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COMPUTERIZATION IN FRANCE: AN EVALUATION BASED ON INDIVIDUAL COMPANY DATA

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In this article we evaluate the contribution of information and communication technologies (ICT) to the growth of value added during the past 15 years in France. Following North American studies, we use traditional growth accounting methods to assess the relative size of two types of contribution: on the one hand the effect of the use of information technologies (IT) on growth due to the accumulation of IT capital taking place within all industries; on the other hand the contribution of the production of ICT to growth due to the strong total factor productivity (TFP) gains achieved in the industries producing ICT. We use individual company data aggregated by industry, which provide us with a measure of the firm's computer stock and makes a detailed investigation possible.

The contribution of the use of IT turns out to be significant around 0.3 of a point for an average annual value added growth of 2.6 percent during the period 1987–98. It is concentrated in a small number of industries that make an intensive use of computers. The contribution of the production of ICT is also substantial: 0.4 of a point over the same period. All in all, we evaluate the contribution of ICT in France at 0.7 of a point of annual growth during the period 1987–98.

We also use the dual approach of growth accounting to evaluate the contribution of ICT to price evolutions. Our results show that the use of IT and the production of ICT have significantly reduced the value-added price inflation by 0.3 and 0.4 of a point respectively for an average annual price growth of 1.4 percent between 1987 and 1998.

1. INTRODUCTION

For a long time it has been thought that companies' investments in information and communication technologies (ICT) have not led to the productivity gains one might have expected. The very strong growth seen in the United States in the second half of the 1990s has revived the discussion concerning this productivity paradox (attributed to Solow). The growth rate for labor productivity in fact rose from 1.5 to 2.5 percent between 1991–95 and 1996–99 in the non-farm market sector. Numerous economists have tried to explain the rebound in the labor productivity growth rate since 1995 by the development of ICT.

At the microeconomic level it has been difficult to find evidence of the impact of ICT on labor productivity (Mairesse, Greenan, and Topiol-Bensaïd (2001), for France) but studies concerning the more recent period now point to a significant effect (Brynjolfsson and Hitt (2000) for the U.S. and Biscourp, Crépon, Heckel and Riedinger (2001) for France). The microeconomic approach is nevertheless not sufficient as it does not provide a quantification of this effect for the whole economy. We use in this study the macroeconomic (growth accounting) approach, which is suitable to measure how large the effect on GDP growth is.

According to the most recent estimates on U.S. data (Oliner and Sichel, 2000), more than half of the increase in labor productivity could be attributed to

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ICT. A major question is whether such a contribution to growth stems from the diffusion of these technologies in the economy (the use of ICT) or whether it finds its origin in the dynamism of sectors producing them (the production of ICT). Whereas Oliner and Sichel attribute substantial effects to both sources of growth, Gordon (2000) maintains that the acceleration in productivity gains at the aggregate level is only concentrated in ICT producer sectors, which results from the substantial technical progress made in the field of new technologies. The rise in the labor productivity growth rate in the United States in the past decade results mainly, in his view, from, on the one hand, gains in total factor productivity (TFP) in the ICT producer sectors and, on the other, from the procyclical nature of productivity. In the other sectors of the economy, which are simply users of ICT, the growth rate of TFP seems to have shown no structural increase as a result of the more intensive use of these technologies.

In the French case, the problem posed is clearly quite different. There was no substantial and lasting upswing during the 1990s, nor was there an increase in the rate of labor productivity gains at the aggregate level. We, therefore, simply measure the level of the contribution of ICT and not its change over the 90s. We also look at the origin of this contribution, namely the use and/or the production of ICT.

Following the North American studies, we use the traditional growth accounting framework to define the contributions of ICT to value-added and labor productivity growth (primal approach). But this study is somewhat unique as it also uses the dual approach of growth accounting to define the contribution of ICT to price change.

In order to determine the contribution of the use of ICT, it is essential to measure the stock of ICT, for which little information is available on this point in France. The work by Mairesse, Cette, and Kocoglu (2000), carried out using national accounts data for the whole of the economy, fills an important gap in this respect. According to this work, ICT's place in the productive factor combination is still marginal in France, and this would partly explain why the contribution of the use of ICT they find is much smaller than the one in Oliner and Sichel (2000). Concerning the contribution of the production of ICT, national accounts data do not yet provide sufficient details in order to isolate the industries producing ICT.

For this article we have used an alternative data set. Our data set is constructed from a large sample of firms (roughly 300,000 a year) aggregated by sector of activity. Our data come from tax returns of firms in industry and market services, excluding the financial sector. This source provides an alternative to the evaluations in the national accounts. It offers the advantage of giving measures of the stock of information technologies (IT)[1] that comes directly from the tax declarations by firms regarding their fixed assets in "office, computing and accounting machinery" (OCAM).

This data set makes it possible to do a more detailed investigation than the aggregate national accounts-based studies. Our sample of firms is aggregated at

[1]We have used the term information technologies (IT) to comprise computers and computer-related equipment (mainly printers). Note that this category only covers computers and not the other capital goods falling under the definition of ICT, such as electronic or communication equipment. Nor does it cover the IT content of production processes.

a fine industry level (2-digit). We are therefore able to investigate the heterogeneity of the use of IT across sectors. Moreover, we are able to focus on the industries producing ICT and to evaluate their TFP gains which is not possible with national accounts data. We are, therefore, able to measure the contribution of the production of ICT to growth.

We find that ICT makes a substantial contribution to value-added growth, amounting to 0.7 of a point per annum in the period 1987–98, out of average GDP growth of 2.6 percent. This total contribution is defined as the sum of the contributions of the use of IT and of the production of ICT. The contribution of the use of IT in all industries amounts to 0.3 of a point. This contribution stems from the intensive use of IT by a small number of sectors. The contribution of the production of ICT amounts to 0.4 of a point and reflects the strong TFP gains in the industries producing ICT.

Our analysis further suggests that the development of ICT has limited the rise in production costs and therefore helped to moderate inflation. According to our calculations, ICT made a negative contribution to the price rise which we put at –0.7 of a point for an average value-added price rise of 1.4 percent over the period 1987–98. Out of this –0.7 of a point, –0.3 corresponds to price declines in the use of IT and –0.4 to price declines in the production of ICT. These contributions are quite substantial. They result mainly from our estimate of the share of IT capital in the productive factor combination which is much higher than the share evaluated from national accounts data (Cette *et al.*, 2000). We discuss possible reasons for such a discrepancy in the section devoted to the results.

In what follows, we first set out the theoretical framework to measure the various contributions of ICT to growth. We then present the data we have used. Finally we discuss our results, first regarding the contribution made by the use of IT and the production of ICT in the whole of the economy, and then focusing on the heterogeneity of these contributions across sectors.

