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Dissemination of information and communication technologies and economic growth – the case of France over the long term period (1980-2000)

Abstract

The contribution of information and communication technologies (ICT) to GDP and labour productivity growth in France is significant. It is estimated to be in the order of 0.2 to 0.3 % per annum for the entire 1980-2000 period. A strong increase occurred in the second half of the 90s concomitant with the contribution of total factor productivity. This contribution of ICT is estimated to be twice as large in the services sector as in industry. Furthermore, total factor productivity (TFP) was much higher in the ICT-producing sector than the ICT-using sector. The conclusions we derive from our assessments are qualitatively similar to those drawn in respect of the United States where the ICT contriubtion however appears to be far greater.

In spite of the major statistical uncertainties involved, the significance of the contribution of ICT to growth seems unquestionable. However two major issues remain: how long will the beneficial effects connected with the dissemination and produciton of ICT continue to be operative? And to what extent will European countries including France benefit in turn from effects whose magnitude is comparable to that observed in the United States?

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I. - Introduction

At a time when output and labour productivity growth have been slowing considerably both in the United States and Europe since the end of 2000 and while this slowdown followed a phase during which companies built up their stock of information and communication technologies (ICT), it might appear contradictory to continue to pay special attention to the relationships between ICT investment and growth in gross domestic product (GDP) and productivity. But the contradiction is only apparent. Indeed, it is clear that one of the reasons (perhaps the main one as regards the United States) for this downturn is the sudden drop in businesses' demand, especially their demand for ICT products, rather than diminished productivity gains on the supply side. This slackened demand for ICT products from businesses follows a period of continuous increase that further speeded up in the second half of the 90s, partly due perhaps to the fears associated with the Y2K "bug". These recent developments should not however lead one to overlook the fact that, in the United States, the increasing dissemination of ICT was concomitant with a productivity acceleration in the previous period. A lot of recent work, based on national accounting data and the standard imputation assumptions derived from the so-called "growth accounting" technique, has analysed the question of ICT contribution to growth in GDP and labour productivity. They all conclude, with various subtle differences, that businesses' expenditure on ICT has been beneficial to labour productivity. These positive effects derive directly from the dissemination of ICT, through substitution of other forms of capital and various labour skills by ICT capital (*capital deepening)*, particularly in ICT-using industries but can also become apparent as multi-factor productivity (MFP) gains, in particular in the ICT-producing industrial and services sectors.[1]

However, recent trends appear to suggest, at least as far as the United States is concerned, that there may have been "excess ICT accumulation" by businesses in the second half of the 90s. The beneficial effects of these ICT investments over that period may not be as pronounced as predicted by standard growth accounting analyses[2]. Naturally, just as with many economic phenomena, several years of hindsight (and improvement in statistical data) will be needed before such a hypothesis can be tested. However, it is worth noting that, in view of the brevity of the useful life of ICT products, the effects of the probable excess accumulation should be temporary and that they can be set aside without adversely affecting medium and long-term analyses.

In the wake of growth accounting research, the aim of this study is to provide a series of elements for assessing how the dissemination of ICT as an input affected GDP and labour productivity growth in France in the 80s and 90s.[3] We shall assume the effects of possible recent excess accumulation of ICT investments to be negligible and, as such, our estimates for the second half of the 90s may be overvalued. We shall begin (I) with a brief overview of growth accounting principles and the special difficulties these raise when applied to ICT (II) and thereafter provide and comment our own assessments (III) before comparing them to those obtained for other developed economies (IV).

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1 Among the most recent, concerning the US economy, see: Gordon (2000-a et –b), Oliner and Sichel (2000), Jorgenson and Stiroh (2000) and Jorgenson (2001); on the United Kingdom, N. Oulton (2001), on France : Cette, Mairesse and Kocoglu (2000 and 2001) and Mairesse, Cette and Kocoglu (2000) together with a tentative international comparison: Schreyer (2000) and Colecchia et Schreyer (2001).

2 However, even if it were possible to properly account for this phenomenon of excess accumulation, it would have no effect on the measure of GDP growth, nor consequently, on that of labour productivity. The measure of the growth in ICT capital services might, as a result, be revised downwards, in particular due to anticipated scrapping of ICT investment or to decreased marginal productivity of those investments, hence paring down the ICT capital deepening effects on labour productivity. But the value of the residual factor, i.e., total factor productivity gains, would automatically move correspondingly upwards, in which case of course it would be incorrect to attribute those gains to ICT!

3 These assessments supplement detailed ones already presented by Mairesse, Cette and Kocoglu (2000), with results on TFP (not just the direct effects of IT dissemination) and sector level findings.

II. – ICT investments and economic growth – how are they related?

ICT investment expenditure may affect the productive supply[4] side of growth accounting measures through two types of effects:

- Substitution effects (*capital deepening)* associated with accumulation of ICT capital. This is itself mainly a result of constant, rapid improvement in the productive performance of ICT investment, as testified by the decrease in their relative prices compared to other capital goods. Price indices for computer hardware (and even more so for microprocessors), that capture this improvement by means of hedonic methods, in particular in the United States, have declined by 20 % (40 %) on average every year in the last three decades.
- the TFP gains connected essentially with the progress achieved in the ICT-producing sectors which itself reflects the very rapid improvement in ICT performance.

What the respective weight of these two types of effects on growth accounts depends crucially on the choice of method used to for the purpose of splitting the quantity and price components of investment series in value terms. Many analyses recall this basic notion.[5] It casts the economic significance of fluctuations in the estimated rate of TFP growth in a more relative light. Let us consider two extreme cases:

- If the quantity/price split follows a pure "factor cost" rationale, improved productive performance of ICT does not affect their price growth. Accelerated growth brought about by dissemination of ICT would thus be fully reflected in TFP gains.
- If the quantity/price split follows a pure « producer services » rationale, enhanced ICT performance translates as a decrease in their price: from one year to the next, the same expenditure in value equates with a larger quantity. In this event, TFP gains are zero and growth is entirely attributable to changes in input quantities, taking into account their enhanced quality.[6]

Current accounting procedures adopted in national accounts to establish the price/quantity split for capital expenditure are based on two approaches – hedonic methods and the 'matched model' approach, i.e., a « producer services»-oriented rationale used for computer equipment both in France and the United States, as well as for pre-packaged software and telephone switchboards in the United States only, and a 'factor cost' rationale for other capital goods in both countries[7]. Nonetheless, methodological changes are to be expected in coming years so as to more broadly capture the quality effects on other ICT goods and services whose importance is growing, e.g., cell phones (see Lequiller (2000)).

