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Résumé

L'augmentation durable des gains de productivité induite par la diffusion des TIC est de nature à élever le rythme de la croissance potentielle, durablement via les effets de substitution capital-travail et les gains de productivité globale des facteurs (PGF) et plus transitoirement du fait de l'ajustement retardé des salaires sur les gains de productivité. Les ordres de grandeur auxquels aboutissent les éléments d'évaluation présentés montrent que l'effet de moyen-long terme pourrait être important. L'existence d'un effet transitoire de court-moyen terme semble empiriquement démentie.

Mots-clés : croissance, croissance potentielle, TIC, investissement, nouvelle économie.
Classification JEL : O3, O4.

Abstract

The sustained increase in productivity gains from the spread of ICTs may increase potential output growth in the medium to long term via capital deepening effects and total factor productivity (TFP) gains, and in the short to medium term via the lagged adjustment of wages to productivity gains. The orders of magnitude resulting from the assessment data presented indicate that the medium to long-term effect could be significant. However, there does not appear to be any empirical evidence to support the existence of the temporary short to medium-term effect.

Keywords: Growth, potential output growth, ICT, investment, new economy.
JEL classification: O3, O4.

Résumé non technique :

L'émergence et la diffusion des technologies de l'information et de la communication (TIC) amènent une augmentation durable des gains de productivité, entretenue par l'amélioration continue et rapide des performances de ces produits. Cette augmentation est de nature à élever le rythme de la croissance potentielle, durablement via les effets de substitution capital-travail (capital deepening) et les gains de productivité globale des facteurs (PGF), et plus transitoirement du fait de l'ajustement retardé des salaires sur les gains de productivité.

L'évaluation empirique des deux types d'effets de la diffusion des TIC sur l'offre potentielle (par rapport à une situation théorique extrême sans TIC) est inévitablement très fragile. Cependant, les ordres de grandeur auxquels aboutissent les éléments de chiffrages présentés montrent que l'effet de moyen-long terme pourrait être important : la croissance potentielle annuelle serait accélérée d'environ deux point aux Etats-Unis et de un point en France. L'existence d'un effet transitoire de court-moyen terme, souvent évoqué dans la littérature, semble empiriquement démentie.

Non-technical summary:

The development and diffusion of information and communication technologies (ICTs) result in a sustained increase in productivity gains that is fuelled by steady and rapid improvements in ICT performance. This rise in productivity gains may increase potential output growth in the medium to long term via capital deepening effects and total factor productivity (TFP) gains, and in the short to medium term via the lagged adjustment of wages to productivity gains.

Any empirical analysis of the dual impact that ICTs have on potential supply, as compared with an extreme and theoretical situation in which there are no ICTs, is inevitably tentative. The orders of magnitude resulting from the assessment data presented indicate that the medium to long-term effect could be significant, with annual potential output growth boosted by roughly two percentage points in the United States and one point in France. However, there does not appear to be any empirical evidence to support the existence of the temporary short to medium-term effect that is often referred to in the economic literature.

I - Introduction

The development and diffusion of information and communication technologies (ICTs) translate into a situation of continual technological change, fuelled by steady and rapid improvements in ICT performance. Price indices for computer hardware, which use hedonic or matched-model techniques to capture improvements in product performance, have declined on average by around 20 % every year for more than three decades. In the case of microprocessors, the decline is 40 %. Quality changes on this scale, which may extend to other types of ICTs such as software and communications equipment, could significantly raise the potential output growth rate. It is important to analyse the mechanisms and magnitude of such an increase, for two reasons : first, a higher potential output growth rate means a rise in prospective per capita income growth, in other words a higher average standard of living ; second, an increase of this type could have an impact on the policy mix, in particular on monetary policy[1]. This paper presents an analysis of the effects of ICT diffusion on potential output growth.

The contribution of ICTs to GDP growth and labour productivity has been extensively discussed[2]. Notwithstanding major statistical uncertainties, these analyses generally suggest that ICTs have made a significant contribution to GDP growth over the last few decades and that their contribution may have grown substantially in the recent period. Two channels have been identified in this regard : capital deepening effects and TFP gains. Cross-country comparisons reveal fairly sharp differences according to the degree of ICT diffusion, with three groups emerging : the United States, where the contribution of ICT is strongest ; Germany, France, Japan and other countries where the contribution is weakest ; and an intermediate group comprising, *inter alia*, Australia, Canada, Finland and the United Kingdom.

ICT diffusion appears to have a lasting impact on medium to long-term potential output growth, via capital deepening effects and TFP gains (II), and a more temporary effect on short to medium-term potential output growth through the lagged adjustment of wages to productivity gains (III).

II – ICT effects on medium to long-term potential output growth

We begin by describing the various types of effect (II.1), before discussing some uncertainties surrounding their magnitude and impact (II.2). We conclude the section with a simplified empirical illustration for the United States and France (II.3).

II.1 – Types of effect

- On potential output growth

We employ a highly simplified representation of the production function, using a Cobb-Douglas function with unit returns to scale, where technological change is Hicks-neutral (i.e. the effects of technological change correspond to TFP gains) and expressed as a trend :

(1) $Q = A.e^{\gamma.t}.K^{\alpha}.N^{1-\alpha}$ or, in growth-rate terms : $\overset{o}{Q} = \gamma + \alpha.\overset{o}{K} + (1-\alpha).\overset{o}{N}$

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[1] See Cette and Pfister (2002).