2. The Theoretical Growth Accounting Framework

Growth in an economy, a sector or a firm can be broken down according to the growth of the various factors entering into production. The formal expression for this decomposition was proposed by Solow (1957). Similarly, price changes can be approximated using the price changes of the different production factors (Shapiro, 1987). The aim of this part is to set out the theoretical framework used to carry out these various decompositions and to identify the contribution of IT to growth in value added and price changes.

The theoretical framework used to decompose growth is based on a production function $Y_t = A_t F(X_t^l, \ldots, X_t^K)$ which relates production (Y_t) to the various factors (X_t^i). Growth accounting consists of decomposing growth in output on the basis of the differentiated form of this function:

$$\begin{aligned} d\log Y_t &= \sum_k \frac{\partial \log F}{\partial \log X_t^k} d\log X_t^k + d\log A_t \\ &= \sum_k \varepsilon_t^k \, d\log X_t^k + d\log TFP_t \end{aligned}$$

where ε_t^k represents the elasticity of output to factor k. The contribution of factor k to growth is then defined by $\varepsilon_t^k \, d\log X_t^k$. The unexplained portion $d\log A_t = d\log TFP_t$ corresponds to the rate of TFP growth, i.e. to that part of growth which cannot be attributed to the increase in any one production factor and is therefore attributed to technical progress.

On the assumption of constant returns to scale ($\sum \varepsilon_t^k = 1$) and perfect competition on the product and factor markets, it can be shown that the changes in the output price (P_t) can be decomposed in similar fashion using the changes in prices of inputs (P_t^k), the shares of their remuneration in total cost ($\alpha_t^k = P_t^k X_t^k / \sum P_t^l X_t^l$) and a residual term that can also be interpreted as the TFP growth rate:

$$d\log P_t = \sum_k \alpha_t^k \, d\log P_t^k - d\log TFP_t$$

The contribution of the price of factor k to the change in prices is then defined simply as $\alpha_t^k \, d\log P_t^k$. Notice that gains in TFP help to lower total cost and therefore contribute negatively to price change.

On the assumption of constant return to scales and perfect competition on product and factor markets, both the elasticities ε_t^k and the shares α_t^k are simply measured by the share of the remuneration of factor k in value added[2]:

(1) $$\varepsilon_t^k = \alpha_t^k = \pi_t^k = P_t^k X_t^k / P_t Y_t$$

It is, therefore, a simple matter to determine the contribution of each factor to output and price growth insofar as one can measure the share of its remuneration in value added.

The strength of these two approaches, known as primal and dual growth accounting approach, is that they require no particular assumptions concerning production technology. On the other hand, they are heavily reliant on the assumptions regarding competition on the product and factor markets, as well as on the assumption of constant returns to scale. Several studies have highlighted the sensitivity of TFP measurement to these assumptions.[3] In fact, the TFP gains that can be estimated on the basis of the primal and dual approaches are generally different and show weak correlation over time. Roeger (1991) shows that this difference can be related to the existence of imperfections on the product markets, invalidating both measures of TFP.

In practice, however, the primal approach is regularly carried out for the standard production factors. This approach is also the one used in all the studies that have attempted to measure the contribution of computerization to growth

[2]On the assumption of perfect competition, the producer maximizes his profits by equating the marginal productivity of each of his inputs to their respective costs, so that elasticities of output to inputs are equal to the ratio of inputs costs to value added:

$$A_t F'_k = P_t^k / P_t \Rightarrow \varepsilon_t^k = A_t F'_k X_t^k / (A_t F) = P_t^k X_t^k / P_t Y = \pi_t^k$$

Under the additional assumption of constant return to scales, value-added is equal to total cost so that:

$$\alpha_t^k = \pi_t^k$$

[3]See Hall (1988), Roeger (1991) and Klette and Griliches (1996).

(see Oliner and Sichel (2000) and Jorgenson and Stiroh (2000) for the U.S.; Schreyer (2000) for a set of European countries; Cette *et al.* (2000) for France). On the other hand, we know of no study that has attempted to determine the impact of ICT on price changes, either in France or the U.S.

The theoretical framework for growth accounting was applied here, adopting the usual hypotheses (competition on product and factor markets, constant returns to scale) and introducing a relatively large set of production factors.[4] As regards labor, three skill levels (L^i) were distinguished. As regards capital, we examined its heterogeneity by introducing nine capital goods (K^i), including IT capital. We then broke down growth as follows:

$$\Delta \log (Y) = \sum \pi^{L^i} \Delta \log L^i + \sum \pi^{K^i} \Delta \log K^i + \Delta \log TFP \quad (2)$$

where π^{L^i} and π^{K^i} represent the share of the remuneration of each skill level and each form of capital in value added. Since it is the rebound in labor productivity in the U.S. that has revived the discussion about the Solow paradox, we also use the primal approach to decompose labor productivity following Oliner and Sichel (2000). By taking the overall workforce L, the direct sum of the numbers of the various skill categories of employees, the growth in labor productivity can indeed be decomposed by changing (2) into:

$$\Delta \log (Y/L) = \sum \pi^{L^i} \Delta \log L^i/L + \sum \pi^{K^i} \Delta \log K^i/L + \Delta \log TFP \quad (3)$$

The magnitude $\sum \pi^{L^i} \Delta \log L^i/L$ is usually interpreted as the change in the average quality of labor.

In a similar manner, the change in prices was decomposed according to the change in the cost of each of these skill levels and each of the types of capital:

$$\Delta \log (P) = \sum \pi^{L^i} \Delta \log P^{L^i} + \sum \pi^{K_i} \Delta \log P^{K_i} - \Delta \log TFP \quad (4)$$

These decompositions can be performed at different aggregation levels. In what follows, we focus on the distinction between the sectors producing ICT and the other sectors which we will call users. We, therefore, perform the decompositions for the group of producers and for the group of users (see Section 3 for the exact definition of the producer sectors).

Contribution of the Use of IT

Looking at the contribution made by the use of IT, IT is considered as an input of the production process. The contribution of the use of IT is therefore simply defined as its contribution as a particular input in the production process, i.e. as $\pi^{IT} \Delta \log K^{IT}$ for the growth in activity, $\pi^{IT} \Delta \log K^{IT}/L$ for the growth in labor productivity and $\pi^{IT} \Delta \log P^{IT}$ for the change in prices. Since IT is used as an input of the production process both in the user and producer sectors, this contribution is defined in both group of sectors.

Note that the contribution defined from the primal approach (contribution to value added and labor productivity growth) implicitly assumes that the growth rate of IT capital (and other inputs as well) is exogeneous. In the case of IT

[4] In order to simplify notations, we suppress from now on the time index.

capital, this simplifying assumption is surely not verified since the accumulation of IT is strongly endogeneous and results from the price declines in IT. Biscourp *et al.* (2001) address this issue in more detail. The decompositions derived from the growth accounting must therefore be understood as formal calculations giving order of magnitudes rather than exact measures (Hulten, 2000).