The impact of such methodological changes is more complex than first meets the eye (see Lequiller (2000)). Let us take the example of an alteration in the price/quantity split in favour of quantitivy for computer services. If these computer services are considered to be intermediate consumption by businesses, this change in accounting convention will not affect the GDP measure either in value or volume. It only affects growth and GDP measures through the final uses made of them by households

4 We do not deal here with the effect that demand for ICT goods and services might have on growth which, as pointed out in the introduction, is one of the causes of the slowdown in the US economy since the end of 2000.

5 See Cette, Mairesse and Kocoglu (2000)

6 Along these lines, Gordon (2000-b) states that: « Indeed, the faster the assumed decline in prices for software and communication equipment, the slower is TFP growth in the aggregate economy... », and Jorgenson & Stiroh (2000), who emphasize that: «… the rapid accumulation of computers leads to input growth of computing power in computer-using industries. Since labor is working with more and better computer equipment, this investment increases labor productivity. If the contributions to output are captured by the effect of capital deepening, aggregate TPF growth is unaffected ».

7 For a more detailed description of the methods used, refer to Jorgenson (2001) for the United States and Cette, Mairesse & Kocoglu (2000) for a comparison between the two countries.

(consumption) and foreign agents (exports). If these computer services are considered to be investments by businesses (e.g., investment in software), the accounting change will affect GDP measure in both value and volume.[8] Furthermore, a price/quantity split with a greater quantity biais for some ICT goods and services might raise the GDP measure through the final uses of domestic production by resident agents (households, businesses and government departments), but lowers the GDP measure through intermediate uses of imports by those resident agents (for this aspect too, see Lequiller (2000)).[9]

The effects of ICT dissemination on the productivity of these two inputs (labour and capital) are divergent[10]. Labour productivity is enhanced both by the capital/labour substitution brought about by the decrease in the relative price of the ICT input and the increase in TFP. The variation in capital productivity is less predictable. It should, by all accounts, be deteriorated as a result of capital/labour substitution, but is raised by TFP acceleration.

There is a great deal of uncertainty in the economic literature concerning the allocation of the TFP gains associated with the dissemination of ICT between sectors and concerning the dissemination of these gains from the producer sectors to the user sectors. The localisation of TFP gains depends largely on the conventions adopted to establish the price/quantity split for those ICT. In a highly simplified model, the economy comprises two sectors – the first is a producer of ICT and the second is producer of consumption goods (and uses the products of the first as capital goods). Under this configuration, the more the price/ quantity split favours quantity over price (for example, due to use of hedonic methods), the more TFP gains within the economy tend to be accounted for in the first sector. This difficulty, which was effectively demonstrated by Brynjolfsson and Hitt (2000)[11], invites caution when discussing the allocation of TFP acceleration as between ICT producer and ICT user sectors. It relativises some of the analyses conducted on U.S. data (e.g., Gordon (2000-a and 2000-b), Jorgenson (2001)) that show that TFP gains connected with the dissemination of ICT occur mainly in the producer sectors, where the price/quantity split for computer equipment is largely based on hedonic methods[12]. If the productive performance of ICT were wholly captured in accounts, the use of ICT would not in itself lead to TFP gains.[13]

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8 As noted by Lequiller (2000), its effect the NDP (net domestic product) measure is smaller as it is not sensitive to accounting conventions relating to the price/quantity split of ICT as regards the share of ICT allocated to fixed capital consumption.

9 It should also be pointed out that the share of ICT in production and in agents' expenditure has considerably increased in the last few decades (see Mairesse, Cette and Kocoglu (2000)). Consequently, the methodology establishing a stabilised price/quantity split for each individual type of good, i.e., the "structure" of the methodologies adopted becomes distorted as they shift more towards those (for instance, the hedonic methods) that attempt to more adequately capture quality effects. This structural change may therefore affect the "mean methodology" for the price/quantity split, thereby bringing about a shift towards quantity and away from price whose amplitude is uncertain.

10 This aspect is discussed in Cette, Mairesse and Kocoglu (2001).

11 The authors conclude as follows (p. 39): « Since it is difficult to compute accurate deflators for complex, rapidly changing intermediate goods like computers, one must be careful in interpreting the allocation of productivity across producers and users ».

12 For instance, Gordon (2000-b) states that: « Nothing is left for a structural acceleration in MPF outside of the computer producing sector ». Except for the sectors that produce consumer durables (including ICT), Gordon's conclusion is that TFP (MFP) has indeed decreased since the end of 1995 by approximately 0.3% a year (Gordon (2000-b, p. 55-56).

13 TFP acceleration may nonetheless derive from phenomena that fail to be considered under growth accounting assumptions. Stiroh (2001) draws attention to the fact:« … that the neo-classical framework predicts no TFP growth use since all output contributions are due to capital accumulation. Computers increase measured TFP only if there are non traditional effects like increasing returns, production spillovers, or network externalities, or if input are measured incorrectly », Stiroh (2001, p. 47).

Another form of uncertainty comes out in much of the research on individual data concerning the conditions required for productivity acceleration to be achieved through dissemination of ICT[14]. Greenan and Mairesse (2000), for instance, have shown that the dissemination of computer hardware only has beneficial effects if it is matched by the availability of more skilled labour. Other work has shown that implementation of ICT has often been concomitant with major reorganisations of businesses and that such reorganisations contribute enormously (indeed, may be a pre-requisite) to the accelerated productivity associated with the dissemination of ICT[15]. In other words, dissemination of ICT does not necessarily lead to enhanced productive efficiency: the existence and proportion of such an improvement rely very much on other human resource management aspects.

Another thing that should be stressed is that in “new economy” (NE) and ICT matters, a number of accounting uncertainties further complicate the task of evaluating GDP and growth. Thus, a recent accounting comparison between France, the United States and other European countries proposed by Lequiller (2000) shows that the allocation of some ICT items between final and intermediate uses is perhaps different in the United States and European countries. This suggests that the share of intermediate uses may be larger in European countries than in the United States (particularly as regards software) and that could have a significant relative impact on assessments of GDP and growth that favours the United States.

In the following assessment of the impact of ICT dissemniation on growth, the uncertainties just mentioned will be largely ignored. We make the usual assumptions that production techniques adopted by businesses are the outcome of perfect optimisation taking into account relative factor prices, and the use of those techniques is rational. Events such as temporary excess accumulation are assumed not to exist (see introduction to this paper).

