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Computerisation in France: An evaluation based on individual company data

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Computerisation in France: an estimation with individual company data

Abstract

In this article we evaluate the contribution of computers to the growth of value added during the last 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 computer diffusion on growth due to the accumulation of productive capital taking place within all industries ; on the other hand the contribution to growth of the total factor productivity (TFP) gains achieved in the industries producing new information and communication technologies (NICT). We use individual company data aggregated by industry, which provide us with a measure of the firm's computer stock.

Diffusion effects turn out to be significant around 0.3 of a point for an average annual value-added growth of 2.6% during the period 1987-1998. They are concentrated in a small number of industries that make an intensive use of computers. Total factor productivity gains in NICT industries also contribute significantly to growth (0.4 of point over the same period). All in all, we evaluate the contribution of computerization in France at 0.7 of point of annual growth during the period 1987-1998.

In addition we show that computer use and TFP gains in the NICT industries 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% between 1987 and 1998.

Keywords: Growth accounting – Aggregate productivity - Computer stock – Information Technologies - Computerisation

Informatisation en France : une évaluation à partir de données individuelles

Résumé

Cet article cherche à chiffrer la contribution que l'informatique a apportée à la croissance de la valeur ajoutée au cours des 15 dernières années en France. A l'instar des études américaines, nous appliquons les modèles classiques de décomposition de la croissance pour estimer deux types de contribution : d'une part l'effet de la diffusion de l'informatique stricto sensu sur la croissance, par accumulation de capital productif dans tous les secteurs de l'économie ; d'autre part la contribution à la croissance des gains de productivité réalisés dans les secteurs producteurs des nouvelles technologies. Nous utilisons des données individuelles d'entreprises (source fiscale) agrégées par secteurs d'activité, qui présentent l'avantage de fournir une mesure du stock de capital informatique au sein de chaque entreprise grâce au poste comptable des immobilisations en matériel de bureau, mobilier et informatique.

Les effets de diffusion sont importants, de l'ordre de 0,3 point pour une croissance de 2,6% par an en moyenne sur la période 1987-1998. Ils sont concentrés dans un petit nombre de secteurs fortement équipés. Quant à l'effet des gains de productivité dans les secteurs producteurs des nouvelles technologies, ils contribuent également de façon significative à la croissance puisque nous les évaluons à 0,4 point sur la même période. Au total, la contribution du processus d'informatisation en France représente selon ces estimations 0,7 point de croissance annuelle sur la période 1987-1998.

Notre analyse montre par ailleurs que la diffusion de l'informatique ainsi que les gains de productivité dans les secteurs producteurs ont sensiblement limité la hausse des prix de la valeur ajoutée, de 0,3 point et 0,4 point respectivement pour une croissance de 1,4% par an en moyenne sur la période 1987-1998.

Mots-clés : Comptabilité de la croissance - Productivité globale des facteurs - Capital informatique - Nouvelles technologies de l'information et de la communication - Informatisation

JEL classification: O30-O40-O41-O47

Introduction

For a long time it was thought that companies' investments in information technology (IT), although on a huge scale, had not led to the productivity gains one might have expected. The extremely 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 labour productivity in fact rose from 1.5% to 2.5% between 1991-1995 and 1996-1999 in the non-farm market sectors. Numerous economists have tried to explain the rebound in the labour productivity growth rate since 1995 by computerisation and, more generally, by the use of NICT (New Information and Communication Technologies)[1]. According to the most recent estimates (Oliner and Sichel (2000)), almost half of this increase in productivity could be attributed to the use of the new technologies.

A major question is whether the contribution of computerisation to growth stems from the diffusion of computers in the economy or, on the contrary, finds its origin in the dynamism of sectors producing the new technologies. For example, Gordon (2000), in contrast to Oliner and Sichel, maintains that the acceleration in productivity gains seen at aggregated level is concentrated in NICT producer sectors and results from the substantial technical progress made in the field of new technologies. The rise in the labour 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 NICT producer sectors and, on the other, from the pro-cyclical nature of productivity. In the other sectors, which are simply users of the new technologies, the growth rate for TFP seems to have shown no structural increase as a result of the more intensive use of computers.

