The Contribution of Information and Communication Technology to French Economic Growth

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February 2001

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Executive Summary:

Information and communication technology (ICT) is increasingly referred to as an important engine of economic growth. This paper brings a tentative response to the two following questions: what is, in quantitative terms, the diffusion of ICT in the French economy and its contribution to economic growth ? Is the French economy lagging behind the US economy and other industrial economies ?

This analysis is conducted on the basis of the classical "growth accounting" framework and its usual assumptions. We distinguish between three types of ICT equipment: computer hardware, software and communication equipment. Our estimates of ICT contribution to growth are faced with well-known measurement problems: estimate of investment flows; breakdown of investment expenditure (in nominal terms) into prices and volumes (i.e. the choice of the appropriate deflator for ICT capital goods); estimate of capital stocks on the basis of investment flows. These problems are particularly acute as regards ICT equipment because of a severe shortage, at least until now, of basic statistics and because of the extremely swift improvement in the performance of ICT capital goods.

Our estimates show that, for the French economy as a whole, ICT's average total contribution to GDP growth amounted to approximately 0.2% per year over 1969-1999. This contribution is attributable up to approximately one half to computer hardware, for one fourth to computer software and for the last fourth to communication equipment. Over the last years (1995-1999), the contribution of ICTs to output growth has gradually increased, to reach approximately 0.3% on average per year, even becoming more important than that of other types of equipment (whose growth and therefore contribution have decreased). These estimates seem to be sensitive to assumptions related to the volume/price breakdown of investment series.

A comparison with estimates made for other countries shows that, before the early 1990s, ICT's contribution to growth would have been 100% larger in the United States than in France. But this gap, which was already a cause of concern, has widened during the last few years (since 1995) in order to reach approximately 300%. The estimated gap for France is similar to that observed for the five other G-7 countries (this difference is however slightly smaller in the case of Canada and the United Kingdom). If such a gap were to be structural in nature, this would be of course extremely worrisome for the medium and long-term future of European economies.

The Contribution of Information and Communication Technology to French Economic Growth

Information and communication technology (ICT) is increasingly referred to as an important engine of economic growth. [1] The case of the US economy, where buoyant growth enjoyed over the last few years coincided with accelerated diffusion of ICT is often cited as a primary example, even though the cause-and-effect relationships are far from being firmly established and clearly understood.[2] Questions raised in connection with this theme are manifold, and it would be extremely time-consuming to report on them exhaustively. We would like only to refer here, as a succinct example, to the issue that is more directly of concern to a central bank. Indeed, the impact of ICTs on growth is largely related to their impact on the productivity of production factors. Such effects may alter the pace of potential growth, in other words of sustainable growth, without a parallel increase in inflationary pressures.

This paper will not cover this issue exhaustively - far from it - even for the French economy. We have chosen a more targeted approach. Our purpose is to provide a tentative response to the two following questions: in quantitative terms, what is the degree of diffusion of ICT in the French economy and its contribution to growth ? Is the French economy lagging behind the US economy and other industrial countries? This paper, which includes information contained in two articles by the same authors, to be published soon in the journal "*Economie et Statistique,*" may only provide a partial and uncertain response to these questions.

We make here a distinction between three types of ICT equipment: computer hardware, software and communication equipment. We deal first with the diffusion of ICT in the economy and discuss briefly problems related to statistical measurement, before proposing an estimate of the contribution of these inputs to economic growth.[3] At each of these stages, we provide, to the greatest extent possible, materials allowing for a comparison with the US and, as regards the last aspect, with other industrial economies.

1. The diffusion of ICT in the French economy

At first it is necessary to make a clear distinction between two possible roles of ICT in the economy: (i) its diffusion and use in all industries; and (ii) the development of industries that produce ICT-related goods and services. This study deals with the first aspect. As regards the second aspect, recent estimates released in Didier and Martinez (2000) show that, compared with the United States, French ICT industry represents a share of the productive activity (in % of GDP) that is relatively very low for computer equipment, almost comparable for IT services (part of which is, by necessity, located closer to users), and rather similar for telecommunication equipment and services, for which France is known to have achieved a rather high level of performance.[4]

Nevertheless, the fact that ICT represents a (relatively) small share of the productive sector in a given country does not necessarily imply that the economic benefits that this country may derive from the use of such technologies are themselves small. Indeed, the country might still import the relevant goods and services without producing them itself. However this important point has been questioned. For example, a recent report by Cohen and Debonneuil (2000) shows that the country leading in terms of ICT production may gain from this position, not only in terms of employment and direct impact on growth, but also by extremely specific spillover effects. These effects are associated with a technological lead and a competitive advantage over other countries and to a faster and more effective adaptation of equipment to the requirements of national users.