14 For a review of the abundant material in this area, see Brynjolfsson and Hitt (2000)

15 For a review of this literature, see Askénazy et Gianella (2000), among others.

Encadré : Accounting breakdown of growth and productivity - methodology

The accounting methodology used here to break down growth into output (in this case, value added) and labour productivity is standard. Under this approach, a factor of production's contribution to growth is expressed as the product of the volume growth rate for that factor by its payment in the value added. The underlying assumptions of this assessment are: that a unit-returns-to-scale production function of the Cobb-Douglas type accurately represents the production combination; that there is perfect competition on the markets for labour and products; that production techniques are always optimal and hence the marginal productivity ratios for any combination of the two factors is equal to their marginal cost ratio. Factor payment in value added is thus computed in the standard fashion, i.e., as the product of the user cost for that factor by the ratio of that factor's value to the output value.

The principle for the breakdown

These calculations are based on the assumption of a Cobb-Douglas relationship, which written as a logarithm and as a first order log difference, is as follows:

$$y = tfp + \sum_j a_j.k_j + a_l l \quad \text{and} \quad \Delta y = \Delta tfp + \sum_j a_j.\Delta k_j + a_l \Delta l \qquad (1)$$

where Δ indicates a first order difference, y, k_j and l are the logarithm of the volume of respectively output, j-type capital and labour; α_i is the elasticity of output to input i, under the unit returns constraint $(\sum_j a_j + a_l = 1)$, and tfp is the logarithm of total factor productivity (TFP) computed from the balance. Formula (1) is used for constructing Table 1.

Formula (1) can also be written as follows:

$$(y - l) = tfp + \sum_j a_j.(k_j - l) \quad \text{and} \quad \Delta(y - l) = \Delta tfp + \sum_j a_j.\Delta(k_j - l) \qquad (2)$$

where $(y - l)$ is the logarithm of labour productivity and $\Delta(y - l)$ the rate of growth in labour productivity. With this formula, trends in labour productivity can be separated out as proposed under Table 2. The rate of growth of labour productivity indeed breaks down into two effects – those connected with TFP acceleration and those connected with capital deepening (second term on the right in formula 2).

For this breakdown and for the computation of TFP from the balance, six factors of production are differentiated – the volume of labour (here, the number of hours worked), computer hardware, software, communications equipment (these three products are the ICT), non-ICT equipment, and plant and buildings.

Determination of output elasticities (a_j) for each factor

For each factor, this elasticity is conventionally expressed as the share of that factor's payment in value added (in value terms):

- Concerning labour, it is the proportion of added value paid as wages. Labour (l) in this case is the number of hours worked, i.e., the product of the average total staff (N) by average working hours (DT). It is assumed that employees and working hours are perfectly substitutable and that output elasticity is the same for average number of employees and working hours.
- Concerning each of the K_j components of capital, capital earnings are the product of the volume of capital by the user cost for that capital. That capital's user cost is the product of the price of the corresponding investment by the sum of the real interest rate and of the scrapping rate. This yields: $\alpha_j = (c_j.\ Kj)/(p.Y)$, where c_j is the user cost of j-type capital, K_j is the volume of j-type capital, p is the price of value added and Y is the quantity of that value added. Computing the user cost of j-type capital is done in the usual fashion: $c_j = p_j.(\delta_j + i - (\Delta p_j/p_j))$, where p_j is the price of investment in product j, δ_j is the scrapping rate for product j and i is the long term nominal interest rate .
- The unit returns to scale constraint is accommodated, for the economy as a whole, by adjusting the interest rate i. The interest rate calculated in this way is applied to every sector individually, and the unit returns to scale constraint is, at this more detailed level, ensured by accordingly altering the share of wages and that of the income of each capital product in the value added using a single coefficient. Elasticities computed in this way come out as fairly stable over the last two decades.

Assessment of factor volumes (k_j and l)

Series concerning the volume and price of value added, average total staff, the volume and price of investment series in non-ICT equipment and plant and buildings are taken directly from the national accounts (base year 1995). The series relating to working hours are taken from national accounts up to 1998 and the data published by DARES in 1999 and 2000. For ICT products, the investment series in value are taken from national accounts since 1978 and, for the previous period when this data was not available, were retropolated as described by Mairesse, Cette and Kocoglu (2000-appendix 2). Concerning, ICT investment prices, the indices in national accounting base 1995 were used for communications equipment, and the American indices adjusted for exchange rate effects were used for computer hardware and software (see Mairesse, Cette and Kocoglu (2000-Appendix 2).

Capital series are calculated by adding up generations of investment modulo an annual scrapping rate of 30% for computer hardware and software, 20% for transportation equipment, 15% for communications equipment and for non-ICT and excluding transportation equipment, 5% for buildings and 2.5% for plant.

Breakdown by sector

The distinction between ICT-producing sectors and the others should be performed at level 100 of the French classification of activities (NAF). This data has only become available in recent years. Hence in this study, a distinction is made at level 40 of the NAF. In this way, for the purposes of the present study, the coverage of the ICT sector is broader than the producer activities for the three ICT products (computer hardware, software and communications equipment). More specifically, the activities of the ICT sector comprise FE3 in the NAF classification - Electrical and Electronic Equipment Industries - and NAF FF6– Electrical and Electronic Component Industries. This produces an average 30% overvaluation of the GVA of the "true" ICT industries over the last five years. The ICT services sector includes Postal and Telecommunications Services and Consulting and Advisory Services (NAF FN1 and FN2). IT consulting activity (software) is included in the business services and consulting item under code FN2. The GVA of IT consulting activities over the last five years accounts for an average 25% of the GVA from all the activities grouped under code FN2. Telecommunications services activities are combined, under NAF code FN1, with postal services. The data does not allow for an assessment of the relative share of ICT activities in this group.

- Industry covers the manufacturing industries (consumer goods, motor vehicles, intermediate goods and capital goods), and accounts for approximately 21 % of value added for the market sector on average over the 1995-2000 period. ICT and non-ICT industries within these activities account for approximately 3 % and 18 % of value added for the market sector respectively.
- Services are all market services (transportation, financial and real property activities, market services to businesses and individuals), and they account for approximately 60 % of value added for the market sector, of which 10 % are ICT and 50 % are non-ICT activities.
- Other market sectors cover the other market sector activities (agriculture, agricultural and food industries, energy and construction) and they account for approximately 19 % of value added for the market sector.

III. – Accounting breakdown of the growth of the French economy

Measures of the contribution of each factor of production to the observed growth of valued added were performed using the methodology described in the boxed text. These evaluations are performed first for the whole of the market sector of the economy, and then on a sector level.