[2] To cite some recent examples : for the US economy, see Gordon (2000-a and –b, 2002, 2003), Oliner and Sichel (2000, 2002), Jorgenson and Stiroh (1999, 2000), Jorgenson (2001, 2003), Jorgenson, Ho and Stiroh (2002), CEA (2001) ; for the French economy, see Cette, Mairesse and Kocoglu (2000, 2002) ; for the UK economy, see Oulton (2002) ; for cross-country comparisons, see Schreyer (2000), Colecchia and Schreyer (2001), Pilat and Lee (2001) and OECD (2003).

In the long term, the capital coefficient remains constant in nominal terms at the potential level :

$$(2)\quad \overset{o}{P}_Q + \overset{o}{Q}{}^* = \overset{o}{P}_K + \overset{o}{K}{}^*, \text{ or } \overset{o}{K}{}^* = \overset{o}{Q}{}^* + (\overset{o}{P}_Q - \overset{o}{P}_K)$$

Notation

Q : Output volume
K : Volume of fixed productive capital
N : Volume of employment
POP : Labour supply
P_Q : Price of output
P_K : Price of investment in fixed productive capital
P_c : Price of household consumption
W : Per capita labour cost
U : Unemployment rate, with N = (1 – U).POP and N* = (1 – U*).POP*, U* denoting the NAIRU

α : Elasticity of output to capital
β_1, β_2 : Coefficients in equation (8) denoting labour cost formation
λ_1, λ_2, λ_3 : Coefficients in relation (7) denoting trends in labour productivity
γ : Autonomous technical progress, or TFP gains
t : Time variable
t_1 and t_2 : Beginning and end of ICT diffusion phase
L : Time lag operator
$\phi(L)$: Polynomial of the time lag operator in the labour cost relation (8), with $\phi(1) = 1$
"CT" as a subscript of a variable denotes its short-term value
"o" above a variable denotes its growth rate
"*" as an exponent of a variable denotes its potential level
"'" as an exponent of a variable denotes its level during the ICT diffusion phase
"Δ" before a variable denotes the differential between the two situations with and without ICT diffusion
Lower case letters denote logs
"-1" as a subscript denotes a variable that has been lagged by one period

In the theoretical long term, there can be no sustained divergence in the relative prices of different products, here investment and output. Historically, however, such divergences have frequently been observed on the potential growth horizon being explored, which is an empirical long term that may extend over several decades. Moreover, these divergences continue to be observed, reflecting structural differences in productivity gains across different economic sectors. In the case of the industrialised countries, a good illustration is provided by the decline in the relative price of agricultural products and of the share of agricultural output in total output, which occurred over a period spanning at least the second half of the 19th century and the first half of the 20th century, with time lags across countries. Over the long run, a similar trend can be seen in industrial prices compared with those in services. Kocoglu, Cette and Mairesse (2002) revisit this hypothesis using a comprehensive theoretical model that distinguishes two economic sectors : the ICT sector and the non-ICT sector. They demonstrate the impact of the hypothesis on the structure of the economy. The model proposed in this paper is a simplified version of that approach and is adequate to characterise the mechanisms at work.

Using the relations given above, the following expression is obtained for potential output growth :

$$(3)\quad \overset{o}{Q}{}^* = \frac{\gamma}{1-\alpha} + \frac{\alpha}{1-\alpha}.(\overset{o}{P}_Q - \overset{o}{P}_K) + \overset{o}{N}{}^*$$

If there is no divergence between output and investment price trends ($\overset{o}{P}_Q = \overset{o}{P}_K$), we obtain the usual expression for potential output growth : $\overset{o}{Q}* = \frac{\gamma}{1-\alpha} + \overset{o}{N}*$.

The emergence and diffusion of ICTs are likely to have two consequences : an increase in TFP gains and a decline in the growth rate of the relative price of investment. Additionally, it is assumed that ICT diffusion does not affect the medium to long-term level of potential employment (N*’ = N*), i.e. that it does not affect the medium to long-term NAIRU level (U*’ = U*) or the potential labour supply (POP*’ = POP*)[3]. This gives us :

$$(4)\quad \overset{o}{Q}*' = \frac{\gamma'}{1-\alpha} + \frac{\alpha}{1-\alpha}.(\overset{o}{P'}_Q - \overset{o}{P'}_K) + \overset{o}{N}* \text{ with : } \gamma' \geq \gamma \text{ and } \overset{o}{P'}_K \leq \overset{o}{P}_K \; ; \; \overset{o}{P'}_Q \leq \overset{o}{P}_Q$$

Gains in potential output growth resulting from ICT diffusion correspond to the difference between relations (4) and (3) :

$$(5)\quad \Delta\overset{o}{Q}* = \overset{o}{Q}'* - \overset{o}{Q}* = \frac{\gamma' - \gamma}{1-\alpha} + \frac{\alpha}{1-\alpha}.[(\overset{o}{P'}_Q - \overset{o}{P}_Q) - (\overset{o}{P'}_K - \overset{o}{P}_K)]$$

This change in the potential output growth rate is the sum of two components (here, we use Jorgenson and Stiroh’s analysis (1999)). The first $(\frac{\gamma' - \gamma}{1-\alpha})$ corresponds to the effect of changes in TFP gains ; the second $(\frac{\alpha}{1-\alpha}.[(\overset{o}{P'}_Q - \overset{o}{P}_Q) - (\overset{o}{P'}_K - \overset{o}{P}_K)])$ relates to the impact of capital deepening caused by the decline in the relative price of investment.