Contribution of the Production of ICT

When considering the contribution of the production of ICT, ICT is considered as the product of the production process. We therefore only consider the decompositions concerning the group of producers. We make the simplifying assumption that the TFP gains in these sectors—i.e. the part of the real growth or price rise that cannot be accounted for by the increase in the inputs or the change in prices of those inputs—represent the substantial technical progress achieved in the field of ICT. The contribution of the production of ICT is then simply defined as the TFP gains in the producer sectors.

Overall Contribution

The contribution of ICT to overall growth in the economy is simply defined as the result of the contributions of the use of IT (in the producer and user sectors) and of the contribution of the production of ICT (in the producer sectors).[5] One can then determine this overall contribution by summing the various components, weighted by the share of these two groups in total value added:

$$(5) \qquad \sigma^{USERS}(\pi^{IT} \log K^{IT})^{USERS} + \sigma^{PROD}(\pi^{IT}\,\Delta \log K^{IT} + \Delta \log TFP)^{PROD}$$

where σ^{USERS} and σ^{PROD} represent the respective shares of the user and producer sectors in total value added ($\sigma^{USERS} + \sigma^{PROD} = 1$). In the same way, one can define the overall contribution to the change in prices by:

$$(6) \qquad \sigma^{USERS}(\pi^{IT}\Delta \log P^{IT})^{USERS} + \sigma^{PROD}(\pi^{IT}\,\Delta \log P^{IT} - \Delta \log TFP)^{PROD}$$

3. The Data Used

Exploitation of the various sources of tax data enabled us to build up a comprehensive sectoral database distinguishing IT capital from other capital goods at a detailed sectoral level (2-digit). In this way we were able to examine in detail the role played by IT over the period 1984–98, taking into account both the heterogeneity of production factors and that of the productive factor combination as between different sectors.

Measuring IT Capital

Our study is based on a measure of IT capital available at the firm level from tax returns of companies subjected to the BRN (normal real profit) tax regime.

[5]Note that for a complete approach we would also have to examine the contribution of "C" i.e. communication equipment in the use of ICT (and not simply IT). However, we do not have data singling out the use of communcation equipment by industry.

This gives a very large sample of firms, averaging (after clean-up[6]) 300,000 firms per year over the period 1984–98 (Appendix A).

To work with this database is particularly interesting for at least two reasons. Firstly, it provides an alternative measure for IT capital which does not rely on the same assumptions as those estimated by national accounts through the so-called perpetual inventory method.[7] It is, therefore, of particular interest to compare the weight of IT capital in the productive combination between this alternative measure and the measure stemming from national accounts to test their consistency. Secondly, this measure can be aggregated at a very fine sectoral level (2-digit). This allows the heterogeneity of the use of IT across industries to be pointed out. It also allows the contribution of the production of ICT to productivity to be evaluated since TFP gains can be computed in the sectors producing ICT goods and services.

In the company accounts, IT capital is included in the item for fixed assets entitled "office, computing and accounting machinery" (OCAM). We have introduced two corrections in order to estimate IT capital from this item (Appendix B). The first correction deals with the fact that the OCAM item includes other office equipment (typewriters, telephone handsets, etc.) and furniture (desks, chairs) in addition to computers. We, therefore, took only a fraction of the OCAM item in measuring the stock of IT capital. On the basis of national accounts data we have chosen a conservative share of 50 percent (in current prices) to be sure that the larger share of IT in value added which we find when compared with national accounts data (see Section 4) is not due to this assumption.[8] Our results are nevertheless heavily dependent on the evaluation of this share[9] and on its homogeneity as between different sectors of the economy.[10]

We introduced a second correction to take into account that fixed assets in company accounts are valued at historic (acquisition) cost. This correction makes it possible to move from the stock measured at historic cost to the stock measured at current prices. It is a function of the average length of life, of the price change and of the amortized portion of the capital good in question.[11]

Our measure of IT capital is actually not available for all the tax returns. Tax returns containing the item OCAM are indeed obtained in quasi-exhaustive

[6]A major clean-up job had to be carried out to take account of the improvement over time in the quality of the recording of information under the BRN regime (Appendix A).

[7]The perpetual inventory method simulates the process of capital accumulation from investment flows in order to compute the corresponding stock. The denomination "perpetual inventory method" is unsuitable since no inventory is done. The denomination "chronological method" seems more relevant (Cette *et al.*, 2000).

[8]This fraction has been fixed on the basis of national accounts data relating to investment in each of the capital goods included in the OCAM item at aggregate level. This fraction was assumed to remain constant over the period of our study, given that it remains stable at aggregate level (Appendix B).

[9]Moving the share from 50 to 75 percent does indeed change importantly the contribution of the use of IT to value-added growth from 0.32 to 0.48 of a point.

[10]Adopting the same share as in the OCAM item for all the sectors does not introduce any bias in our measurement of IT capital at aggregated level. Nevertheless it leads to underestimation of this stock in sectors where the share is high and overestimation in sectors where it is low.

[11]This adjustment comes down simply to assimilating the stock of capital to an investment made in the past at date t-a where a is the average age of the capital (Appendix B).

fashion for the larger firms[12] but by sampling for the others. The information on OCAM is only available for a sample of 30,000 firms per year. We have aggregated this sample of 30,000 firms into detailed (2-digit) sectors and used the shares to break down the broader item of fixed assets which is available for all the tax returns and which includes not only the OCAM item but also items corresponding to general installations, transport material and reusable packaging materials.[13]

Measuring Other Inputs

In all there were nine capital goods from the tax returns, which we have regrouped in three aggregates: the first comprises construction, buildings and general installations; the second brings together technical installations, transport equipment, office equipment, furniture and reusable packaging; the third corresponds to IT.

In order to take account of the heterogeneity of labor input, we used a different source of individual employee data, namely the DADS (annual declarations of social data made by firms). These declarations show remunerations and occupational categories for a large sample of employees. Using this information we built up data for three skill levels: one for unskilled blue- and white-collar workers, a second for skilled blue- and white-collar workers, and the third for business heads, senior executives and intermediate occupations. Using this sample of employees at a detailed sectoral level (2-digit), we built up fixed breakdown scales, making it possible to break down the number of employees as well as the total wage bills available in tax returns (Appendix B).

These data were aggregated at a fine sectoral level (2-digit) and, when necessary, deflated using chained price indices from the national accounts. The index for the prices of investment in IT was partly based on the American index produced by the Bureau of Economic Analysis, which has been calculated using hedonic methods over a longer period of time than the French series which has only been available since 1990 (Appendix C).

Measuring the Sectors Producing ICT

This detailed sectoral data set is used to single out sectors that produce ICT which we define as:

- The IT branch: manufacture of OCAM, wholesaling of OCAM (services), IT activities (services).
- The electronics branch: manufacture of electronic components, manufacture of electrical equipment (wires and cables), manufacture of measurement and control instruments, manufacture of reception and recording equipment (sound and images).