III.1 – Measures performed for the whole of the market sector of the economy

The results of the breakdown for the whole market sector between growth in value added and growth in labour productivity as observed in France over the 1980-2000 period, are summarised in Tables 1 below. Some of these findings have already been commented in Mairesse, Cette and Kocoglu (2000) and, as such, are only briefly reviewed. In a nutshell, the conclusions that can be derived from these two tables are as follows:

- Although the contribution of ICT to output and per capita productivity growth arising directly from capital deepening has accelerated in recent years, it nonetheless remains limited (0.3 % to 0.35 % per annum since 1995). However, in recent years, this contribution appears to have risen sharply compared to that of other equipment. Thus, whereas ICT contribution to growth was less than half of that of other equipment in the 80s and through the first half of the 90s, they have become practically equivalent (0.35 % compared to 0.40 %) in the latter half of the 90s.
- That ICT contribution has accelerated rapidly in the last few years. It nearly doubled as between the first and the second half of the 90s. At the same time, the contribution of other equipment and of buildings has considerably slowed. This indicates two effects – on the one hand, capital deepening, with the relative price of ICT products continuing to drop sharply compared to other equipment, but also no doubt, the effect of excess accumulation of ICT capital, partly fostered perhaps by the fears associated with the Y2K bug (see introduction).
- The contribution of total factor productivity in output and labour productivity growth follows a pattern that is consistent with the business cycle, indicating that an effect relating to the rate of utilisation of the factors is at work, as will be shown below. It has accelerated sharply since 1995 to a practically equal extent for the ICT and the non-ICT sectors. For the whole period, fluctuations in the contribution of TFP are particularly large in the non-ICT sectors, and more moderate in the ICT sectors.

As stated above, a high degree of uncertainty is attached to the quantity measurement of ICT capital expenditure by businesses. The impact of these two types of uncertainty on measures can be illustrated by means of variants. These variants have already been extensively described in Mairesse, Cette and Kocoglu (2000) and as such are briefly recalled here. The results in terms of the corresponding measures are provided in Table 2.

One uncertainty relates to the price/quantity split of capital expenditure by businesses expressed in value terms (see above). The effects of this uncertainty can be bounded by two extreme variants:

Table 1-A **Contributions to the average annual growth of gross value added**

Percent. Coverage: Market sector of the French economy

	1980-2000	1980-1990	1990-2000	1990-1995	1995-2000
Value added by volume	1.88	2.42	1.35	0.50	2.20
Total ICT, including	0.25	0.24	0.27	0.17	0.36
Computer hardware	0.11	0.11	0.11	0.08	0.15
Software	0.08	0.07	0.08	0.05	0.12
Communications equipment	0.06	0.05	0.07	0.05	0.09
Other equipment	0.56	0.63	0.49	0.57	0.40
Plant and buildings	0.36	0.43	0.29	0.44	0.14
Labour, including	-0.47	-0.60	-0.34	-0.83	0.15
Labour force	-0.11	-0.20	-0.02	-0.69	0.67
Working hours	-0.36	-0.40	-0.32	-0.14	-0.50
Total factor productivity	1.19	1.74	0.64	0.15	1.13

Source: authors' evaluation

Table 1-B **Contributions to average annual growth of per capita producti vity**

Percent. Coverage: Market sector of the French economy

	1980-2000	1980-1990	1990-2000	1990-1995	1995-2000
Value added by volume	1.88	2.42	1.35	0.50	2.20
Employment	-0.14	-0.26	-0.01	-1.13	1.11
Per capita productivity	2.02	2.69	1.36	1.63	1.09
Total ICT, i.e.,	0.25	0.24	0.26	0.20	0.33
Computer hardware	0.11	0.11	0.11	0.08	0.15
Software	0.08	0.07	0.08	0.05	0.11
Communications equipment	0.06	0.05	0.07	0.06	0.08
Other equipment	0.57	0.66	0.49	0.77	0.21
Plant and buildings	0.37	0.45	0.29	0.66	-0.08
Working hours	-0.36	-0.40	-0.32	-0.14	-0.54
TFP, including:	1.19	1.74	0.64	0.15	1.13
ICT sector	0.35	0.31	0.39	0.14	0.65
Non-ICT sectors	0.66	1.21	0.11	-0.17	0.39
Structural effects	0.18	0.22	0.14	0.18	0.09

Source: authors' assessments

Table 2 **Contributions to annual average growth of gross value added**
Variants for ICT price measurement and allocation of expenditure on ICT products between intermediate consumption and capital goods

Percent. Coverage: Market sector of the French economy

	Large price change variant		**Small price change variant**		**Variant on allocation between intermediate and final capital expenditure**	
	1980-2000	1995-2000	1980-2000	1995-2000	1980-2000	1995-2000
Value added by volume	1.88	2.20	1.88	2.20	1.88	2.20
Total ICT, including:	0.50	0.71	0.17	0.31	0.48	0.68
Computer hardware	0.11	0.15	0.04	0.06	0.23	0.31
Software	0.18	0.31	0.08	0.16	0.19	0.28
Communications equipment	0.20	0.25	0.06	0.09	0.06	0.09
Other capital goods	0.92	0.54	0.92	0.54	0.92	0.54
Labour	-0.47	0.15	-0.47	0.15	-0.47	0.15
Total factor productivity	0.93	0.80	1.26	1.20	0.95	0.83

Source: authors' assessments.

- In the first case (the so-called “large price change variant”), it is assumed the fluctuations in software and communications equipment prices are identical to those of computer hardware prices. This variant is thus based on the the bold assumption that the productive performance of software and communications equipment improves every year at the same pace as that of computer hardware. Hence, for the entire period from 1980 to 2000 (and for the second half of the 90s), the average annual variation in price is -14.2 % (-18.8 %) for all three ICT products. Instead of 1.2 % (2.8 %) for software and 1.0 % (-4.1 %) for communications equipment, as per the intermediate measure. This much sharper downward trend in software and communications equipment prices naturally generates more dynamic behaviour in capital volumes for these products. Compared to the intermediate measure, ICT contribution to growth is doubled; it goes up from an annual rate of 0.25 % to a rate of 0.50 % for the 1980-2000 period, and from 0.36 % to 0.71 % for the second half of the 90s. Conversely, the contribution of TFP to growth is correspondingly decreased.
- In the second case, (the so-called “small price change variant”), it is assumed that price trends for computer hardware and software are identical to those for communications equipment, i.e., practically disregarding the performance improvement feature. On the basis of small price changes for software (1.2 % on average from 1980-2000) and for communications equipment (1.0 %), the only discernible impact of this variant is on the assessment of the computer hardware contribution. ICT contribution to growth is down to a sixth, compared with a quarter under the intermediate valuation. For the entire 1980-2000 period, it drops from an annual rate of 0.25 % under the interemediate valuation to 0.17 % under this variant, and from a rate of 0.36 % to 0.31 % for the second half of the 90s. Conversely, the TFP contribution increases correspondingly.