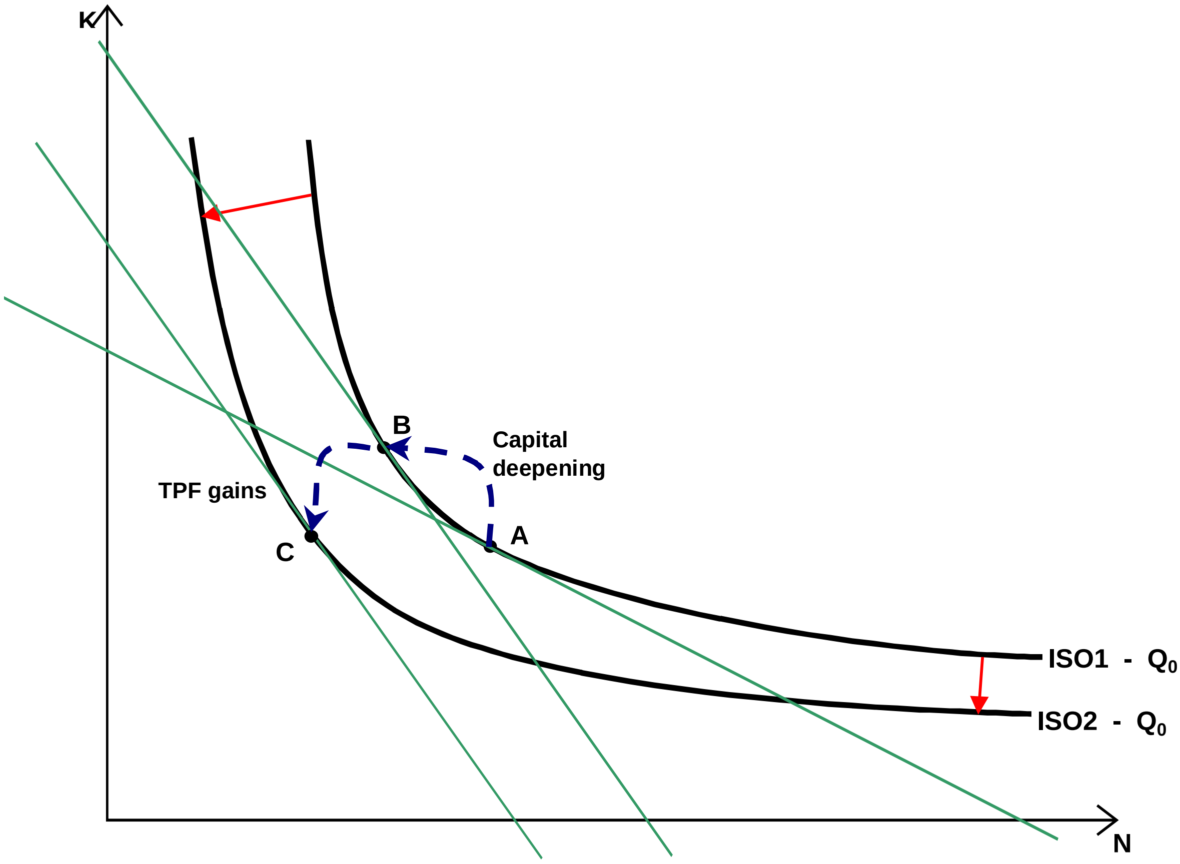
Chart 1 illustrates how these two effects of ICT diffusion impact potential output. We assume production of a quantity Q_0 of output. The starting point is A, where the factor costs line is tangent to the initial isoquant. The change in the relative price of capital resulting from ICT diffusion alters the slope of the costs line, moving the tangency with the first isoquant from A to B. This shift corresponds to the impact of capital deepening. TFP gains make it possible to produce the same quantity Q_0 of output with smaller input volumes, which is shown by the move to the second isoquant. The factor costs line is tangent to the new isoquant at C, which indicates the input combination minimising production costs following ICT deployment.

The accounting treatment used to break down the volume and price components in nominal investment and output series has a crucial bearing on the impact attributed to TFP and capital deepening in any accounting analysis of changes in potential output growth. Many studies make this point, including Gordon (2000-b)[4], Stiroh (2001) and Cette, Mairesse and Kocoglu (2000, 2002). For this reason, the economic significance of changes in the estimated TFP growth rate should be put into perspective.

[3] We will see later how ICT diffusion may temporarily affect the NAIRU level in the short to medium term.

[4] As Gordon (2000-b) states : “Indeed, the faster the assumed decline in prices for software and communication equipment, the slower is TPF growth in the aggregate economy...”

Chart 1 : **Use of ICTs : impact on the production system**



- <u>On potential factor productivity</u>

The diffusion and improved performances of ICTs raise labour productivity, but may lower capital productivity (via the capital deepening effect). They do not affect TFP when prices are perfectly measured using a "quality adjusted" approach[5]. We assume here that ICT productive quality is not necessarily captured in full in the price measurement.

Potential labour productivity is improved by capital deepening (the shift from A to B in Chart 1) and by the increase in TFP (the shift from B to C). Since we are assuming that potential employment is unaffected by ICT diffusion (N*' = N*), potential labour productivity is improved by the diffusion of ICT in exactly the same way as potential output. Thus, we have :

(6) $$\Delta(\overset{o}{Q/N})^* = \Delta\overset{o}{Q}^* = \frac{\gamma'-\gamma}{1-\alpha} + \frac{\alpha}{1-\alpha}.[(\overset{o}{P'}_Q - \overset{o}{P}_Q) - (\overset{o}{P'}_K - \overset{o}{P}_K)] \geq 0$$

Changes in potential capital productivity are more uncertain. Logically, this type of productivity is eroded by capital deepening (the shift from A to B in Chart 1) and improved by an increase in

[5] For example, in Jorgenson and Stiroh (2000): "… 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".

TFP (the shift from B to C). Based on relation (2), which holds with and without ICT diffusion, we obtain : $\Delta(\overset{o}{Q/K})^* = -(\overset{o}{P'_Q} - \overset{o}{P_Q}) + (\overset{o}{P'_K} - \overset{o}{P_K}) \geq \text{or} \leq 0$.