[12]The information concerning the item OCAM is available for more than 90 percent of firms with more than 500 employees.

[13]We made various attempts at adjusting this information *ex post* to allow for the fact that it is available essentially for the very large firms. The resulting changes were only minor—probably due to the fact that the large firms are the largest contributors to the capital stock—with the result that in the end we stayed with the unadjusted information (see Appendix B for further details).

- The telecommunications branch: manufacture of broadcasting and transmission equipment (telephones), telecommunications (services) including telecom services.

The share of these sectors in total value added (in current prices) within the total firm population in our study was relatively stable from 1987 to 1998, averaging 7.6 percent over this period. Since the coverage we have chosen is restricted, including only non-farm non-financial private sectors, whose weight in total value added (estimated using national accounts data) is 64 percent on average over the period in question, the share of the ICT producing sector in total value added of the whole economy is somewhat smaller—around 4.9 percent ($0.64 \times 7.6\%$). Within the ICT producer sectors, computer services are largest in terms of value added, accounting on average for 25 percent of value added of all ICT producer sectors in the period 1987–98. Next comes the manufacture of computers at 19 percent.

Measuring the Share of the Remuneration of Each Factor in Value Added

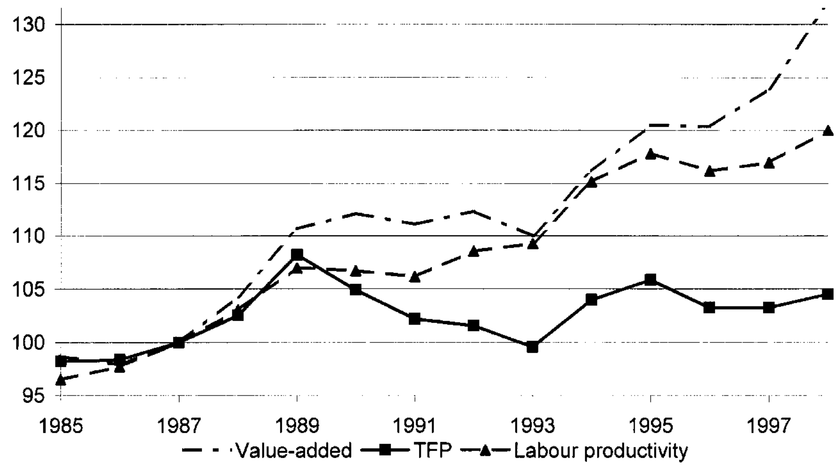
For all the decompositions defined in the first section, determining the share of the remuneration of each factor in value added is an important step. The principle we adopted consisted of breaking down the share of wages in value added among the various forms of labor, with the residual shared out between the various capital goods *pro rata* to their share in the total cost of capital.

Rather than measuring the level of remuneration directly, we chose to break down the totality of the residual portion of value added into the share of the remuneration of each of the capital elements since this is the approach most commonly adopted, notably by Jorgenson. In theory these two approaches should lead to identical shares. In practice, the approach we have preferred offers a definite advantage in that it does not require measuring of the absolute cost of each capital element, but only a measure which represents the relative cost between each capital item. Even so, breaking down the residual value added between the various forms of capital probably leads to an overestimation of the share of each of the forms of capital in question, for at least two reasons. Firstly, if the firms apply a mark-up on their overall cost, the residual portion to be broken down between the various types of capital is too large. Secondly, if certain factors are not observed, such as the intangible assets, the distribution of their remuneration between the various types of capital will be incorrect.

The Choice of Period

The decomposition of growth is hard to interpret when it covers only a short period, as it is then liable to be influenced by cyclical effects. Indeed, as Figure 1 shows, TFP is pro-cyclical. The respective contributions to growth of the various factors of production and TFP gains are therefore substantially affected by the choice of starting and finishing dates.

For our decomposition, we therefore chose a long period (1987–98). The choice of the end of the period was dictated by our concern to take advantage of the most recent data, while that of 1987 was dictated by the fact that this year



Note: TFP is estimated through the primal approach. For all three series 1987 = 100. Coverage: non-financial non-farm enterprises. Evaluations made using data from tax returns by firms subject to the BRN regime.

Figure 1. Value Added, Labor Productivity and TFP Over the Period 1984–98

seemed to occupy the same place in the preceding cycle as 1998 does in the current one. As a result, part of the effects related to the economic cycle are eliminated (inasmuch as one has a complete cycle), such as the increase in capacity utilization rates during periods of rapid growth, which would be liable to falsify the long-term analyses. This marks a major difference between our study and the American studies where a decomposition was applied to the second half of the 1990s, giving a very short period of four or five years, in order to determine whether there has been an acceleration in the role of the ICT. The theoretical framework we adopted makes it possible to analyze the long-term determinants of growth and the evolution in prices. It seems difficult, therefore, to identify a change in trend by focusing on the end of the 1990s.

4. Contributions of the Use of IT and of the Production of ICT

The overall contribution of ICT to value-added growth (as defined in equation 5) is substantial. It amounts to 0.7 of a point of the 2.6 percent growth in the period 1987–98 (Table 1). This strong contribution stems both from the contribution of the production of ICT and of the use of IT, which are of the same orders of magnitude (0.4 and 0.3 of a point).

Similarly, the use and production of ICT are seen to have reduced inflation substantially, by 0.7 of a point, compared with inflation of 1.4 percent over the period 1987–98 (equation 6). Here again, both contributions are important and of roughly the same magnitude (–0.4 and –0.3 of a point).

The substantial contribution of the production of ICT results from the substantial TFP gains in the producer sectors: these TFP gains are consistently estimated at 5.2 percent taking the primal approach, and 5.8 percent taking the dual

TABLE 1

CONTRIBUTION OF THE USE OF IT AND OF THE PRODUCTION OF ICT (1987–98)

	Value Added	Prices
Growth rate	2.6%	1.4%
Overall contribution	0.7%	–0.7%
Users (92.4% of VA): IT use	0.28%	–0.21%
Producers (7.6% of VA)	0.43%	–0.47%
IT use	0.04%	–0.04%
ICT production	0.39%	–0.44%

Note: Annual average changes. Coverage: non-financial non-farm enterprises. Evaluations made using data from tax returns by firms subject to the BRN regime.

approach over the period 1987–98 (Table 2). This is in sharp contrast to the TFP gains in the user sectors, which were of the order of 0.1 percent under the primal approach and even negative in the dual approach. Productivity gains enabled the producer sectors to expand more rapidly and to reduce their prices to a great extent.[14] Despite their low share in total value added within the coverage of our study (7.6 percent), the producer sectors therefore make substantial contributions to value-added growth (0.43 of a point) and to price change (–0.47 of a point).

