by E. BONACCORSI DI PATTI and G. GOBBI (June 2001).

No. 405 — *Money Demand in the Euro Area: Do National Differences Matter?,* by L. DEDOLA, E. GAIOTTI and L. SILIPO (June 2001).

No. 406 — *The Evolution of Confidence for European Consumers and Businesses in France, Germany and Italy,* by P. CARNAZZA and G. PARIGI (June 2001).

No. 407 — *A Primer on Financial Contagion,* by M. PERICOLI and M. SBRACIA (June 2001).

No. 408 — *Correlation Analysis of Financial Contagion: What One Should Know before Running a Test,* by G. CORSETTI, M. PERICOLI and M. SBRACIA (June 2001).

No. 409 — *The Role of the Banking System in the International Transmission of Shocks,* by M. SBRACIA and A. ZAGHINI (June 2001).

No. 410 — *International Transmission Via Trade Links: Theoretically Consistent Indicators of Interdependence for Latin America and South-East Asia,* by C. BENTIVOGLI and P. MONTI (June 2001).

No. 411 — *Why is the Business-Cycle Behavior of Fundamentals Alike Across Exchange-Rate Regimes?,* by L. DEDOLA and S. LEDUC (August 2001).

No. 412 — *Political Institutions and Policy Outcomes: What are the Stylized Facts?,* by T. PERSSON and G. TABELLINI (August 2001).

No. 413 — *Equilibrium Welfare and Government Policy with Quasi-Geometric Discounting,* by P. KRUSELL, B. KURUŞÇU and A. A. SMITH, Jr. (August 2001).

No. 414 — *Insurance within the Firm,* by L. GUISO, L. PISTAFERRI and F. SCHIVARDI (August 2001).

No. 415 — *Limited Financial Market Participation: A Transaction Cost-Based Explanation,* by M. PAIELLA (August 2001).

No. 416 — *Decentramento fiscale e perequazione regionale. Efficienza e redistribuzione nel nuovo sistema di finanziamento delle regioni a statuto ordinario,* by G. MESSINA (August 2001).

No. 417 — *Personal Saving and Social Security in Italy: Fresh Evidence from a Time Series Analysis,* by F. ZOLLINO (August 2001).

No. 418 — *Ingredients for the New Economy: How Much does Finance Matter?,* by M. BUGAMELLI, P. PAGANO, F. PATERNÒ, A.F. POZZOLO, S. ROSSI and F. SCHIVARDI (October 2001).

(*) Requests for copies should be sent to:
Banca d'Italia – Servizio Studi – Divisione Biblioteca e pubblicazioni – Via Nazionale, 91 – 00184 Rome (fax 0039 06 47922059). They are available on the Internet at www.bancaditalia.it