

ICT diffusion and potential output growth

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I - Introduction

- Spread of ICTs induces a continual technological change, by the rapid improvements in ICT performances
- Price indices for computer hardware 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 could significantly raise the potential output growth rate.

I – Introduction

- It is important to analyse the mechanisms and magnitude of such an increase, for two reasons :
 - 1. a higher potential output growth rate means a rise in prospective per capita income growth, in other words a higher average standard of living ;
 - 2. an increase of this type could have an impact on the policy mix, in particular on monetary policy

I – Introduction

We analyse successively :

- Part II : The impact of ICT diffusion on medium to long-term potential output growth, via capital deepening effects and TFP gains
- Part III : The effect on short to medium-term potential output growth through the lagged adjustment of wages to productivity gains

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

- We assume a Cobb-Douglas function

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

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

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

- Relation (2) is here THE important relation

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

- In traditional approach of potential growth (theoretical long term), it is usually supposed

$$PQ^0 = PK^0 \text{ and then } K^* = Q^*$$

- But in the empirical long-term, sustained divergence in the relative prices of different products have frequently been observed (decline in the relative price of agricultural products; decline of industrial prices compared with those in services...)

- These divergences reflect structural differences in productivity gains across different economic sectors.

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

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

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

If $\overset{\circ}{P}_Q = \overset{\circ}{P}_K$, we obtain the usual expression $\overset{\circ}{Q}^* = \frac{\gamma}{1 - \alpha} + \overset{\circ}{N}^*$

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

The emergence and diffusion of ICTs are likely to have two consequences :

- an increase in TFP gains
- a decline in the growth rate of the relative price of investment.

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

The potential growth with ICT can be written :

$$(4) \quad \overset{\circ}{Q}^{*'} = \frac{\gamma'}{1-\alpha} + \frac{\alpha}{1-\alpha} \cdot (\overset{\circ}{P}'_Q - \overset{\circ}{P}'_K) + \overset{\circ}{N}^*$$

with : $\gamma' \geq \gamma$ and $\overset{\circ}{P}'_K \leq \overset{\circ}{P}_K$; $\overset{\circ}{P}'_Q \leq \overset{\circ}{P}_Q$

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

Gains in potential output growth : difference between relations (4) and (3)

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

These gains are the sum of two components

- $\frac{\gamma' - \gamma}{1 - \alpha}$: effect of changes in TFP gains
- $\frac{\alpha}{1 - \alpha} \cdot [(\overset{\circ}{P}'_Q - \overset{\circ}{P}_Q) - (\overset{\circ}{P}'_K - \overset{\circ}{P}_K)]$: impact of capital deepening caused by the decline in the relative price of investment.

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

- This mechanism has been described in other way by Jorgenson – Stiroh (1999)
- As for evaluation of the effect of ICTs spread on effective growth, 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 (see Gordon (2000), Stiroh (2001), 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.

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

- Effect on potential factor productivity

We get :

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

The two components of this effect are positive

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

$$\Delta(Q/K)^* = -(\overset{\circ}{P}'_Q - \overset{\circ}{P}_Q) + (\overset{\circ}{P}'_K - \overset{\circ}{P}_K) \geq \text{or } \leq 0.$$

The first term is positive (because $\overset{\circ}{P}'_Q \leq \overset{\circ}{P}_Q$) and the second is negative (because $\overset{\circ}{P}'_K \leq \overset{\circ}{P}_K$), which explains the general uncertainty.

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

An empirical illustration

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).

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

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).

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

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 ICT	0.25 – 1	0.2 – 0.7
Total	1.45 – 2.2	0.8 – 1.3