The second uncertainty examined relates to the allocation of ICT spending as between final and intermediate expenditure. Lequiller (2000), for instance, has shown that in 1995, the share of investment in IT resources is more than 50 % in the U.S. national accounts, as against 20% approximately in French national accounts. This large discrepancy is due mainly to differences in statistical methods. As such, its is worth assessing the contribution that ICT would make to French growth under the assumption that an identical share of investment in France and the U.S. goes to computer products and software resources. This need not be applied to communications equipment since the split between final and intermediate expenditure is very similar in both countries. With the adjusted investment series, capital stocks and growth measures for computer products and software are higher. Compared to the intermediate valuation, ICT’s contribution to growth is double. For the whole 1980-2000 period, it increases from an annual rate of 0.25 % in the intermediate assessment to 0.48 % under this variant, and from a rate of 0.36 % to 0.68 % for the second half of the 90s. The contribution of TFP to growth declines correspondingly.

These variants show how significant uncertainties involved in assessing the contribution of ICT to growth are. It should be noted that the uncertainties connected both with measuring prices and allocating the split of ICT resources as between final and intermediate uses tend to push estimations of the contribution of ICT to growth downwards. The middle assessment no doubt significantly undervalues the contribution made by business investment to the growth of the French economy.

As mentioned above, the contribution of total factor productivity to the growth of valued added follows a pattern that is consistent with the business cycle. This is by no means surprising considering how it is measured: it is the balance in the growth identity that embodies the effects of cyclical fluctuations in the utilisation rate of factors of production that are not specifically itemised under the accounting breakdown. Although working hours are explicitly considered, two other indicators of rates of utilisation are not – the rate of utilisation of the productive capacities of existing factors and the equipments’ useful life. To distinguish between the cyclical component from a more structural one in the contribution of TFP to growth, the elasticity of this contribution to various measures of utilisation rate fluctuations for the factors of production needs to be evaluated. There have been many econometric estimates of this elasticity published, both on a sectoral level and for the whole market sector of the economy, that explain the contribution of TFP to the growth in value added in terms of variations in the rate of productive capacity utilisation and in useful equipment life, of growth in ICT capital or the variation in the share of ICT in total capital, with a variety of time-lag structures for the different explanatory variables[16]. These estimates give rise to aberrant results or to non-significant coefficients at the branch level for all the explanatory variables apart from variations in the productive capacity utilisation rate. Consequently, only the estimates for the market sector as a whole that use variations in the productive capacity utilisation rate as the explanatory variable are considered here.

The results for these estimates are provided in Table 3. By these estimates, the apparent elasticity of the contribution of TFP to the growth in the rate of productive capacity utilisation is indeed significant and amounts to approximately one-third.

Table 3: **Elasticity of the contribution of TFP to growth to the rate of productive capacity utilisation**

Results derived from estimates - Coverage: Market sector of the French economy
Dependent variable: contribution of TFP to growth in value added
Period of estimate: 1981-2000; annual data

Explanatory Variables			Characteristics of estimates		
ΔLog (TU)	AR1	Constant	R^2	DW	SEE
0.314 (3.61)		1.012 (506.47)	0.406	1.25	0.0091
0.327 (3.95)	0.362 (1.60)	1.011 (323.93)	0.498	2.08	0.0088

TU : production capacity rate of utilisation ; AR1 : Dependent variable lagged by one period.
The numbers in brackets are the estimated coefficients corresponding to the Student T value.

On the basis of this result, the cyclical component of the contribution of TFP to growth (as derived in the previous Table 1-A) can be distinguished from the structural component as shown in Table 4. The cyclical component of the average contribution of TFP comes out as positive and fairly strong (0.17 % per annum) in the 80s, mainly due to the buoyant conditions of the latter part of the decade, whereas it was negative but very small (-0,06 %) during the 90s, where good performance at the end of the decade did not offset the highly adverse conditions that prevailed in the first half. Taking the two halves of the 90s separately, the cyclical component of the average contribution of TFP was negative and fairly strong (-0,28 %) in the first half, and positive and of smaller magnitude (0.15 %) in the second half. The structural combination of the contribution of TFP to growth is highly fluctuating but the amplitude of these fluctuations is nonetheless smaller than that of fluctuations in the overall contribution of TFP, which goes to show why it is important to break down these contributions.

Table 4 : **Contributions of TFP to the average annual growth of gross value added**

%. Coverage: Market sector of the French economy

	1981-1990	1991-2000	1991-1995	1996-2000
Total factor productivity, including	1.72	0.64	0.14	1.15
Cyclical component	0.17	-0.06	-0.28	0.15
Structural component	1.55	0.70	0.42	1.00

Source: Authors' valuations

16 Available indicators relating to the utilisation rate of production capacity and useful equipment life are derived from surveys among industrial enterprises. Because the scope is more restricted than for the market sector as a whole and because the amplitude of business cycle fluctuations in the industrial sector is greater than for the whole market sector, the estimated elasticity of TFP to the rate of utilisation is much less than one. The indicator for the rate of utilisation of productive capacities used here is taken from the Bank of France's monthly business survey, applied on a yearly basis. How we build the indicator for the useful life of equipment from a specific Bank of France annual survey is described in detail in Cette (1999).

III.2 – Sector level assessments

The assessments just described for the entire market sector of the economy were also performed at sector level, with a distinction being made between the industrial and services sectors, as well as within those two subdivisions, between activities relating to ICT production and those not related to ICT production, and finally, also for other market sectors (mainly farming). A summary of the results for these sector level assessments is presented in Table 5 (a more detailed presentation is available in Cette, Mairesse and Kocoglu (2001b)).

Main conclusions that can be derived therefrom:

- In all areas of activity, the contribution of ICT capital accumulation to growth in value added declined in the first half of the 90s compared to the previous decade, and then accelerated rapidly in the second half of the 90s. With the exception of the ‘other market sectors’, this contribution was higher in the second half of the 90s than for the full 80s decade.
- In all areas of activity once again, the contribution of the accumulation of capital in non-ICT goods and services instead decreased over that period, beginning in the first half of the 90s in industry and the other market sectors, while not until more or less the second half of the 90s in the services sector. There is a very sharp decrease (more than ½ point of annual contribution) in the ICT-producing sector.
- As a consequence of the above changes, just as already noted for the whole market sector of the economy, the contribution of ICT accumulation increased in all sectors compared to the contribution of non-ICT capital accumulation. In the ICT-producer manufacturing and services sectors, as well as in the other market sectors, this change was particularly significant and, moreover, the contribution of ICT capital is significantly larger than the contribution of non-ICT capital in the second half of the 90s.
- In all sectors, the contribution of labour slackened considerably in the first half of the 90s compared to the previous decade and then increased significantly again in the second half of the 90s. That contribution, which mainly reflects the variations in total staff employed through the first half of the 90s as well as the effect of decreased working hours in the more recent period, has remained negative throughout in the non-ICT industrial sector and the other market sectors, and positive throughout in the services sector. In the ICT industrial sector, it shifted from constantly negative figures to positive ones in the second half of the 90s.