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[1] On this theme and the "Solow paradox": "You can see the computer age everywhere but in the productivity statistics," see for instance the first part of Foray and Mairesse (ed.) (1999). On the current consensus, see for instance OECD (2000).

[2] See for instance the French Council of Economic Advisers (2000).

[3] For additional information on measurement issues and results, readers may refer to the authors' two articles to be published in "*Economie et Statistique.*"

[4] On this theme, see also Berthier (2000).

In practice, the diffusion of ICT in the economy is often measured through various quantitative indicators of equipment rate (such as the percentage of employees working on computer equipment in businesses).[5] However, these indicators remain insufficient when it comes to identifying the relationship between the diffusion of ICT and economic growth. Indeed, in such case, it is necessary to measure ICT capital goods as a productive factor, i.e. in terms of investment flows and accumulated stock of capital. We then face the typical problems of 1) measuring investment ; 2) decomposing investment (in nominal terms) into prices and volumes; 3) estimating capital stocks on the basis of investment flows. These problems become particularly acute for ICT, because until recently, basic statistics were sorely missing, and because equipment performance improves very fast. We shall not detail here the difficulties arising in this regard and the way in which statisticians and national accountants attempt to solve them, but it is necessary to refer briefly to these problems.

The first serious difficulty is that of measuring the mere value of ICT investment and, at a preliminary stage, of defining this investment and delineating its boundaries with other forms of investment. As is the case in most recent studies, we shall consider here all investment in ICT equipment (computer hardware, software and communication equipment).[6] This kind of investment flows is poorly known for several reasons, and in particular because its boundaries with investment related to other capital goods and services are often very much blurred.

Software is a case in point. Software integrated into computer equipment is in fact not isolated for accounting purposes (this would be difficult to implement in practice), and the corresponding expenditure is therefore added to that of the equipment component. Also, we must distinguish between three types of software (not integrated into computer equipment): pre-packaged software, own-account software, and custom software which is a tailored adaptation of acquired software. Expenditure corresponding to these last two categories (in-house or improvement of software by businesses) is difficult to grasp, because corresponding payroll expenses are generally not identified specifically for accounting purposes.[7]

There is yet another significant example: computer equipment costs correspond in general to “physically” identified equipment but do not cover computer equipment integrated into other productive equipment, such as machine tools or robots. The costs corresponding to this “integrated” computer equipment are recorded as investment related to the “host” equipment and not as computer equipment as such; the figures involved are however extremely high, and it is estimated that they may amount to twice the investment in computer equipment strictly defined.[8]

In France, for the economy as a whole, the share of ICT in the total investment value (excluding buildings) increased from approximately 10% in 1980 to 18% in 1999, i.e. from approximately 1% of GDP in 1980 to 1.8% in 1999 (Table 1). Out of the three ICT components among which we distinguish, software experienced the fastest growth, reaching in 1999 more than FRF 70 billion, i.e. 45% of the total, against FRF 55 billion (35%) and FRF 33 billion (20%), for communication equipment and computer equipment respectively.

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5 See for instance SESSI, SJTI, INSEE (1999).

6 As was the case in these studies, we ignore specific training and apprenticeship expenses relating to the use of this equipment and software, although such expenses are probably high.

7 These expenses are calculated by National Accountants from fragile sources, and sometimes from certain irregular surveys (in the United States) indicating time spent by employees on programming activities and their remuneration.

8 In the input-output tables of national accounts, these expenses are very logically recorded as intermediary consumption (of businesses producing capital goods) and not as gross fixed-capital formation.