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

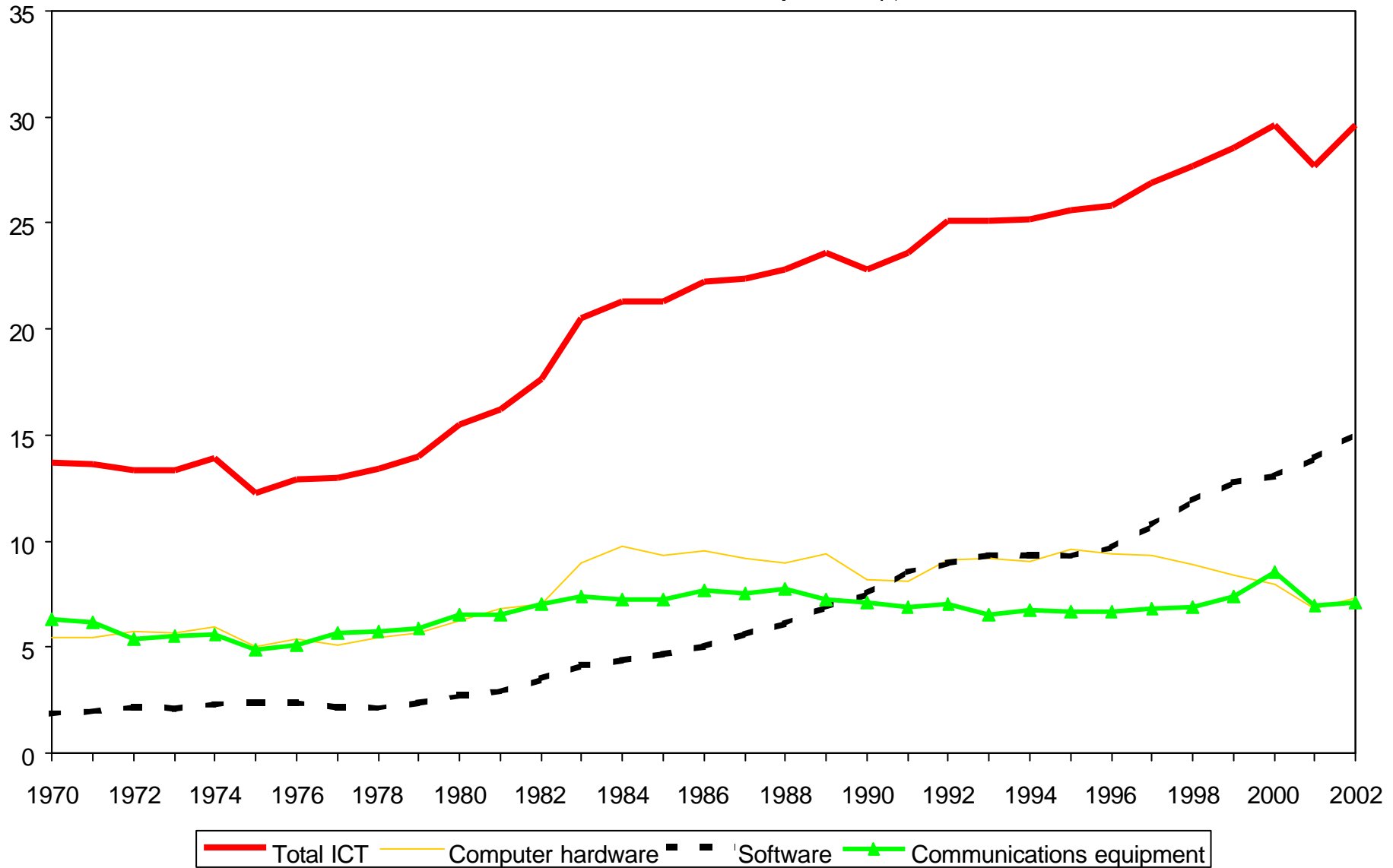
II – ICT effects on medium to long-term potential output growth

- ICT diffusion have a considerable impact on potential output growth;
- Remember that this evaluation compare two extreme situations :
 - . a situation in which ICTs are present with actual level of diffusion
 - . a theoretical situation in which they are not present at all.