Table 5 : **Breakdown of French growth – Synopsis of industry level results**
Contributions to average annual growth of gross value added – percent

	1980-2000	1980-1990	1990-2000	1990-1995	1995-2000
A - Coverage: Industry as a whole					
Value added in volume terms	2.21	2.20	2.21	1.15	3.29
Total ICT	0.12	0.11	0.13	0.05	0.21
Other fixed capital	0.71	0.92	0.50	0.65	0.35
Labour	-1.62	-1.78	-1.45	-1.97	-0.92
Total factor productivity	2.99	2.95	3.03	2.41	3.66
B - Coverage: ICT industry					
Value added in volume terms	6.63	5.55	7.72	6.02	9.44
Total ICT	0.14	0.17	0.11	0.03	0.20
Other fixed capital	0.93	1.68	0.18	0.33	0.03
Labour	-0.68	-0.70	-0.67	-1.56	0.23
Total factor productivity	6.24	4.39	8.09	7.22	8.98
C - Coverage: Non-ICT industries					
Value added in volume terms	1.55	1.68	1.43	0.46	2.42
Total ICT	0.12	0.11	0.13	0.05	0.21
Other fixed capital	0.68	0.81	0.55	0.70	0.39
Labour	-1.72	-1.91	-1.54	-2.02	-1.06
Total factor productivity	2.48	2.66	2.29	1.72	2.87
D - Coverage: All services					
Value added in volume terms	2.53	3.46	1.60	0.47	2.75
Total ICT	0.35	0.34	0.36	0.26	0.47
Other fixed capital	1.11	1.13	1.09	1.37	0.81
Labour	0.57	0.63	0.51	0.11	0.91
Total factor productivity	0.50	1.36	-0.36	-1.27	0.57
E - Coverage: ICT services					
Value added in volume terms	4.39	4.79	4.00	1.49	6.57
Total ICT	0.43	0.41	0.45	0.32	0.59
Other fixed capital	0.73	0.83	0.63	1.07	0.28
Labour	1.36	1.52	1.20	0.69	1.71
Total factor productivity	1.88	2.03	1.73	-0.48	3.99
F - Coverage: Non-ICT services					
Value added in volume terms	2.18	3.25	1.13	0.29	1.98
Total ICT	0.34	0.32	0.35	0.25	0.45
Other fixed capital	1.18	1.18	1.18	1.45	0.91
Labour	0.45	0.51	0.40	0.02	0.78
Total factor productivity	0.21	1.24	-0.80	-1.43	-0.16
G - Coverage: Other market sectors					
Value added in volume terms	-0.22	-0.01	-0.43	0.01	-0.87
Total ICT	0.08	0.10	0.06	0.04	0.08
Other fixed capital	0.55	0.97	0.13	0.35	-0.09
Labour	-1.72	-1.88	-1.55	-2.06	-1.02
Total factor productivity	0.86	0.80	0.92	1.69	0.16

Source: authors' assessments

The detail for these sector level assessments is provided in Cette, Mairesse and Kocoglu (2001b).

- With the exception of the ICT-producing industry and the other market sectors, the contribution of TFP declined considerably in the first half of the 90s and then increased in the second half. Its increase was particularly sharp in the ICT-producing services sector. For the ICT-producing industry, the contribution of TFP was very high and increased continuously. In the other market sectors, that the TFP contribution varied in the opposite direction to that of all sectors taken together, increasing in the first half of the 90s and declining in the second half.
- Finally, it appears that the contribution of ICT capital accumulation is always far greater in the services sector than in industry and in the other market sectors. This discrepancy is no doubt partially attributable to the fact that ICT expenditure is only considered to be investment in ICT when the products involved are physically distinguishable. Hence, ICT components that are embodied in productive equipment such as machine-tools or robots are not accounted for as ICT investments as such, but rather as intermediate expenditure by the companies that produce those capital goods. No doubt, this explains why the national accounts measure of investment in ICT appears to be far more concentrated in the services sector where clear quantity components are more readily distinguishable (e.g., large mainframes or PCs) than in industry. Thus, the relative share of ICT in total investment (excluding plant and buildings) is much higher in the services sector ((roughly 30 % in 1999) than industry (6 %). This aspect that has been emphasised in many studies abroad (e.g., Stiroh (1998) and Diewert & Fox (1999)) and is more extensively described in Mairesse, Cette and Kocoglu (2000, p. 129-130)[17]. However, this uncertainty affects only the breakdown of capital expenditure by type of product, not its overall measurement in value terms.

IV. Tentative international comparison

For the time being, there a few comparable empirical analyses for other industrialised countries available. Many relate to the U.S. economy, including the work done by Jorgenson (2001), Jorgenson and Stiroh (2000)), Oliner and Sichel (2000) and the CEA (2001). Oulton (2001) has conducted a comparable assessment for the United Kingdom. For France, in addition to this work and our previous research ((see Cette, Mairesse and Kocoglu (2000), Mairesse, Cette and Kocoglu (2000)), Crépon and Heckel (2000)[18] have also published an analysis. Furthermore, Schreyer (2000) and Colecchia and Schreyer (2001) propose some tentative international comparisons.

An overview of the assessments relating to the U.S. economy is provided in Table 6. The major conclusions that can be drawn from a comparison between these and our own valuations concerning France are as follows[19]:

17 That study shows that if intermediate consumption of computer equipment and software in industry is accounted for as investment, the investment figure for these two products would be multiplied by a factor of 6!

18 A comparison between the results of our assessments and those of Crépon and Heckel (2000) is made in Mairesse, Cette and Kocoglu (2000).

19 This comparison would be invalidated if there were any methodological discrepancy between the price/quantity split for ICT investment. The Cette-Mairesse-Kocoglu assessments use U.S. price indices (adjusted for the exchange rate effect) for computer hardware and software, while for communications equipment the French indices are not significantly different from U.S. indices.

Table 6 **Contributions to the average annual growth of hourly productivity**
Percent. Coverage: Market sector of the U.S. economy

A – Source of valuations: Jorgenson (2001) (starting from Table 8 pg. 25).