The first term to the right of the equal sign is positive (because $\overset{o}{P'_Q} \leq \overset{o}{P_Q}$) and the second is negative (because $\overset{o}{P'_K} \leq \overset{o}{P_K}$), which explains the general uncertainty. In the case of an economy producing few ICTs (where, as indicated above, $\overset{o}{P'_Q} \approx \overset{o}{P_Q}$) we thus have : $\Delta(\overset{o}{Q/K})^* \approx (\overset{o}{P'_K} - \overset{o}{P_K}) \leq 0$

II.2 – Major uncertainties persist

Much has recently been written about the uncertainties surrounding the magnitude and duration of TFP gains and capital deepening effects arising from ICT diffusion. Cette, Mairesse and Kocoglu (2002) describe some of these issues in detail and here we briefly recall only those with a direct bearing on the current analysis.

There is a twofold uncertainty about the duration of a major ICT impact on growth and productivity :

- First, there is uncertainty about how long gains in ICT performance will last. The main gains in efficiency come from microprocessors, where capacity has steadily increased at a pace close to that of Moore's law, which predicts that capacity will double every 18-24 months. Jorgenson (2001), Jorgenson, Ho and Stiroh (2002) or Collin (2002) warn against extrapolating this trend to infinity. This is further compounded by uncertainty about the human ability to capitalise on these growing capacities. Gordon, notably, emphasises this point (2000-b).
- There is also uncertainty about price elasticity of ICT demand. During the ICT diffusion phase, elasticity is greater than one : the decline in ICT prices driven by enhanced product performance is accompanied by faster growth in demand for ICTs. This raises the ICT input share and hence increases the ICT contribution to growth. ICT deployment leads progressively to saturation, which corresponds to a decline in the price elasticity of ICT demand. Eventually, when elasticity falls below one, the decline in the price of ICTs is accompanied by a decline in the ICT input share and hence (assuming a regular decline in prices) ICTs make a steadily decreasing contribution to growth. This analysis, which Oulton (2002), *inter alia*, proposes, almost certainly corresponds to a situation that is still far off from the present period.

Gordon (2000-b, 2002) points out another twofold uncertainty of a different nature. He posits that the effects on output growth and productivity of the emergence and diffusion of ICTs are not necessarily more significant than those of previous technological revolutions, such as the steam engine in the 19th century or electric power in the early 20th century. Further, comparisons are weakened by the fact that input and especially output measurements have become far more sophisticated in recent decades. They are now better at capturing (via price declines and corresponding volume increases) qualitative improvements left out of older statistics, like enhanced comfort in rail transport and in the home. However, in an analysis of the US economy over a long period, Crafts (2002) estimates that since 1974 and especially since 1995, the contribution of ICT diffusion to annual growth in output and productivity has considerably exceeded the contribution made by the steam engine over its most intensive phase of deployment (1830-1860), or by electric power between 1899-1929 and even 1919-1929. Fraumeni (2001) and Litan and Rivlin (2001) stress that many types of qualitative improvement in services like retail and healthcare resulting from ICT diffusion are not taken into account in the national account statistics. As a result, output volume growth would appear to be understated over the current period.

II.3 – An empirical illustration

How big an impact has ICT diffusion had on potential output growth in the United States and France ? A question of this type cannot be answered with real accuracy. However, we can bring some empirical light to bear, although we are forced to make numerous assumptions. Our analysis identifies the impact of capital deepening and the impact on TFP for the United States and France. Tables 1 to 3 contain the data used for this simplified calculation.

In the United States, ICTs' share of investment rose steadily every year until 2002, except in 2001 (Chart 2). For now, we lack the distance to know whether the levels reached at the close of the period (a share of around 30 % for ICT as a whole) represent a ceiling reflecting full ICT diffusion in the production system. We make the assumption – and this may understate our assessment of ICT-driven capital deepening effects – that the levels reached in 2002 for the ICT investment share do correspond to full ICT diffusion in the production system. There is an annual divergence in price growth of some 2.4 points between non-residential investment and value added over the 1995-2002 period, almost entirely explained by the divergence in ICT price trends (Chart 3). Assuming that this represents a structural divergence in price trends and that the differential was negligible before ICT diffusion, and with a corporate profit margin of about 1/3 (Cf. Baghli, Cette and Sylvain (2003)), we find, applying relation (5), that ICT-led capital deepening added some 1.2 percentage points per year to potential output growth.

In our assessment of the effects of ICT diffusion on the TFP growth rate, we rely on the findings of Jorgenson, Ho and Stiroh (2002) and Oliner and Sichel (2002) for the USA, and on Cette, Mairesse and Kocoglu (2002) for France (Table 2). Making assessments of this type is tricky. Notably, we do not know how big the TFP gains related to ICT diffusion are in sectors that do not produce ICTs. Let us consider two extreme cases. In the first, ICT-induced TFP gains are considered to be the difference in the contribution to TFP gains between producing sectors and non-producing sectors, i.e. 0.25 to 0.50 of a point per year. This assumes, however, that ICT-using sectors enjoy no ICT-related TFP gains. The second case assumes that all TFP gains are linked to ICTs, i.e. an impact of 0.75 to 1 percentage point per year. ICT diffusion appears to have a major overall effect on US potential output growth, of some 1.4 to 2.2 percentage points per year (Table 3).