The contributions of the use of IT are also substantial. The contribution to value-added growth indeed amounts to 0.32 (0.28 + 0.04) of a point whereas that to price change is equal to –0.25 (–0.21–0.04) of a point (Table 1). These gains are mainly located in the user sectors. The small contributions of the use of IT in the producer sectors (0.04 and –0.04 of a point for value added and prices respectively)

TABLE 2

DECOMPOSITION OF GROWTH IN VALUE ADDED AND IN PRICES IN THE PRODUCER/USER SECTORS (1987–98)

	Decomposition of Growth in Value Added		Decomposition of Growth in Prices	
	Users	Producers	Users	Producers
Growth rates in value added or prices	2.1%	8.3%	1.9%	–4.3%
Labor	0.9%	1.9%	1.6%	1.6%
Unskilled	–0.07%	–0.16%	0.08%	0.03%
Skilled	0.08%	0.08%	0.74%	0.36%
Highly skilled	0.89%	1.96%	0.81%	1.24%
Capital	1.2%	1.2%	–0.1%	–0.2%
Building, construction,	0.14%	–0.08%	0.15%	0.21%
Technical installations	0.73%	0.77%	0.02%	0.09%
Information technology	0.30%	0.55%	–0.23%	–0.48%
TFP growth rate	0.1%	5.2%	–0.3%	5.8%

Note: Annual average changes. Coverage: non-financial non-farm enterprises. Evaluations made using data from tax returns by firms subject to the BRN regime.

[14]Note that the value-added deflator in the producer sectors even decreased at –4.3 percent.

reflect the small weight of these sectors in total value added. Indeed, IT use in the producer sectors contributes 0.6 of a point to value added growth in those sectors, which is two times larger than the corresponding contribution in the user sectors (0.3 of a point) (Table 2).[15] Related to the sectors' growth rate the relative contribution of IT use (0.3 of a point out of 2.1 percent and 0.6 of a point out of 8.3 percent) is nevertheless more important in the user than in the producer industries.

The substantial contributions of the use of IT in the producer and user sectors result from the strong increase in the stock of IT capital and from the strong decrease in its cost (Table 3). Both the increase in the volume of IT capital and the decrease in its cost are strongly related to the use of hedonic price indices. It is mainly because of the very steep fall observed in the price of IT equipment that the growth rate in the stock of computers is so rapid and the fall in IT cost so strong. The strong contributions of IT use therefore reflect mainly the increase in value-added and the decrease in prices to expect from the improvement in the quality of IT equipment.

TABLE 3

PRODUCTION FACTORS IN THE PRODUCER/USER SECTORS (1987–98)

	Factor Shares		Factor Growth Rates (volume)		Factor Cost Growth Rates	
	Users	Producers	Users	Producers	Users	Producers
Labor	67.9%	72.7%	1.3%	2.6%	2.4%	2.3%
Unskilled	9.9%	4.7%	–0.5%	–3.3%	0.7%	0.4%
Skilled	24.0%	17.1%	0.4%	0.6%	3.0%	2.1%
Highly skilled	33.9%	50.9%	2.6%	3.9%	2.5%	2.6%
Capital	32.1%	27.3%	3.7%	4.6%	–0.2%	–1.1%
Building construction	10.8%	6.5%	1.4%	–1.3%	1.4%	2.6%
Technical installations	19.8%	17.5%	3.7%	4.5%	0.0%	0.1%
Information technology	1.5%	3.3%	19.9%	16.7%	–15.1%	–14.9%

Note: Shares are average over the priod. Growth rates are average annual changes. Coverage: non-financial non-farm enterprises. Evaluations made using data from tax returns by firms subject to the BRN regime.

Given the large change in the stock and in the cost of IT, a key parameter in these decompositions is the share of IT in value-added. This share represents the weight of IT in the productive process. It is relatively small when compared to the share of other inputs. This share is much higher in the producer sectors than in the user sectors: 3.3 percent against 1.5 percent (Table 3). At the aggregate level, this share amounts to 1.7 percent ($7.6\% \times 3.3\% + (1 - 7.6\%) \times 1.5\%$) on average over the period 1987–98. Notice further that the producer sectors are also much more intensive users of highly-skilled manpower than the user sectors (51 percent against 34 percent).[16]

Contributions to Labor Productivity Growth

Using the primal approach to decompose labor productivity (Table 4) points to a strong increase of labor productivity in the producer sectors. This stresses

[15] The same argument holds for price growth.

[16] Contrary to what one might have expected, the growth rate of IT capital is slightly less rapid in the producer sectors than in the user sectors. The contributions to value-added growth is nevertheless higher in the producer sectors since the share of IT is much higher in these sectors.

TABLE 4

DECOMPOSITION OF GROWTH IN LABOR PRODUCTIVITY IN THE PRODUCER/USER SECTORS (1987–98)

	Users	Producers
Value added growth rate	2.1%	8.3%
Growth in numbers employed	0.9%	1.7%
Growth in labour productivity	1.3%	6.6%
Improvement in labor quality	0.3%	0.7%
Contribution from capital intensity	0.9%	0.7%
Building, construction, general installations	0.04%	−0.20%
Technical installations	0.55%	0.46%
Information technology	0.29%	0.49%
TFP growth rate	0.1%	5.2%

Note: Annual average changes. Coverage: non-financial non-farm enterprises. Evaluations made using data from tax returns by firms subject to the BRN regime.

that the producer sectors have for some time been benefiting from the technical progress achieved in the field of ICT, which has enabled them to increase their workers' productivity substantially. This decomposition also reveals that the ICT producer sectors have been more dynamic in terms of employment. The growth rate in numbers employed in these sectors was 1.7 percent, compared with 0.9 percent for the user sectors. Only the most highly-skilled workers, however, have benefited from this dynamism of employment. Labour quality has indeed increased over the period, pointing to the increase in the number of skilled and the decrease in the number of unskilled (Table 3). This increase in labor quality is more important in the producer sectors than in the user sectors.

Comparison with Other Studies

The results of our study can be compared to those of other studies based on national accounts data. Our evaluation of the contribution of the use of IT to value-added growth (0.3 of a point) is substantially higher than those of other studies using French data (Mairesse *et al.*, 2000; Schreyer, 2000), which gave estimates ranging around 0.1 of a point. This difference stems mainly from differences in the evaluation of the share of IT capital in value added,[17] which Mairesse *et al.* (2000) put at 0.5 percent, whereas according to our calculations it is 1.7 percent (Table 5). This difference is all the more striking as we have adopted a conservative assumption regarding the share of IT in the item OCAM (Appendix B).

A potentially important difference between studies based on national account data and our own is the pattern of physical decay,[18] i.e. the way IT equipment is scrapped. Concerning studies using national accounts data, the usual assumption is a geometric rate of depreciation which means that each year, a constant fraction of the stock is scrapped. This particular assumption is not made in our approach.