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

ICT % share of investment – United States – Aggregate economy

Ratio of ICT investment to non-residential investment spending

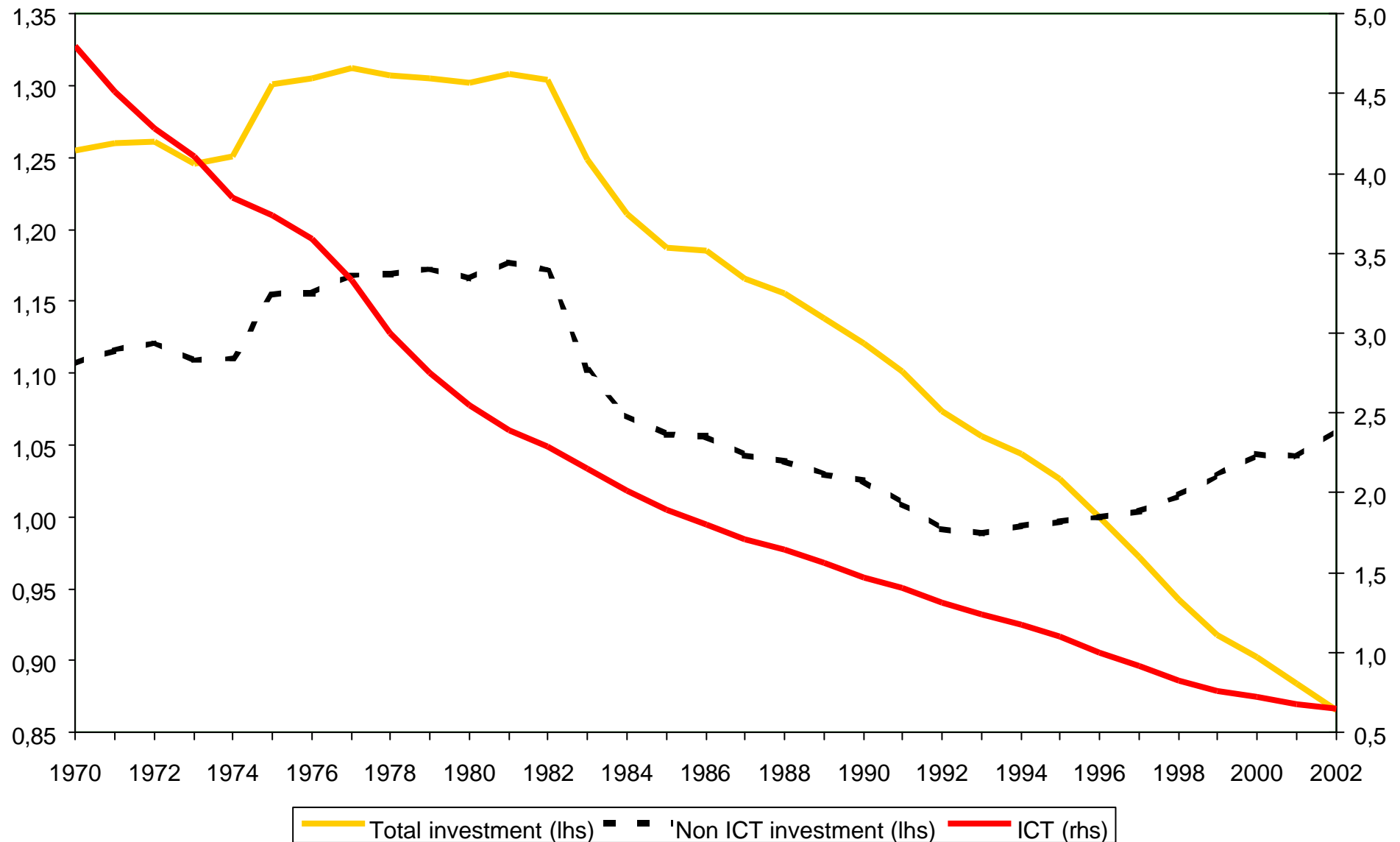


Source : Authors' calculations from basic data supplied by van Ark et alii (2002), extended with BEA data

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

Index of the price of investment relative to the price of value added

United States – Aggregate private sector



Source : Authors' calculations from BEA data

III. – Short to medium-term effects

The principal of these effects is also quite simple :

During a productivity acceleration process (here from ICTs diffusion), the lagged adjustment of wages to productivity may reduce inflationary pressures

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 (see for example Ball and Tchaidez (2002)).

III. – Short to medium-term effects

This model is partly inspired from Meyer (2000a)

Labour productivity (in logs) :

$$(7.1) \quad (q - n) = \lambda_1 \cdot t + \lambda_3 \quad \text{before diffusion, when } t < t_1$$

$$(7.2) \quad (q - n) = \lambda_1 \cdot t + \lambda_2 \cdot (t - t_2) + \lambda_3 \quad \text{after the diffusion phase,}$$

when $t > t_2$

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

when $t_1 \leq t \leq t_2$

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

III. – Short to medium-term effects

Wages :

$$(8) \quad \overset{\circ}{W} = \beta_1 + P\overset{\circ}{c}_{-1} - \phi(L)(\overset{\circ}{Q}/\overset{\circ}{N}) - \beta_2 \cdot U_{t-1}, \text{ where } \phi(1) = 1$$

The “long-term” NAIRU can easily be derived from relation (8) : $U^* = \beta_1 / \beta_2$.

In the short run, during the diffusion phase, we have $\phi(L)(\overset{\circ}{Q}/\overset{\circ}{N}) \prec (\overset{\circ}{Q}/\overset{\circ}{N})$, owing to the lagged adjustment of wage growth to productivity growth.