Table 1: **Investment in France per major category of products (in *value)***

	Total value in FRF billion				**% of the total**				**% of GDP**			
	1980	1990	1995	1999	1980	1990	1995	1999	1980	1990	1995	1999
Total ICT, of which:	**29.0**	**90.3**	**98.7**	**162.0**	**10.3**	**12.2**	**13.0**	**17.8**	**1.0**	**1.4**	**1.5**	**1.8**
Hardware	7.8	29.3	28.2	33.6	2.8	3.9	3.7	3.7	0.3	0.4	0.4	0.4
Software	7.0	27.9	35.7	73.6	2.5	3.8	4.7	8.1	0.2	0.4	0.5	0.8
Communication equipment	14.2	33.1	34.8	54.8	5.0	4.5	4.6	6.0	0.5	0.5	0.5	0.6
Non-ICT equipment, of which:	**201.4**	**495.6**	**479.7**	**555.1**	**71.6**	**66.7**	**63.3**	**61.1**	**7.0**	**7.5**	7.2	**6.3**
Transportation equipment	49.9	127.9	126.9	155.8	17.7	17.2	16.7	17.2	1.7	1.9	1.9	1.8
Other equipment	151.5	367.6	352.9	399.3	53.9	49.5	46.6	44.0	5.3	5.6	5.3	4.5
R&D	**50.8**	**157.2**	**179.1**	**190.9**	**18.1**	**21.2**	**23.6**	**21.0**	**1.8**	**2.4**	**2.7**	**2.2**
Total	**281.2**	**743.1**	**757.5**	**908.0**	**100.0**	**100.0**	**100.0**	**100.0**	**9.8**	**11.2**	**11.4**	**10.3**

Source: National accounts and the authors' calculations

In the United States, investment in ICTs seems to be significantly higher than in France. However, this comparison may be only relevant when restricted to investment in the private sector. On this basis, ICT investment represented in 1998 approximately 3.6% of US GDP (i.e. more than twice the French ratio). The gap with France was negligible in 1970, but widened regularly since. This gap has become particularly large for computer hardware and software and remains smaller for communication equipment. At the same time, the share of ICT capital goods in total investment is also increasing much faster in the United States than in France, from 17% in 1970 to 36% in 1998. On the basis of these assessments derived from national accounts, it seems undeniable that ICT is much more widespread in the United States than in France.

The second major difficulty with the estimate of ICT capital goods as a productive factor is the need to decompose investment (in nominal value) into prices and volumes. This is required in order to determine changes in actual investment volume, independent of price changes (deflator). Two extreme methodological approaches may be considered in order to carry out this breakdown: (i) a "factor costs" approach based only on input content but ignoring the productive performance of the capital goods concerned and (ii) a "productive services" approach taking fully into account the productive performance of these goods. Either approach leads in principle to the definition and calculation of different price indices, and therefore different volume indices. The first approach only takes into account progress made in the production of goods, while the second one also takes into account improvement in the quality of these goods. It is conceivable that the respective changes in these indices may be quite different in industries where innovations relating to products and processes are significant and interact to reduce both the production costs and the performance of equipment.