	1948-1999	1948-1973	1973-1990	1990-1995	1995-1999
Hourly productivity	2.09	2.82	1.26	1.19	2.11
Total ICT	0.30	0.15	0.35	0.43	0.89
Non-ICT capital	0.83	1.30	0.44	0.21	0.35
« Quality » of labour	0.34	0.46	0.22	0.32	0.12
TFP, including	0.61	0.92	0.25	0.24	0.75
ICT sectors	0.16	0.06	0.19	0.25	0.50
non-ICT sectors	0.45	0.86	0.06	-0.01	0.22

N.B.: in Jorgenson's (2001) and Jorgenson and Stiroh's (2000) assessments, output measurements incorporates depreciation of consumer durables purchased by households.

B – Valuations by Oliner & Sichel (2000) (starting from Table 2 pg. 13).

	1974-1990	1991-1995	1996-1999
Hourly productivity	1.37	1.53	2.57
Total ICT	0.44	0.51	0.96
Non-ICT capital	0.37	0.11	0.14
« Quality » of labour	0.22	0.44	0.31
TFP	0.33	0.48	1.16

C - CEA (2001) valuations (starting from Table 1.1, pg. 28).

	1973-1995	1995-2000
Hourly productivity	1.39	3.01
Cyclical component	0.00	0.04
Structural component	1.39	2.97
Total ICT	0.41	1.03
Non-ICT capital	0.30	0.06
« Quality » of labour	0.27	0.27
TFP, including	0.40	1.59
IT sector	0.18	0.36
Other sectors	0,22	1,22

A more detailed description of these assessments is provided in Cette, Mairesse & Kocoglu (2001b).

– Starting from the first oil shock to the beginning of the 90s, the contribution of ICT-related capital deepening to growth in labour productivity appears to be twice more in the United States than it is in France (roughly 0.4 %-0.5 % per annum as compared with 0.25%). Over the first half of the 90s, it accelerated by roughly ¼ in the United States, whereas it remained more or less stable in France. Over the second half of the 90s, it appears to have doubled in the United States (reaching approximately 1 %) as well as in France (reaching approximately 0.35 %). All in all, for the second half of the 90s, this contribution to labour productivity growth due to the ICT-related capital deepening effect was three times stronger in the U.S. than in France. These differences can be explained by slower dissemination of ICT, and slower acceleration thereof, in France (compared to the United States), partly due perhaps to the fact that price drops for ICT were dampened in France by the appreciation of the dollar. Part of this discrepancy may also derive from the differences mentioned above relating to national accounting conventions and do not necessarily reflect true economic differences.
– In both countries in the second half of the 90s, the data suggests that the contribution of the ICT capital deepening effect became even greater than that of the other components of fixed productive capital.
– In both countries, the contribution of TFP appears to have accelerated in the second half of the 90s – more so in France than in the U.S. The recent acceleration of TFP would seem to be more or less equal in the ICT sector and the non-ICT sectors. That does not prevent part of that acceleration from being associated with the dissemination of ICT: "properly" capturing ICT effects on

productive performance (quality effects) by means price indices yields TFP gains that are more localised in the ICT sectors (due to a more quantity-oriented price/quantity split of output),while when less consideration is given to these effects, the TFP gains tend to be more apparent in the user sectors (and with less capital deepening effects in these sectors).[20].

Furthermore, from these assessments, it appears that (see Table 7-A) the acceleration of TFP growth in the U.S. economy taken as a whole is very recent – according to these findings, it began in the United States in the middle of the 90s. As a result, some economists, e.g., Gordon (2000-a and -b), consider there is a major cyclical component to this acceleration that is connected with the acceleration in overall economic growth in the U.S. in the 90s. Using Oliner and Sichel's (2000) findings, Gordon (2000-b) estimates that, comparing the recent short period (1995 :4-1999 :4) to the 1972 :2-1995-4 period, hourly productivity on an annual basis has grown by approximately 1.33 %, 0.33 % of which derives from capital deepening effects, 0.50 % from the cyclical effect, 0.31 % from the increase in TFP gains, 0.14 % from the effects of changes in price measurement methods and 0.05 % from improved labour quality (gender distribution and qualifications)[21]. This analysis of the incidence of the cyclical component is not endorsed by most other analyses such as Jorgenson & Stiroh (2000), Jorgenson (2001), Oliner and Sichel (2000) and CEA (2001). Jorgenson (2001) estimates that ICT dissemination has never ceased to contribute to the acceleration of labour productivity over the last four decades, through a continuous increase in ICT-capital deepening effects and TFP gains in ICT-producing sectors. However, he believes the continuous deceleration in non-ICT capital deepening effects and in the TFP of non-ICT producing sectors concealed this positive development until 1995. Since then, the deceleration has stopped, and the acceleration in the ICT-producing sectors comes out in assessments of the economy as a whole.[22].

We use the valuations made in the present study for France to present a breakdown of the variations in labour productivity over the 1995-2000 period compared to the previous period (see. Table 7-B). These variations vary considerably from those concerning the United States just described. First, a striking feature in the case of France that requires explanation is the roughly ½ point average decline in productivity in contrast to an acceleration. Secondly, the figures suggest that the rise in average growth entailed productivity gains of a cyclical nature to the tune of roughly 0.4 point on average per annum which means that the overall structural slowdown comes to approximate average of 1 point per annum. For that period, the *capital deepening* effects of ICT capital appear to have accelerated slightly but slowed very sharply for other types of capital. According to these findings, this decline, plus to a minor extent, the reduction in working hours, are at the root of the structural slowdown in labour productivity at a time when TFP gains had intensified, particularly in the ICT-producing sector..

20 This feature is emphasized in many studies including ours; e.g., Brynjolfsson and Hitt (2000), « … the allocation of productivity depends on the quality –ajusted transfer prices used. If a high deflator is applied, the upstream sectors get credited with more output and productivity in the national accounts, but the downstream firms get charged with using more inputs and thus have less productivity. Conversely, a low deflator allocates more of the gains to the downstream sector. In both cases, the increases in the total productivity of the economy are, by definition, identical. […] one must be careful in interpreting the allocation of productivity across producers and users ».