[17]Mairesse *et al.*'s (2000) evaluation of the contribution of the use of IT is 0.1 of a point (0.5% × 0.2%) compared with our estimate of 0.3 of a point (1.7% × 0.2%). Both studies point to a growth rate of IT stock of around 20 percent. The main difference thus comes from the share in value-added.

[18]We are grateful to Paul Schreyer who made this relevant remark to us.

TABLE 5

Comparison to Other Studies

	Data Source	Share of IT in Value-added	Elasticity of Output to IT
Mairesse *et al.* (2000)	National accounts	0.5%	–
Crépon and Heckel (2000)	Large firm level sample	1.7%	–
Biscourp *et al.* (2001)	Firm level sample	–	4%

Note: Evaluations drawn from Mairesse *et al.* (2000) over the period 1990–98, this study over the period 1987–98, and Biscourp *et al.* (2001) over the period 1994–97.

In the company accounts, an asset is taken into account in the (gross) stock when it is present in the firm. When the asset is scrapped, it is removed from the stock. Therefore, we do not use any particular assumption regarding the pattern of physical decay since we use a measure of the stock (and not of investment flows) that takes into account the scrapping of equipment.[19]

Another point worth mentioning is that the results in this study are derived from OCAM/equipment shares for large firms which may bias the contribution of IT for all firms. However, adjustment for this selection bias affects the share of IT capital only marginally (Appendix B), most probably because of the complete coverage of large firms, which are the largest contributors in terms of capital. Uncertainties regarding the evaluation of the IT capital share in value added also emerge in studies using American data. The shares estimated by Jorgenson and Stiroh (2000) and Oliner and Sichel (2000) range from 1.0 to 1.7 percent during the 1990s. These studies show a much more rapid rate of accumulation of IT capital in the second half of the 1990s, a result which stems largely from the more rapid decline in the deflator of IT capital (Appendix C). They find, therefore, much larger contributions to growth over this period (0.5 and 0.6 of a point respectively).

It is also possible to compare our results with those of firm level studies not relying on the growth accounting framework to estimate the elasticity of output to IT (equation 1). The comparison with Biscourp *et al.* (2001) is particularly relevant since they use a balanced sample of 5,000 firms from the same data set. Their results point to a significant elasticity of output to IT substantially larger than our share of IT in value-added. This result is consistent with other recent studies based on firm level data (Lehr and Lichtenberg, 1999; Brynjolfsson and Hitt, 2000). It raises an issue as far as macro studies are concerned since they use the share of IT to estimate this elasticity.[20]. Van Ark (2000) reviews some possible

[19]One may argue that the physical decay pattern should take into account not only the scrapping but also the wear and tear of the equipment. We have not corrected for the fact that wear and tear is not measured in the gross stock. To address this issue completely, we are planning to study in more detail the decay pattern of IT capital by simulating its process of accumulation using investment flows as well as stocks given in company accounts following the methodology of Atkinson and Mairesse (1978).

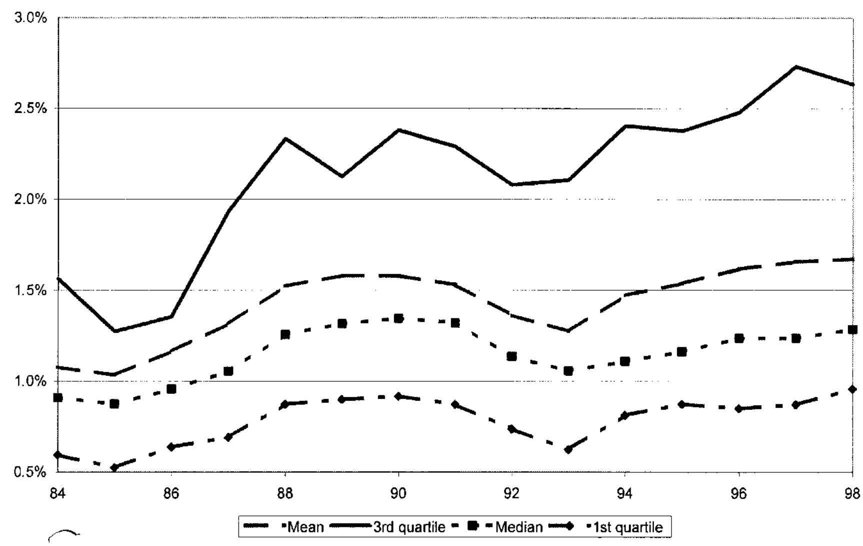
[20]The interest of growth accounting is that it is valid—even if there is a great heterogeneity across firms—as long as the share of IT is equal to the elasticity of output to IT at the firm level. It therefore allows quantification of the contribution of IT at the aggregate level—despite the heterogeneity across firms—under the assumption that this condition is verified.

reasons for this issue, including sample selection of firm level studies, the role of complementary intangible capital and possible aggregation effects.

5. The Use of IT at Sectoral Level

The contributions of the use of IT are substantial, both in the producer and user sectors. Nevertheless, one cannot conclude that the diffusion of IT has equally affected all sectors in the economy. The user sectors may indeed be very heterogeneous as far as the use of IT is concerned. To address this issue, we focus in this section on the user sectors using our data at a refined sectoral level (2-digit). The bulk of the contribution of the use of IT is shown to be concentrated in a few sectors making intensive use of this input. Recall that this conclusion holds without the financial sector, which is actually the biggest user of IT (Appendix A).

The weights of IT in the productive factor combination as measured by its share in value-added vary widely between sectors. The average share of IT (in the user sectors) has risen from 1.1 percent in 1984 to 1.7 percent in 1998 (Figure 2). This growth reflects the tendency at aggregate level to install IT equipment. Examination of the evolution of the distribution of the share of IT capital shows that the dispersion of this share has dramatically increased over time, with the interquartile difference widening from around 0.9 percent in 1984 to 1.6 percent in 1998. This widening of the dispersion is mainly due to the strong increase of the IT share at the end of the 1990s in the sectors that already were the most equipped (above the median).



Note: This graph shows the mean (with each sector weighted by its value added) as well as the three quartiles of the distribution of the share of IT in value added. Coverage: non-financial non-farm enterprises, excluding ICT producer sectors.

Figure 2. Distribution of IT Share Over the Period 1984–98 (User Sectors)

The dispersion of IT share across the user sectors[21] shows that there are large differences in the degree of IT use among these industries. Following Stiroh (2001) and Van Ark (2001), we separate the decomposition of value-added growth between intensive and less intensive IT users to study this heterogeneity (Table 6). IT intensive users are defined as the sectors whose IT share is above 2 percent on average during 1987–98. The 13 out of 90 sectors selected in this manner represent 24.1 percent of total value-added within the coverage of our study.[22] The sectors mainly concerned were the following: wholesale distribution, retail distribution, pharmaceuticals, services to professionals, publicity and market research, and leasing of equipment without operator.