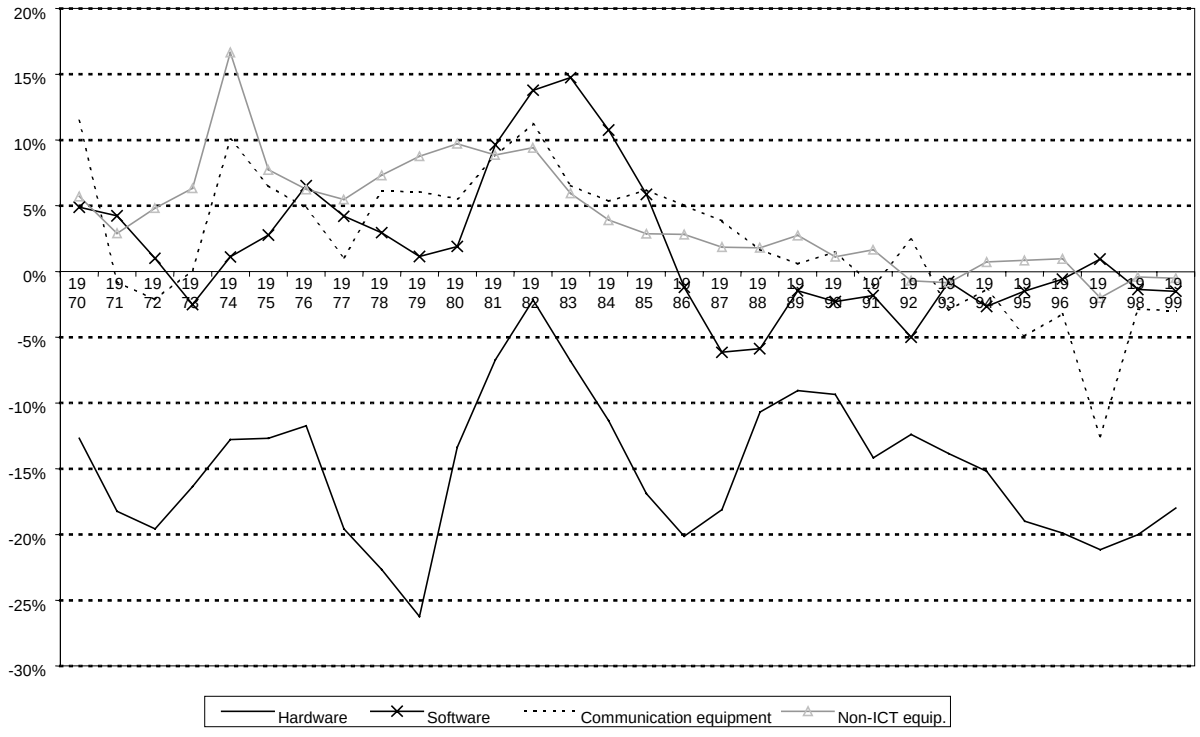
In practice, we may consider that the approach used in national accounts in order to distinguish between "standard" capital goods is more or less a compromise between the "factor costs" approach and the "producer services" method, although it is closer to the former. However, as regards ICT, whose performance is supposed to change very fast, and in particular computer hardware, specific efforts have been made in order to estimate a volume-price breakdown that is closer to a "producer services" logic. The methods used are mainly the hedonic method and the matched method. But it is clear that these methods reach their goal only imperfectly.[9]

[9] Hedonic methods aim at linking , through econometric equations, the differences between the prices of a same type of goods (e.g. laptops) with the differences related to their main features (e.g. speed, memory, weight, etc.).

Despite major efforts already made by statisticians and national accountants, it appears that in France, but also in the United States, methods currently used to estimate the price of investments are heterogeneous depending on the type of equipment concerned. Taking into account changes in the relative share of the various equipment, this heterogeneity has an impact on the interpretation of growth factors. This is the case even within the three equipment categories constituting ICT because hedonic methods are being applied to computer equipment and not yet to communication equipment. In the United States (and not in France), these methods are applied to part of software equipment only. Accordingly, the estimates we are providing here are likely to overstate changes in the price of software and communication equipment and therefore to sharply underestimate changes in the corresponding investment and capital volumes. Therefore, in order to avoid irrelevant comparisons between France and the United States on the basis of heterogeneous indices, we decided to adopt, for each of the three ICT categories concerned, the US National Accounts price indices, adjusted in order to take into account changes in the FRF/USD exchange rate.[10]

Graph 1 (see below) shows for instance that the price of hardware has sharply declined over the entire period, in comparison with the price of communication equipment and software (this is probably largely related to differences in estimation methods) and even more so in comparison with other types of equipment (excluding buildings). Between 1970 and 1999, the price of computer hardware was divided by more than 100%, while the price of software increased by approximately 55%, that of communication by 80% and that of equipment by 230%.

Graph 1: **Annual growth rate of price increases for capital goods in France**



Source: National accounts and authors' calculations

The third major difficulty encountered when estimating ICT as a productive factor (and this is the last difficulty we shall refer to here) is that of estimating capital stocks on the basis of estimates of investment flows (in volume). The chronological method (most often called the "perpetual inventory" method) consists in simulating the capital accumulation process on the basis of past investment series and by specifying "writing off and depreciation" rules (or "mortality" and amortising rules). Although we apply here a very simple form of this method, this is unlikely to have a sizeable impact on our results. In practice, we assume a