In terms of the structure of investment, ICT diffusion in France appears to be between one-third to one-half the level observed in the United States, with ICTs accounting for a 13 % share of investment spending in France, compared with 30 % in the United States. Some of the difference can be certainly attributed to different conventions in the national accounts for booking business spending on ICT products under investment and intermediate consumption. For the sake of simplicity, we assume that the process of ICT diffusion is half as complete in France as in the United States. Thus the effect of capital deepening is assumed to be half as great in France as in the United States. We assess the TFP growth rate using the same method as for the United States and again find that the impact of ICT diffusion is half as strong as in the USA. Overall, because of this less-advanced diffusion process, ICTs may have added 0.8 to 1.3 points per year to potential output growth in France, i.e. half the US impact. If we assume that France will gradually benefit, with a lag, from the same impact on potential output growth from ICT diffusion as the United States, then the effects already felt could double.

Table 1 : **Price and structure of investment – 1995-2002**

As a %	**Change in price of investment relative to price of value added, United States**[2] (Annual average growth rate)	**Share in investment spending** (average)	
		United States	**France**
Investment, o/w	-2.4	100	100
.ICTs, o/w	-7.2	30	13
.Computer hardware	-21.7	9	4
.Software	-2.0	13	6
.Communications equipment	-3.0	8	3
.Total hardware, software, equip.	-3.6	75	75
.Structures	1.4	25	25
Profit margin (level)[1]		1/3	1/3

(1) Market economy ; (2) Aggregate economy.

Sources : Except profit margin, Cette and Noual (2003) from van Ark et alii (2002) and BEA for the USA ; INSEE for France. For profit margin : Baghli, Cette and Sylvain (2003).

Table 2 : **TFP gains in the United States and France, 1995-2000**
Contribution to GDP growth

As a %	**United States**		**France**
	Jorgenson, Ho and Stiroh (2002)[1]	Oliner and Sichel (2002)[1]	Cette, Mairesse and Kocoglu (2002)
TFP gains, o/w	0.80	0.99	1.15
.Cyclical component	-	-	0.43
.Structural component, o/w	0.80	0.99	0.72
.ICT-producing sectors[2]	0.51	0.76	0.45
.Other sectors	0.27	0.23	0.27

Market economy.

1 : 1996-2001.

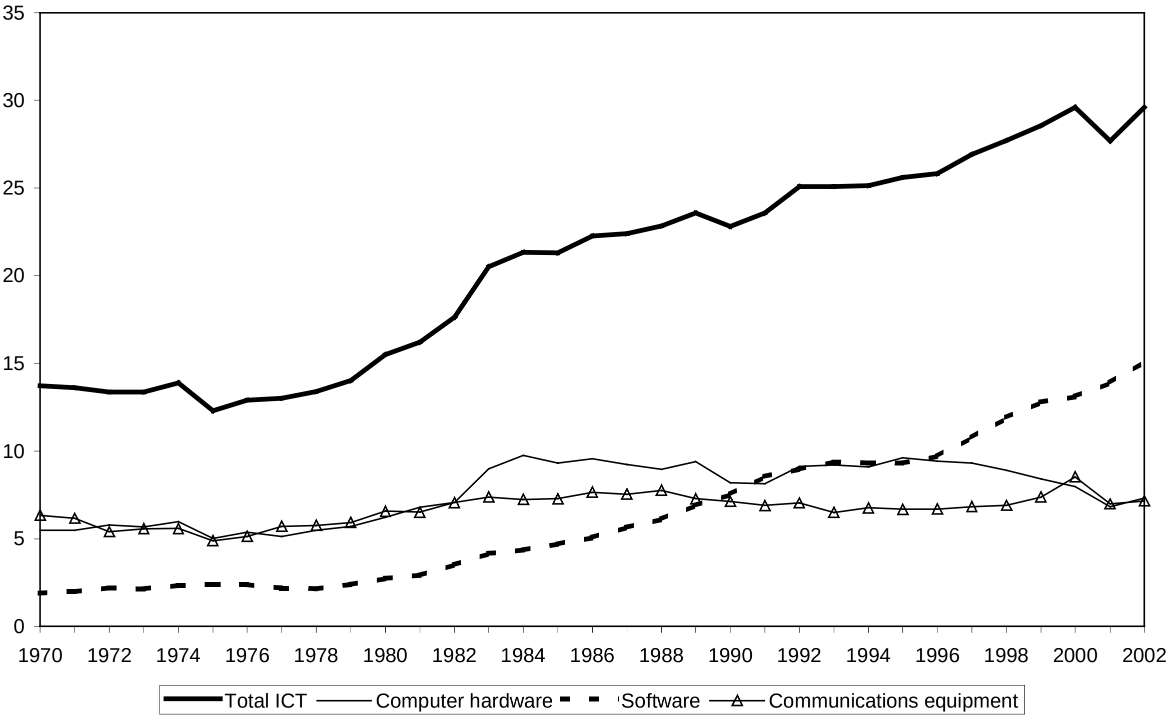
2 : Computer hardware, software and communications equipment for Jorgenson, Ho and Stiroh (2002) and Cette, Mairesse and Kocoglu (2002) ; same plus semi-conductors for Oliner and Sichel (2002).

Table 3 **:** **Impact of ICT diffusion on potential output growth**
(Difference in annual average growth rate, in points)

	United States	**France**
Capital deepening effect	1.2	0.6
Contribution of TFP resulting from ICTs	0.25 – 1	0.2 – 0.7
Total	1.45 – 2.2	0.8 – 1.3