The short term NAIRU is :

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

III. – Short to medium-term effects

From relations (1) and (9), we obtain a temporary gain in potential output :

$$(10) \quad \Delta_{CTq}^* = (1 - \alpha) \cdot \Delta_{CTn}^* \approx (1 - \alpha) \cdot (U^* - U_{CT}^*) = \frac{(1 - \alpha)}{\beta_2} \cdot ((1 - \phi(L)) Q / N)$$

III. – Short to medium-term effects

Table 4 : Annual average growth of productivity per employee

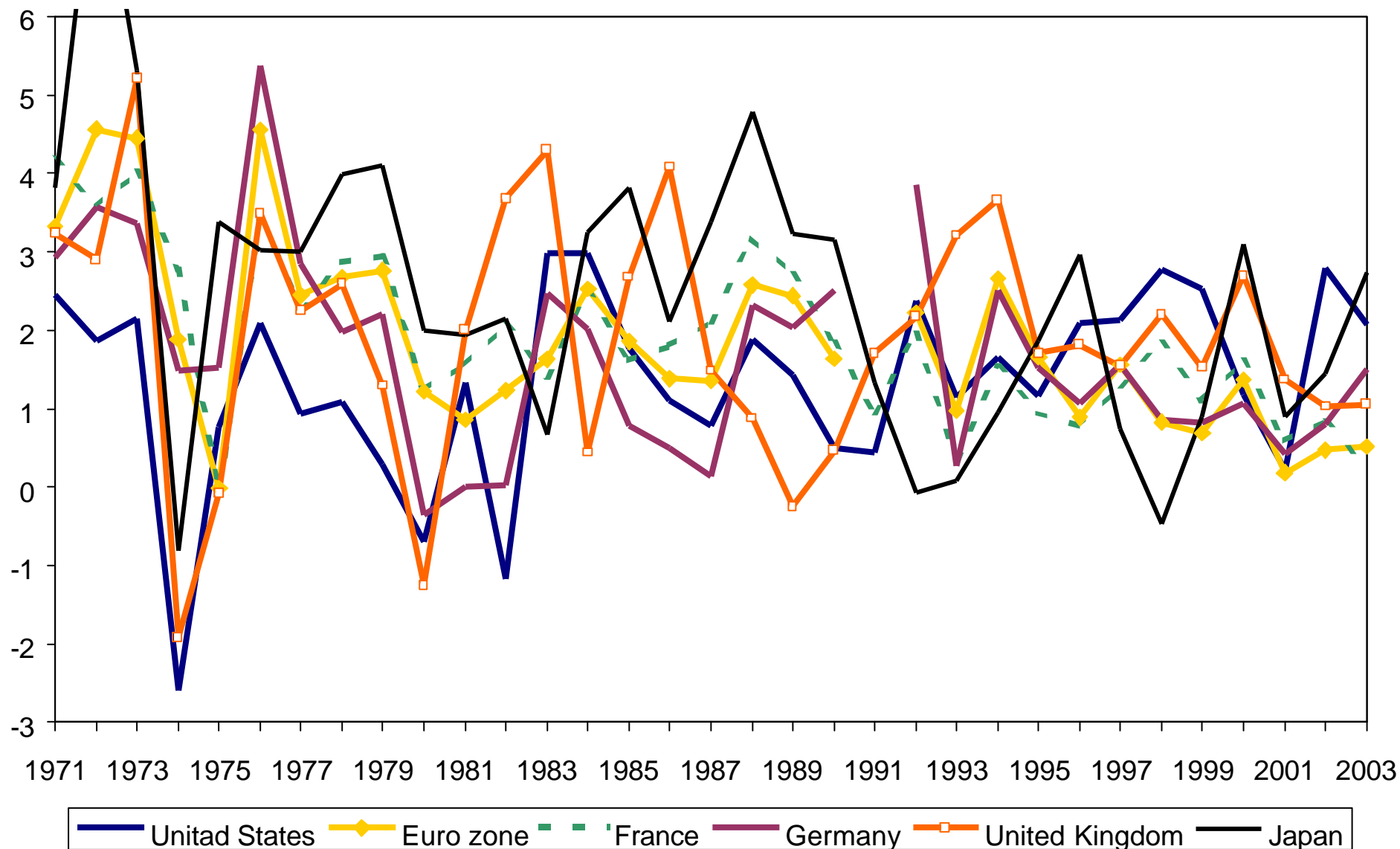
Aggregate economy, as a %

	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
1995-2003	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, December 2003.

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



Aggregate economy ; Source : OECD, economic Outlook, June 2003.

III. – Short to medium-term effects

The size of this effect on potential output is extremely hard to estimate.