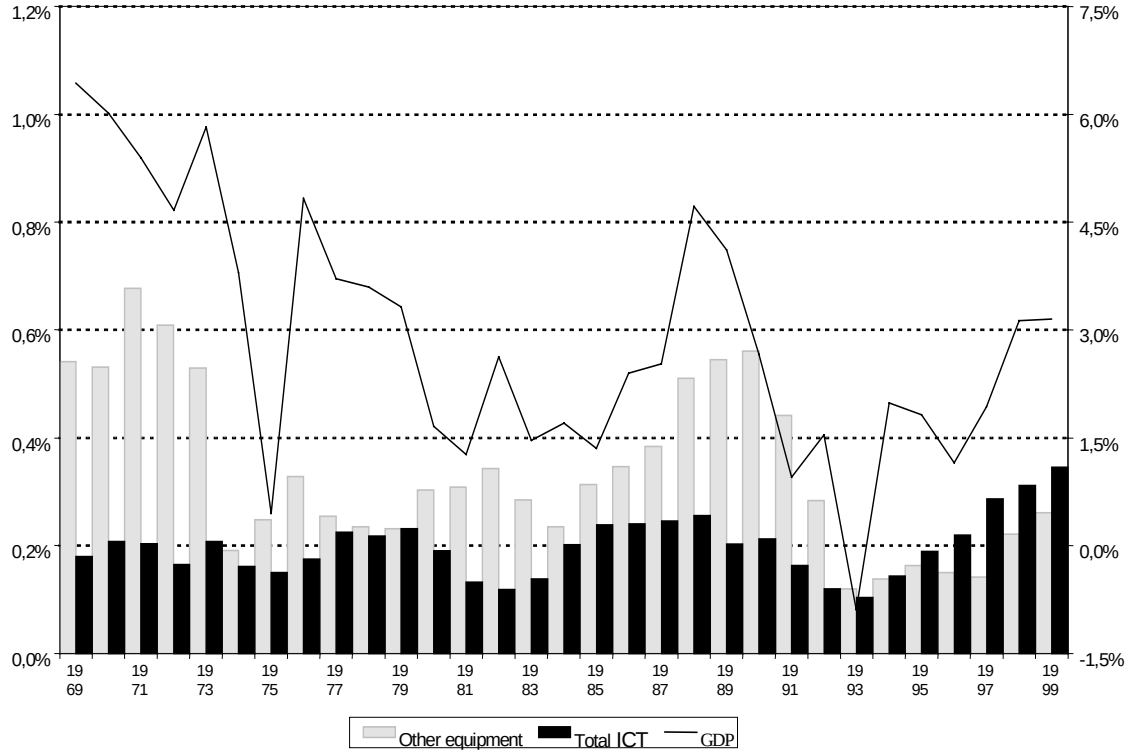
[10] Changes in price indices related to hardware, restated to take into account the quality effect in France and the United States, are very similar in these two countries. For non-ICT equipment, we chose on the contrary to use the French National Accounts indices, but this does not have a strong impact when comparing results between the two countries.

constant annual depreciation rate of 30% for computer hardware and software and 15% for communication equipment and other equipment. These rates are more or less consistent with the (implied) rates used in French National Accounts and are also close to those used in US National Accounts.

2. What is the contribution of ICT to French economic growth ?

On the basis of the classical "growth accounting" methodology and its typical assumptions, it is possible to estimate the accounting contribution of the various productive factors to economic growth. This methodology relies in particular on modelling productive economic activities in terms of production function. It also assumes perfect competitive markets for both inputs and outputs. It is here applied to the French economy as a whole and separately for hardware and communication equipment and software on the one hand and for other types of equipment on the other hand[11]. Graph 2 and Table 2 (page 8) summarise our estimates for France.

Graph 2: **ICTs' contribution to French GDP growth (accounting approach)**



Scope: Whole economy
Source: Authors' calculations
(the graph should read as follows: the contribution of ICT to growth in 1999 was 0.35% against 0.30% for other equipment, while GDP growth rate was 2.9%.)

11 More specifically, the methodology leads to an estimate of a productive factor's contribution to growth as the product of this factor's growth rate in volume and its income share. Capital volumes are estimated in the manner explained above for ICT and other equipment, and the corresponding income share is calculated on the basis of an estimate of the cost of use of these factors. For clarifications of the methodology in general and our estimates on the cost of use and remuneration share, please refer to the authors' two articles in *Economie et Statistique.*

Table 2: **Contribution of capital to French GDP growth (annual average, in %) (accounting approach)**

	1969-1979	1979-1989	1989-1999	1989-1995	1995-1999
Total ICT, of which	**0.19**	**0.20**	**0.21**	**0.16**	**0.27**
Hardware Equipment	0.12	0.13	0.10	0.09	0.13
Software	0.03	0.04	0.07	0.05	0.09
Communication equipment	0.04	0.03	0.04	0.03	0.05
Non-ICT equipment, of which	**0.40**	**0.35**	**0.28**	**0.32**	**0.19**
Transportation equipment	0.09	0.04	0.07	0.07	0.06
Other equipment	0.31	0.31	0.21	0.25	0.12