21 These figures are taken up by Gordon (2000-b, Table 2, pg. 55).

22 See Jorgenson (2001, Tables 6 and 7).-

Table 7 : **Explanations for labour productivity acceleration starting from 1995**
Coverage: Market sector of the economy; Percentage annual average growth rates

A – U.S. Economy

	Jorgenson et Stiroh (2000)	Oliner et Sichel (2000)	CEA (2001)	Gordon (2000-a , –b)
Labour productivity (acceleration), including:	0.9	1.2	1.5	1.4
. Cyclical component	Ns	ns	ns	0.7
. Structural component, including:	0.9	1.2	1.5	0.7
. Capital/labour substitution effect	0.3	0.3	0.5	0.3
. ICT capital	0.3	0.5	na	na
. Other	0.0	-0.2	na	na
. Quality of labour input	0.0	0.0	0.1	0.1
. TFP gains, localised in ICT-	0.7	0.8	0.9	0.3
. producing sectors	0.3	0.3	0.2	0.3
. using sectors	0.4	0.5	0.7	0.0

ns : non-significant; na: not available.
Source: Bosworth & Triplett (2001, p. 23).

B - French economy

Per capita labour productivity (decline), including:	-0.5
. Cyclical component of TFP	0.4
. Structural component, i.e.:	-0.9
. Capital/labour substitution effect	-1.2
. ICT capital	0.1
. Other	-1.3
. Working hours	-0.3
. TFP gains, localised in ICT -	0.6
. producing sectors	0.4
. using sectors	0.2

Source: Cette, Mairesse & Kocoglu (2001a)

Oulton (2001) proposes valuations for the United Kingdom that incorporate very considerable adjustments of national accounting data on investment in computer hardware so as to alleviate the effects of differences in accounting conventions. The data relating to software are adjusted so that investment matches the same share of resources as in the United States. The data relating to computer hardware are also adjusted so that the ratio between investments in these products and investments in software is the same as the ratio for the United States. As with our own assessments, U.S. price indices, adjusted for exchange rate effects, are used for ICT measures. Oulton's conclusions (2001) are that the contriubtion of ICT to the growth of labour productivity is overall nearly always a third less in the United Kingdom than in the United States, and half as much as our assessment for France. The same acceleration is observed for the second half of the 90s when the ICT contribution was significantly larger than that of other fixed capital. In view of the adjustments made by the author, the results found for the United Kingdom can be compared with the "intermediate vs. final capital expenditure split" variant for France presented in Table 2. The ICT contributions are comparable for the two countries. A trend that seems specific to the United Kingdom is the steep decline in the contribution of TFP during the second half of the 90s, in contrast with the United States and France as described above.

The findings of a recent international comparison by Colecchia and Schreyer (2001) are reviewed in Cette, Mairesse & Kocoglu (2001b)[23]. They concern only the contribution of ICT capital accumulation

[23] Here again, the comparison would be invalidated if a different methodological approach to the price/quantity split of ICT investment expenditure were used. Hence, the valuations use relative U.S. price indices for the various ICT items.

to growth. The results for France in this comparison are less detailed but fully consistent with those presented in this study. The conclusions to be drawn form the comparisons were previously provided in Mairesse, Cette & Kocoglu (2000) and, as such, are just briefly recollected here. They are principally:
:

- The results for France are highly comparable with those for Germany, Italy and Japan. The contribution of ICT to growth in this group of countries is roughly between 0.20% à 0.35% at the most per annum for the four periods considered from 1980 à 1999, and amounts to between a quarter and half of the contribution of other plant and buildings. There is a clear contrast between this group of countries and the United States where the contribution of ICT to growth is far greater. Australia and Finland, together with the United Kingdom and Canada (as far as can be judged on the basis of incomplete data) make up a second group which lies roughly in an intermediate position between Group 1 and the United States. The contribution of ICT to growth in these four countries is broadly speaking higher than for France and the other countries in Group 1 and tends to come closer to the contribution measured for the United States.
- These findings do however provide a striking indication that the very significant intensification of the contribution of ICT to growth that we observed for France in the last five years (1995-1999), alsoccurred in all countries where growth accelerated (i.e., all countries except Germany and Japan). But in this respect too, the United States appear to stand apart form the other countries inasmuch as the acceleration there was far greater.

V. – <u>Conclusion</u>

The contribution of ICT to growth in GDP and labour productivity in France is large, although apparently still much less than in the Untied States. An important issue is how long improved productive performance by ICT products continue in the future. The primary efficiency gain comes from microprocessors whose capacity has continually increased at a pace close to that of "Moore's law (capacity doubles every 18-24 months). Jorgenson (2001) speculates that in coming years the dissemination of the Pentium 4 (released at the end of 2000) will prolong (perhaps accelerate) gains in ICT productive performance, associated with an annual 40 % to 50 % (Moore's law) decline in the price of micro-processors. He believes that progression can be extrapolated at least over the entire present decade. But he cautions against extrapolating this trend to infinity[24]. In addition to this uncertainty, there is also an uncertainty relating to straightforward human capacity to make use of increasing capacity. Gordon (2000-b) recently studied this aspect[25].

Another important issue relates to the benefits, in terms of productivity and growth, of the dissemination of ICT for industrialised European countries (including of course France and the euro-zone countries). In a recent study, Gust & Marquez (2000) draw the conclusion that the beneficial effects of the NE and of ICT on labour productivity and TFP will eventually become apparent in all industrialised countries. What is less predictable is the amplitude and the time lags for these effects in the United States and the other countries. The uncertainty relating to amplitude is compounded in Europe by lack of knowledge about beneficial interaction via the so-called spillover effects between ICT producing and ICT-using sectors. If such interaction is significant, the benefits deriving from the

24 « Falling IT prices also serve as an indicator of rapid productivity growth in IT-producing industries. However, it would be premature to extrapolate the recent acceleration in productivity growth in these industries into the indefinite future, since this depends on the persistence of a two-year product cycle for semiconductors. » ; Jorgenson (2001, p3).

25 « The fixed supply of time to any individual creates a fundamental limitation on the ability of exponential growth in computer speed and memory to create commensurate increases in output and productivity. As Zvi Griliches once said, 'the cost of computing has dropped exponentially, but the cost of thinking is what it always was. » ; Gordon (2000-b, p. 62). Gordon also points out that Griliches is thought to have continued with: « That's why we see so many articles with so many regressions and so little thought ».

dissemination of ICT will be smaller in Europe than in the U.S. due to the smaller size of the ICT-producing sector. This issue is broadly discussed in other studies (e.g., Cohen and Debonneuil (2000)). In a recent study, Pilar & Lee (2001, p. 21-22) put forward several arguments whereby having a large ICT-producing sector does not necessarily suffice for the full benefits thereof to accrue to the user – it could be that software producers are more crucial than hardware producers in this respect. Furthermore, several countries (for instance, Australia) appear to derive major benefits from using ICT in spite of the fact that there is no large ICT-producing sector there. This would suggest that the contribution of ICT to growth in France and in the European countries may step up considerably in the coming years.

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