In the case of the United States, Ball and Moffit (2001) estimate that the NAIRU dropped temporarily by about one percentage point at the end of the 1990s.

However, between 1995 and 2000, especially after 1997, it therefore does not appear that the faster rate of US labour productivity led to lower inflation via this sort of temporary decline in the NAIRU.

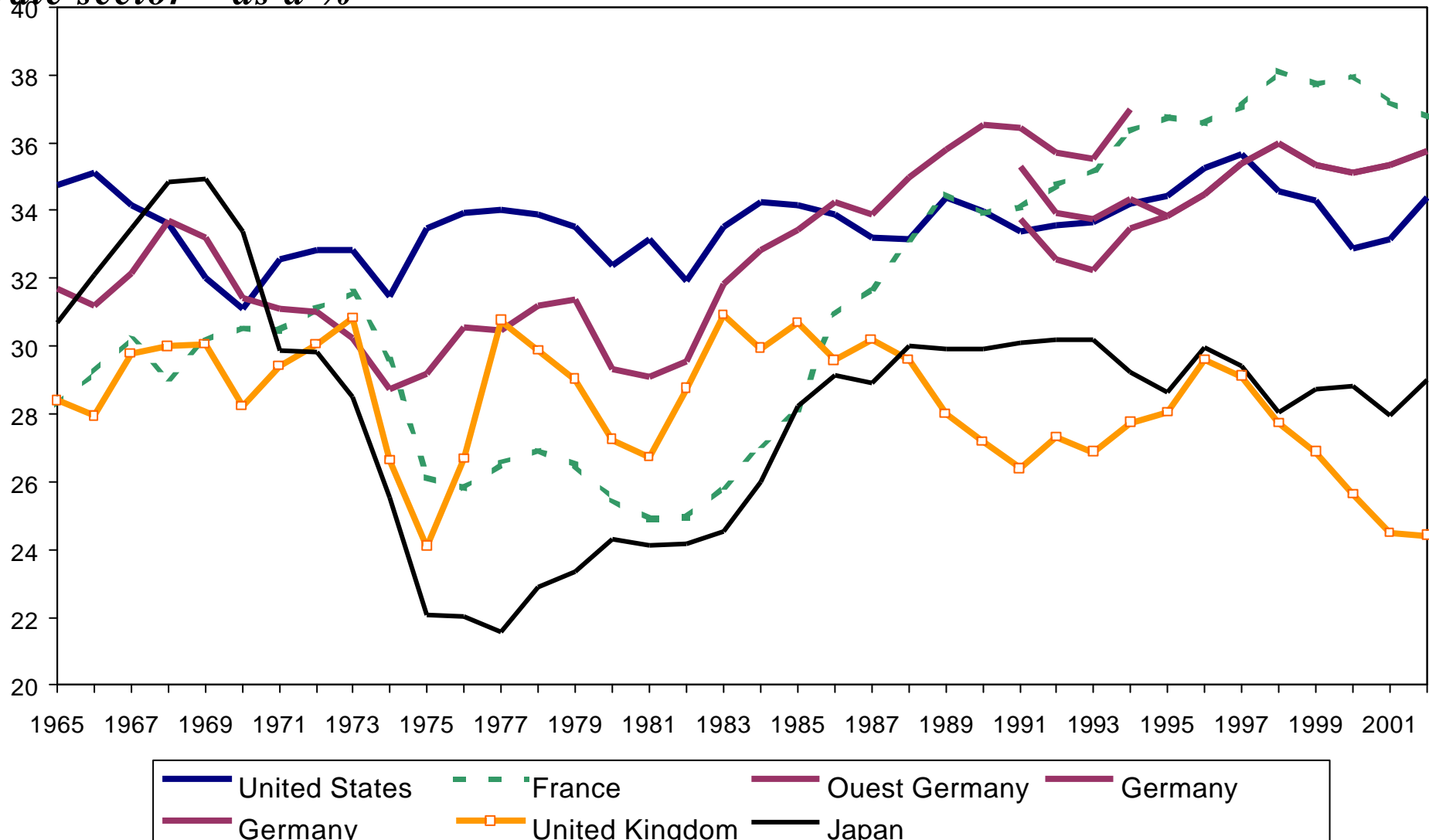
III. – Short to medium-term effects

On the contrary, growth in per capita labour costs exceeded productivity growth over the period, causing the profit margin to fall. 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.

III. – Short to medium-term effects

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

Private sector – as a %



IV – Concluding remarks

1. 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.
2. 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.
3. How much longer will ICT diffusion continue to provide gains in potential output growth ?