Scope: Whole economy
Sources: Authors' calculations

They show that, for the French economy as a whole, ICTs' total contribution to GDP growth would have amounted on average to approximately 0.2 % per year for the 1969-1999 period. This increase would have been accounted for approximately one half by hardware equipment and for one quarter by software equipment and for the last quarter by communication equipment. This contribution would thus represent approximately two thirds of that of other types of equipment, although these represented over that period between 80 % and 90 % of total investment. The importance of ICT's contribution is mainly explained by the extremely swift increase in the corresponding investment (volume of capital), particularly for hardware (more than 30% on average between 1969 and 1999) but also to a lesser extent for software (13 %) and communication equipment (7 %). Non-ICT investment has grown at a much more moderate pace (4%). In recent years (here 1995-1999), ICT's contribution has increased gradually, reaching approximately 0.3 % per year on average, and even becoming more important than that of other types of equipment (whose growth and therefore contribution have decreased).

We referred above to certain difficulties relating to the measurement of ICT investment expenditure and to the allocation of this expenditure between price and volume. It is interesting to assess the possible impact of these uncertainties on the estimates that were provided above regarding ICT's contribution to French economic growth. We shall provide here such material regarding the volume-price breakdown of investment figures (expressed in nominal terms).

Price data used in this study correspond, for hardware and software, to US series (BEA) corrected for foreign exchange fluctuations, and for communication equipment to data from French National Accounts. The volume-price breakdown for hardware equipment mainly relies on a hedonic method and leads (see Graph 1) to a swift and continued fall in prices (-15 % per year on average for the 1969-1999 period). For communication equipment, the methodology used is not very different from a factor costs approach and leads to a more important increase (approximately 2 %). For software, an intermediary method is used (1.6 %). Two variants have been developed. In the first one (called "weak" price variant), prices of the three kinds of ICT equipment are supposed to evolve in the same manner as those of communication equipment; when this variant is compared with the central estimate contained in this study, price changes are therefore sharper, much more so for hardware equipment and to a lesser extent for software. In the second method (called "strong" price variant), the prices of all three kinds of equipment are supposed to change along the same line as hardware equipment; compared with the central estimate, price changes are therefore much smaller for software and communication equipment. There is no doubt that these variants correspond to extreme estimates and that, as regards the volume-price breakdown issue, economic truth is somewhere in-between these estimates.

These estimate variants show that the estimate of ICT's contribution to growth is rather uncertain and is sensitive to the way investment (expressed in nominal terms) is apportioned between volume and price (See Table 3). Accordingly, over the last few years (1995-1999), ICT's average annual contribution to GDP growth would be within a 0.2%-0.6% range, compared with a central estimate of 0.3 %. Although this example does not invalidate the conclusion suggested above, it shows that ICT's contribution to growth might be twice as important as in the central estimate, if we consider that producer services for all ICTs are growing at the same pace as for computer equipment.

Table 3: **Contribution of capital to French GDP growth (accounting approach) - Two estimate variants (Annual average, in %)**

	"Weak price" variant			"Strong price" variant		
	1979-1989	1989-1995	1995-1999	1979-1989	1989-1995	1995-1999
Total ICT, of which	**0.09**	**0.08**	**0.21**	**0.43**	**0.33**	**0.60**
Hardware	0.03	0.02	0.04	0.13	0.09	0.13
Software	0.03	0.03	0.12	0.13	0.12	0.29
Communication equipment	0.03	0.03	0.05	0.17	0.12	0.18

In the "weak" price variant, the prices of communication equipment are applied to the volume-price allocation of hardware and software equipment. In the "strong" price variant, the prices of hardware equipment are applied to software and communication equipment.
Scope: Whole economy
Sources: Authors' calculations

3. Is France's situation comparable to that of other industrial countries ?

Other estimates comparable to ours have been produced under the aegis of the OECD by Schreyer (2000) for France and other G-7 countries, including computer and communication equipment on the one hand and all types of fixed capital (all equipment and construction) on the other hand. As shown in table 4, this study leads to results whose orders of magnitude for France are similar to those we have identified.