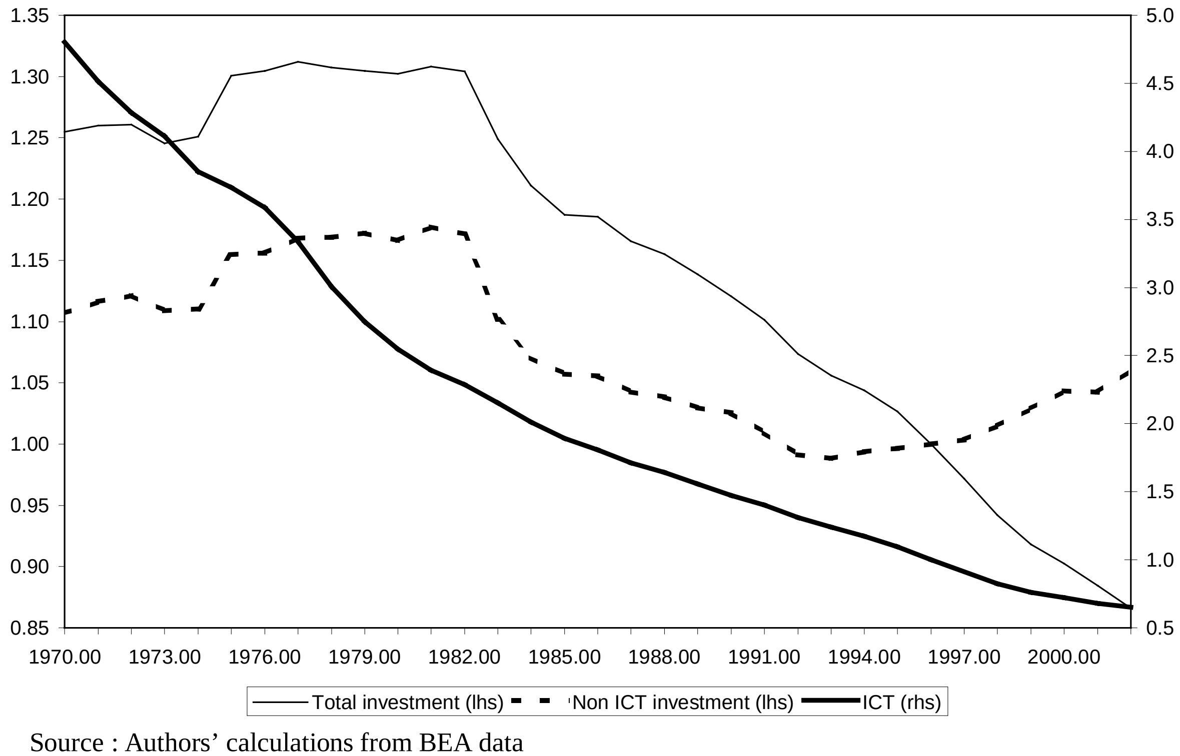
See text for details of calculations (relation (6)).

Chart 2
ICT % share of investment – United States – Aggregate economy



Ratio of ICT investment to non-residential investment spending
Source : Authors' calculations from basic data supplied by van Ark et alii (2002), extended with BEA data.

Chart 3
Index of the price of investment relative to the price of value added
United States – Aggregate private sector



Source : Authors' calculations from BEA data

ICT diffusion may appear to have a considerable impact on potential output growth. However, remember that these brief assessments compare an observed situation in which ICTs are present to an extreme theoretical situation in which they are not. Further, note that the capital deepening component is significantly reduced by the fact that measurements of software and communications equipment prices continue to take little account of quality. An extreme assumption would be to suppose that, in economic reality, software and communications equipment prices follow the same pattern as computer hardware prices because of improved performance and services. This is one of the scenarios that Jorgenson and Stiroh (2000) use to assess the effects of ICT diffusion on actual growth in the USA and that Cette, Mairesse and Kocoglu (2002) use for France. Under such an assumption, the effects of ICT-induced capital deepening on potential output growth would be doubled in both countries compared with the previous assessment, but TFP gains linked to ICT diffusion would diminish.

III. – <u>Short to medium-term effects</u>

We begin by describing the effects at work (III.1) before presenting a brief empirical assessment (III.2).

III.1 – Types of effect

The process of ICT diffusion is a gradual one. The associated increase in potential output growth and labour productivity induced by this process is thus similarly gradual. Once diffusion is complete, ongoing ICT renewal and improved ICT performance maintain potential growth at its new pace. During the diffusion phase, the lagged adjustment of wages to prices may reduce inflationary pressures. Table 4 and Chart 4 show that US labour productivity has accelerated in recent years, apart from a brief hiatus in 2001 when growth slowed. Oliner and Sichel (2002, p. 30) estimate that labour productivity in the United States will grow at an annual average over the next decade of between 1.98 % and 2.84 %. Jorgenson, Ho and Stiroh (2002, p. 10) put the increase at between 1.33 % and 2.92 %. In other words, they argue that the growth rates observed since the second half of the 1990s are set to continue.

A simplified formalisation of the temporary gains in potential output induced by the pick-up in productivity is proposed here. For simplicity's sake, it is assumed that labour productivity grows at a constant rate before and after ICT diffusion. We also assume that productivity accelerates at a constant rate during the diffusion phase. The ICT diffusion phase runs from date t_1 to date t_2. We represent labour productivity in a simplified form with the following relations (in logs) :

(7.1) $(q-n)=\lambda_1.t+\lambda_3$ before diffusion, when $t < t_1$

(7.2) $(q-n)=\lambda_1.t+\lambda_2.(t-t_2)+\lambda_3$ after the diffusion phase, when $t > t_2$

(7.3) $(q-n)=\lambda_1.t+\lambda_2.\frac{t-t_1}{t_2-t_1}.t+\lambda_3$ during the diffusion phase, when $t_1 \le t \le t_2$

Labour productivity thus grows at an annual rate of λ_1 before diffusion, $\lambda_1+\lambda_2$ after it, and $\lambda_1+\lambda_2.\frac{t-t_1}{t_2-t_1}$ during the diffusion phase itself.