TABLE 6
DECOMPOSITION OF VALUE-ADDED GROWTH IN THE HIGH IT USERS/LOW IT USERS
(1984–98)

	Decomposition of Growth in Value Added	
	High IT Users (24.1%)	Low IT Users(68.2%)
Growth rates in value added or prices	3.2%	1.7%
Labor	1.3%	0.8%
Unskilled	0.03%	–0.10%
Skilled	–0.10%	0.15%
Highly skilled	1.37%	0.73%
Capital	1.7%	1.0%
Building, construction, general installations	0.08%	0.13%
Technical installations	1.00%	0.63%
Information technology	0.61%	0.20%
TFP growth rate	0.2%	0.0%

Note: Coverage: non-financial non-farm enterprises, excluding ICT producer sectors.

The contribution of the use of IT is much larger in the high IT users than in the low IT users (0.6 against 0.2 of a point). As a result, most of the contribution of the use of IT to overall growth is found in the intensive users of IT. Out of the overall contribution of the use of IT to value-added growth (0.3 of a point), 0.15 (0.24×0.61) of a point took place in these sectors, accounting together for slightly less than 25 percent of value added.

Furthermore, the contribution of TFP is also larger in the IT intensive users (0.2 against 0.0 of a point). One may argue that such a contribution reflects externalities and economies of scale effects of IT. Nevertheless, since TFP is a "measure of our ignorance" (Hulten, 2000), there may be many other reasons leading to this result for a set of so heterogeneous sectors.

One should keep in mind that the quantitative calculations presented in the two last sections are based on a set of assumptions that have a strong influence on the results. For one thing, there are assumptions concerning the data.[23] But more importantly the calculations we have made, like all growth accounting studies, are based on a set of a theoretical hypotheses (constant returns to scale,

[21]Defined in the previous section as all the industries that are not ICT producers.
[22]Less intensive users represent 68.2 percent of total value-added and ICT producers 7.6 percent.
[23]In particular, concerning the share of IT equipment in the item OCAM and the correction to move from historic cost to replacement cost (Appendix B).

perfect competition on product and factor markets). These assumptions are nevertheless necessary in order to approximate the magnitude of the effect of ICT.

Conclusion

In this study we have attempted to evaluate the contribution of ICT to growth and prices, using company accounts. This source has enabled us to estimate the share of IT at a detailed sectoral level and, on various hypotheses, the contributions of the use of IT and of the production of ICT. One should keep in mind that these results are only a formal calculation. Our study forms part of a broader research effort carried out in France and abroad that should make it possible to get a better idea of the role of computerization in our economy.

In line with Gordon (2000) and Oliner and Sichel (2000), we distinguish the ICT producer sectors from the others in order to measure the respective importance of the effects of the use of IT and the effects related to the production of ICT. Our results show that the contribution of the use of IT, as well as contribution of the production of ICT, made a substantial contribution to French growth over the period 1987–98.

In particular, we find a much larger contribution of IT use to growth than has been reported in the other studies using French national accounts data. This is mainly due to the data source used: aggregated firm data automatically gives a larger share to IT capital in value added than national accounts data. Further work needs to be done on the way IT capital is accumulated in order to find the origin of this difference. Considering both investment flows and capital stocks available in company accounts may help to shed light on this point (Atkinson and Mairesse, 1978).

In our study, we have isolated two mechanisms by which computerization has exercised an influence on the economy. One stems from the productivity gains in the producer sectors and the other from the diffusion of this technology in the economy. But there are surely other channels by which ICT contributes to growth. In particular, the growth accounting framework applied with constant return to scales does not allow measurement of the potential externalities and economies of scale effects of IT. Theoretical contributions refer nevertheless to such effects as a crucial difference between IT and other capital goods.

We also examine the sectoral heterogeneity of the use of IT, finding that this use remains confined to a small number of sectors.

Appendix A: The BRN Tax Source

Information from tax returns provides us with a measure of activity and of the utilization of production factors (value added, employment and stocks of capital). This information is available for all firms that are subject to the principal tax regime known as BRN (normal real profits). This regime covers virtually the totality of the productive system, representing roughly 90 percent of taxable firms in terms of sales. The data were examined for the period 1984–98. For each year, we have a very large sample of around 600,000 firms.

A substantial clean-up job had to be carried out on the individual data in order to take account of the evolution over time in the quality of the recording of firms in the BRN database. In fact, examination of the gross BRN data shows a rapid and irregular growth in the total number of firms, reflecting a widening of the coverage of the firms listed in the database. The value-added growth rates that can be calculated by direct aggregation of the company data are very large and do not evolve with the economic cycle. To take account of this bias, the data were cleaned up using the 'consistency over time' principle. When a firm appears in the database several years after the latter's creation, it is eliminated for the whole of the period examined.

Following this procedure, we have at our disposal a database of roughly 300,000 firms which are distributed over most sectors in industry and services. Note that banks and insurance companies had to be excluded from the coverage of the study, despite the fact that they account, on average, for roughly 24 percent of the stock of IT capital at current prices for all sectors over the period 1984–98. This was because of the difficulties related to the measurement of their value added on the basis of corporate accounts. For the same reason, most of the GEN (very large public and semi-public firms) were excluded from the sample.

The data are simply[24] aggregated by sector of activity at 2-digit level. In this way, one obtains a breakdown into roughly 100 sectors, making it possible, in particular, to isolate the sectors producing ICT. The scale of the sample, as well as the aggregate evolutions attained ensure the representativeness of this sample.

Appendix B: Production Factors: Value, Volume and Cost

We distinguish nine types of capital goods, assembled into three groups: IT, technical installations and building, construction and general installations. We also distinguish three skill levels for the labor factor. The series were all compiled on the basis of individual data, aggregated at a fine sectoral level (2-digit).

Data Concerning the Labor Input

The data concerning labor input were compiled on the basis of the tax returns of companies subject to the BRN (normal real profits) regime and the DADS (annual declarations of social data). The BRN source provides information on workforce numbers and the total wage bill, with no distinction between skill levels. The DADS data are from a sample built up on the basis of the comprehensive DADS databases, which are not available over the long period. This sample includes information concerning only those individuals born in October one year out of two, so that the sampling ratio is 1/25. The information contained in the DADS relates to occupational category and remuneration.

Given the sampling ratio, this information was used only to break down workforce numbers at sectoral level and the wage bill by skill levels. The data enabled us to carry out this breakdown distinguishing 36 sectors. For each of

[24]No particular treatment was used for deal with mergers/demergers.

them we took three skill levels defined on the basis of the occupational category.[25]

Once the workforce numbers and the remuneration had been broken down by these three skill levels, the average cost for each of them was calculated as the wage bill divided by the workforce numbers.

Data Concerning the Capital Factor

The construction of the data relating to the capital factor was carried out on the basis of stocks of fixed assets reported in the BRN source. We were unable, for lack of sufficiently long time series, to apply the perpetual inventory method.