Table 4: **Contribution from ICT equipment to GDP growth in G-7 countries. (Per year, in %)**

		1980-1985	1985-1990	1990-1996
France	ICT equipment	0.17	0.23	0.17
	Total fixed capital	1.0	1.3	1.0
(West) Germany	ICT equipment	0.12	0.17	0.19
	Total fixed capital	1.0	1.2	1.0
Italy	ICT equipment	0.13	0.18	0.21
	Total fixed capital	0.9	0.9	0.7
United Kingdom	ICT equipment	0.16	0.27	0.29
	Total fixed capital	0.8	1.1	0.8
United States	ICT equipment	0.28	0.34	0.42
	Total fixed capital	1.1	1.0	0.9
Canada	ICT equipment	0.25	0.31	0.28
	Total fixed capital	1.3	1.1	0.7
Japan	ICT equipment	0.11	0.17	0.19
	Total fixed capital	0.8	1.3	1.0

Scope: Whole economy
Source: Estimate by Schreyer (2000).

In addition to Schreyer's estimates, two other very recent estimates have been produced for the US by Oliner and Sichel (2000), and by Jorgenson and Stiroh (2000). These estimates, which cover the private sector; are summarised in table 5 along with our own estimates on the basis of the same coverage. Out of these two estimates, the one by Oliner and Sichel (2000) is the most comparable to ours from a methodological standpoint. Jorgenson and Stiroh (2000) consider the depreciation of durable goods held by households as fixed capital consumption. This leads to a specific estimation of "capital services" as well as to a different measure of GDP. When compared with our figures (this analysis has to be made very cautiously because of the minor differences in scope and methods and above all because of the general uncertainty surrounding estimates in both countries), it appears that, before the early 1990s, ICT' s contribution to growth in the US would overall have been 100% larger in the US than in France. But this gap, which was already worrisome, has widened over the last few years (since 1995), reaching an order of magnitude of 300 %. For the period prior to 1996, estimates by Schreyer (2000) show that the gap for France and the other five G-7 countries are very similar (slightly less so however for Canada and the United Kingdom).

Table 5: **Contribution of capital to GDP growth - Compared estimates for France and the United States**
(Per year, in %)

	France			United States					
	Our estimates			Jorgenson and Stiroh (2000) (*)			Oliner and Sichel (2000)		
	1973-90	1990-95	1995-98	1973-90	1990-95	1995-98	1973-90	1990-95	1995-98
Total ICT	**0.20**	**0.15**	**0.26**	**0.35**	**0.40**	**0.76**	**0.49**	**0.57**	**1.10**
Hardware	0.11	0.07	0.10	0.20	0.19	0.46	0.27	0.25	0.63
Software	0.04	0.04	0.07	0.07	0.15	0.19	0.11	0.25	0.32
Communication equipment	0.05	0.03	0.07	0.08	0.06	0.10	0.11	0.07	0.15
Other capital	**0.85**	**0.61**	**0.48**	**0.81**	**0.51**	**0.86**	**0.86**	**0.44**	**0.75**

Scope: Private sector
Sources: National Accounts and authors' calculations (for France)
(*) Estimates by Jorgenson and Stiroh (2000) are not directly comparable to ours. Indeed, these authors consider that the depreciation of household durables is a consumption of fixed capital. This leads to a specific estimate of "capital services" and to another measurement of GDP.

The recent widening of such gaps with the United States may be seen as the result of the economic environment which has been more favourable over the last few years in the US than in other countries, including France. This more favourable economic outlook, through an acceleration effect, would have triggered a strong capital accumulation benefiting the most advanced technology and in particular ICT. The improvement of the economic environment in Europe and in France might somewhat reduce the gap with the United States. The assumption that these countries might catch up has been made by several authors (see for instance Gust and Marquez (2000)). This optimistic interpretation of the recent widening of the gap in ICT contribution must still, of course, be ascertained over the next few years. It remains however that, even before the most recent period, the faster diffusion of ICT in the United States would have brought a greater contribution to growth than in France or in other European countries, with differentials already highly significant. Some economists have suggested that ICT's favourable effects are mainly to be found in those industries producing ICTs, which are much more developed in the United States than in other European countries such as France (see for instance R. Gordon (2000)). If this assumption were to be confirmed by subsequent research (and were not linked to uncertainty, which remains very high in all these estimates), this would of course be a serious source of concern for the medium and long-term performance of all European economies.

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