As regards wages, and more specifically per capita labour costs, we follow Meyer (2000a) in assuming a detrended adjustment of wage growth to productivity growth :

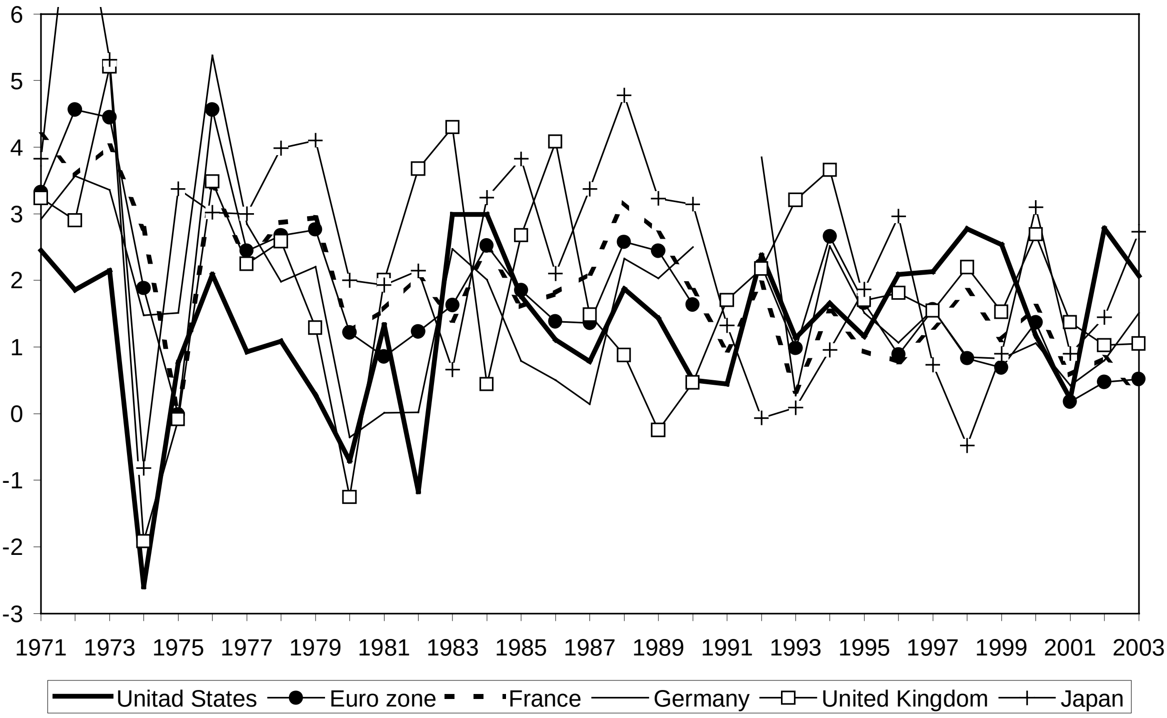
(8) $\overset{o}{W} = \beta_1 + \overset{o}{P}c_{-1} + \phi(L)(\overset{o}{Q/N}) - \beta_2.U_{t-1}$, where $\phi(1)=1$

Table 4 : **Annual average growth of productivity per employee**
Aggregate economy, as a %

	United States	Euro area	France	Germany	United Kingdom	Japan
1970-1973	2.15	4.11	3.93	3.28	3.78	5.82
1973-1982	0.22	1.96	2.13	1.68	1.34	2.53
1982-1990	1.68	1.93	2.15	1.60	1.76	3.05
1990-2003*	1.73	1.17	1.08	1.35	1.97	1.26
o/w						
1990-1995*	1.35	1.88	1.14	2.03	2.49	0.83
1995-2002	1.97	0.81	1.04	1.01	1.65	1.53

* : 1991-2003 and 1991-1995 for Germany.
Source : Authors' calculations from national accounts and OECD Economic Outlook, June 2003.

Chart 4 : **Annual average GDP growth per person in employment** (as a %)



Aggregate economy; Source : OECD, Economic Outlook, June 2003.
Persons in employment correspond to the sum of all salaried labour (including in the general government sector), non-salaried labour (except in the United Kingdom, where this information is not available) and unpaid family workers.

Before the diffusion phase, i.e. before t_1, or after it, i.e. after t_2, and once wage growth has adjusted to productivity growth, the "long-term" NAIRU can easily be derived from relation (8.2) : $U^* = \beta_1 / \beta_2$.

In the short run, during the diffusion phase, we have $\phi(L)(\overset{o}{Q/N}) \prec (\overset{o}{Q/N})$, owing to the lagged adjustment of wage growth to productivity growth. As a result, the NAIRU falls temporarily below its long-term level, as demonstrated by Meyer (2000a) :

$$(9)\quad U^*_{CT} = U^* - \frac{1}{\beta_2}.((1-\phi(L))\overset{o}{Q/N})$$

The fact that the NAIRU is temporarily lower than its long-term level paves the way for a temporary gain in potential output. We define potential employment N* by the relation :

N* = (1 – U*) . POP*, where POP* is the potential labour supply, whose level is assumed to be unaffected by ICT diffusion (POP* = POP).

On the basis of relation (1), written logarithmically, and relation (9), we thus obtain a temporary gain in potential output :

$$(10)\quad \Delta_{CT} q^* = (1-\alpha) \,.\, \Delta_{CT} n^* \approx (1-\alpha) \,.\, (U^* - U^*_{CT}) = \frac{(1-\alpha)}{\beta_2} \,.\, ((1-\phi(L))\, \overset{o}{Q}/N)$$

During the transitional period, first of productivity acceleration then of adjustment, where average wages are below their equilibrium level, the NAIRU falls and potential output is consequently increased compared with a situation where average wages adjust immediately to their equilibrium, level. This inflation-reducing mechanism has been described in many studies, including Meyer (2000a and b), Blinder (2000), Ball and Moffit (2001) and Ball and Mankiw (2002). The question of how US monetary policy might be affected by the impact of a temporary decline in the NAIRU has been discussed at length in the economic literature and is not revisited here[6].