Fixed Assets Recorded at Historic Cost

The evaluation of the stock of capital of the various goods is based on direct exploitation of the gross stock of fixed assets appearing in the company accounts. The stocks are recorded at historic cost, i.e. at their value at the time of entry into the company balance sheet. An adjustment, therefore, had to be made to move from stocks valued at historic cost (KH) to stocks valued at current prices (KV). This adjustment comes down simply to assimilating the stock of capital to an investment made in the past at date $t-a$ where a is the average age of the capital: $KV_t \approx KH_t p_t / p_{t-a}$. Notice that this correction needs assumptions, namely that the price change is constant and not too large. These assumptions are particularly strong in the case of IT equipment where the average rate of price change is estimated at –13.5 percent. The sense of the bias is however ambiguous analytically. To address this issue in more detail, one should follow the empirical methodology developed by Atkinson and Mairesse (1978) and use flows and stocks in order to determine the sense as well as the order of magnitude of the bias.

In this correction, the average age of the capital is estimated on the basis of the length of life and of the amortized portion of the capital good. Concerning length of lives, we assumed that IT equipment is used during 6 years.[26] Concerning the other capital goods, length of lives vary between 6 years and 27 years.[27] They are close to those used for the French national accounts and to those usually applied in the United States (Fraumeni, 1997). Oliner and Sichel (2000), for example, use an average length of life of five years for IT.

Breakdown of Fixed Assets Between the Different Types of Capital

For all firms of our sample (around 300,000 each year), the fixed asset accounts distinguish only three types of capital and this is not sufficient to isolate

[25]See our companion paper (Crépon and Heckel, 2000) for the fine definition of the skill levels according to occupational category.

[26]One may argue that 6 years is too long for the length of life of IT, particularly at the end of the period of study. Anyway the contribution of the use of IT is not too sensitive to its length of life. Moving it from 6 years to 4 years changes the contribution of the use of IT to value-added growth only from 0.32 to 0.36 of a point.

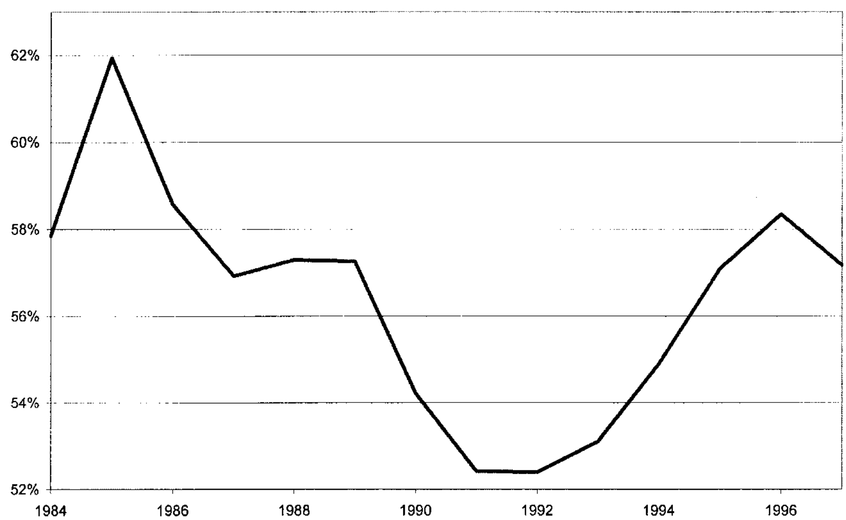
[27]More precisely, the length of life in years of construction is 27, of general installations 12, of technical installations 11, of transport equipment 7, of office and accounting machinery 6, and of packaging and miscellaneous 6.

IT capital satisfactorily. These three types are: construction, technical installations and other tangible fixed assets. The detail in the fixed assets accounts, containing eight types of capital including "office, computing and accounting machinery" (OCAM) is entered only for a sample of around 30,000 firms each year. This sample was used to break down the stock figures available for all firms.

This sample is virtually exhaustive as regards the larger firms, since it covers more than 90 percent of firms with more than 500 employees subject to the BRN regime. Small firms, on the other hand, are under-represented, only 2.5 percent of them being included in the sample. However, adjustment for this selection bias affects the share of IT capital only marginally, raising it from 2.83 to 2.98 percent (historic cost). This is a consequence of the complete coverage of large firms, which are the largest contributors in terms of capital. In the rest of the study, the gross figures have been used.

Share of IT Capital in the OCAM Item

The share of IT capital in the OCAM item was fixed on the basis of the investment flows in the national accounts at aggregated level for each of the goods making up this item. Figure A1 shows that there has been little evolution during the period in question and that this share is on average slightly above 50 percent. We have, nevertheless, chosen a conservative share of 50 percent to be sure that the larger share of IT we find when compared with national accounts studies (see Section 4) is not due to this assumption.



Note: Share of information technology equipment in the total related investment plus office machines, chairs, furniture and metal furniture.
Source: National Accounts.

Figure A1. Share of IT Equipment in the Investment Corresponding to the Item OCAM

Appendix C: The IT Equipment Price Index

The measurement of prices in the IT sector has been the subject of substantial work aimed at taking into account the improvement in product quality so that the measured volume should properly reflect the increase in the services provided by IT equipment. For this purpose the so-called hedonic price method is used (Griliches, 1971). INSEE has only been compiling this type of index since 1990. This index is not markedly different from the American price index calculated, using similar methods, by the Bureau of Economic Analysis (BEA), at least until 1995.

From then on, however, the American price index has declined faster than the French one (Lequiller, 2000).

We have, therefore, constructed a composite index drawing on the results obtained by the BEA, which has compiled this type of index since the mid-1970s. Our index is defined like that of the BEA with the addition of half the exchange-rate variations before 1990. It was then linked into the national accounts index from 1990 onwards. The series thus obtained was then smoothed by taking a three-year moving average. A dollar effect was added to the BEA index to take account of the fact that computers are mainly traded in U.S. dollars. Hence, exchange rate fluctuations between the U.S. dollar and the French franc has a strong impact on IT prices. It is, nevertheless, assumed that exchange-rate variations are not entirely passed on into the prices of IT equipment.

We then get a steep drop in prices of IT equipment in the past 25 years, reflecting the technical progress achieved in the IT field and the considerable improvements in computers. The rate of decline in the prices of IT equipment obtained in this way is roughly constant over the whole of the period, being around 13.5 percent a year. This points to a major difference with the U.S. where there was an acceleration of the rate of price change from an average of around –15 percent before 1995 to an average of –30 percent after 1995 (Gordon, 2000).

Considering a decrease of –30 percent in the price of computers for France would dramatically boost the contributions of the use of IT. For instance, the contribution of the use of IT to value-added growth for the whole economy would be $1.7\% \times (20\% - 13.5\% + 30\%) = 0.6$ of a point.

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