III.2 – Some empirical evidence

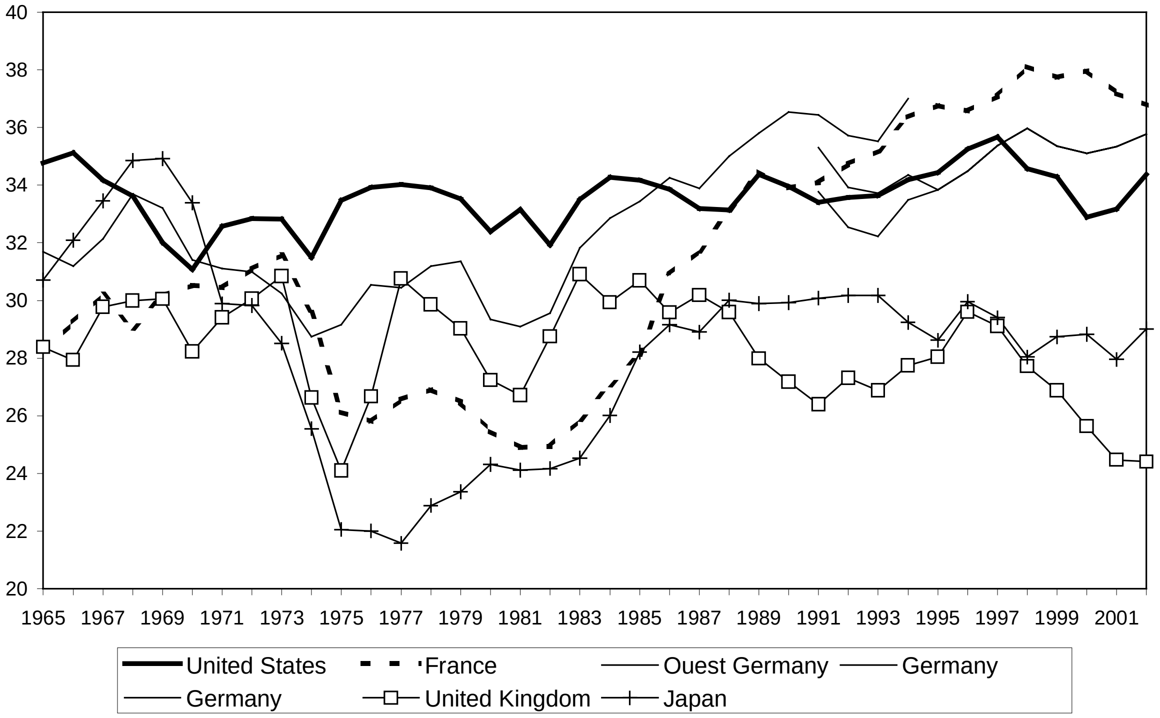
The size of this effect, for a given growth rate of labour productivity, depends on the pace with which average wages adjust to productivity. This adjustment is extremely hard to estimate. In the case of the United States, Ball and Moffit (2001, pp. 24 and 25) assume a very gradual adjustment and estimate that the NAIRU dropped temporarily by about one percentage point at the end of the 1990s following the acceleration in productivity.

Cette and Sylvain (2003), however, demonstrate that between 1995 and 2000, when productivity accelerated in the United States, especially after 1997, the average profit margin in the US private sector fell sharply (Cf. Chart 5). Growth in real per capita labour costs accelerated in the United States in the second half of the 1990s, overtaking labour productivity growth. It therefore does not appear that the faster rate of US labour productivity observed in the latter half of the 1990s led to lower inflation via a temporary decline in the NAIRU resulting from a lagged adjustment of wages to productivity. On the contrary, growth in per capita labour costs exceeded productivity growth over the period, causing the profit margin to fall. In other words, the decline in joblessness in the United States over the period was accompanied by an acceleration in labour costs, but this did not fuel inflation because corporate margins were being squeezed. It is nevertheless worth pointing out that previous analyses, which assumed that faster productivity growth was accompanied by a temporary fall in the NAIRU, were based on the statistics available at that time. On the basis of these data, it was impossible to detect a clear decline in the profit margin in the second half of the 1990s.

[6] Ball and Tchaidze (2002), for example, state that the Fed's 1995-2000 monetary policy was partly informed by just such a decline in the NAIRU resulting from the pick-up in US productivity between 1995 and 2000. For a summary, cf. Cette and Pfister (2002).

Chart 5

Gross operating profit as a percentage of value added, at factor cost and adjusted for non-salaried labour



Private sector – as a %

Source : Calculations by Cette and Sylvain (2003), updated using data from national accounts and OECD Economic Outlook, June 2003.

For Germany, we construct two series from 1990 onwards. In the first, the increase in the Treuhand Agency's debt is considered to be a subsidy to firms, in the second it is not. The two series are identical as of 1995.

IV – <u>Concluding remarks</u>

This analysis raises many questions. The following two would appear to be the most significant :

- Will potential output growth in France and the other European countries ultimately benefit from an ICT-induced impact as great as that recorded by the United States ? In other words, given that Europe is a smaller producer of ICTs, will the impact on potential output growth be weaker ? This question has already been widely debated, for example in Gust and Marquez (2000), Gordon (2003), and OECD (2003).
- How much longer will ICT diffusion continue to provide gains in potential output growth ? Opinions are divided on this highly technological issue. See Jorgenson (2001), Jorgenson, Ho and Stiroh (2002) and Collin (2002).

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