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 labour productivity gains. What we have therefore tried to do is simply to measure the role of IT in the French productive system and the contribution it has been making to growth. Like both Gordon and Oliner and Sichel, we have also looked at the role of NICT producer sectors, as well as their performance.

In order to determine the role of computerisation in the economy, it is essential to be able to measure the stock of IT equipment. Little information is available on this point in France. The work by Cette, Kocoglu and Mairesse (2000b), carried out using national accounts data for the whole of the economy, fills an important gap in this respect. According to this work, the contribution of IT to growth in the whole of the economy is evaluated at 0.12 of a point and 0.17 of a point for the periods 1990-1995 and 1995-1999, respectively. These figures can be compared with those obtained by Oliner and Sichel (2000). For the United States, the contributions made by IT capital to growth in the periods 1991-1995 and 1996-1999 are much larger (0.25 and 0.63 of a point, respectively). According to the estimates by Cette et al. (2000b), IT's place in the French productive factor combination is still marginal, and this would partly explain its very small contribution to growth

In this article, we measure the contribution of IT capital to growth using data from individual firms aggregated by sector of activity. The coverage of our study is different from that of Cette et al. (2000b), as our data come from a sample of firms (roughly 300,000 a year) in market sectors in industry and services, excluding the financial sectors. This source offers the advantage of giving a measurement of IT equipment that comes directly from declarations by firms regarding the book value of fixed investment in "office equipment, furniture and IT equipment". This information provides an interesting alternative to the evaluations in the national accounts, even though it covers only computers and not the IT content of production processes. Nor does it cover the other assets falling under the definition of NICT, such as software or communication equipment.

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[1] We have used the term information technologies (IT) to comprise computers and computer-related equipment (mainly printers). The term new information technologies (NICT) is used to cover, in addition, other electronic and communications technology equipment.

We find that IT makes a substantial contribution to growth, amounting to 0.3 of a point per annum in the period 1987-1998, out of average growth of 2.6%. The fact that this figure is much larger than the contribution shown in the study by Cette et al. (2000b) results mainly from our higher estimate of the share of IT capital in the productive factor combination. In terms of labour productivity, we find that 0.3 of a point of the growth in labour productivity, itself put at 1.7%, can be attributed to the rise in IT capital per head. Moreover, our analysis suggests that the fall in computer prices has limited the rise in production costs and therefore helped to moderate inflation. According to our calculations, the fall in the cost of IT capital made a negative contribution to the price rise which we put at 0 3 of a point for an average value-added price rise of 1.4% over the period 1987-1998.

Exploitation of our data has also enabled us to provide quantitative detail regarding the productivity gains in the NICT producer sectors and on the diffusion of IT in the sectors using these technologies. Our data show that total factor productivity gains have been substantial in the producer sectors, that their contribution to growth is large but that they do not explain the totality of the global contribution of computerisation to growth, which is the sum of the impact of TFP in the producer sectors and the effects of diffusion in the user sectors. Out of growth of 2.6% a year over the period 1987-1998, the overall contribution of computerisation is evaluated at 0.7 of a point, of which 0.4 corresponds to productivity gains made in the producer sectors and 0.3 to the diffusion effects.

Finally, looking at the diffusion at a more refined level of the classification, we find that its impact is substantial only in a small number of sectors. In fact, 50% of the contribution of IT to growth occurs in the 13 sectors where IT is used most (out of a total of 90 sectors examined), accounting together for 25% of the value added. It would therefore seem that a large number of sectors are still relatively unconcerned by the computerisation process and the growth it procures.

It should be noted that the quantitative calculations are based on a set of assumptions that have a strong influence on the results. For one thing, the heading "office equipment, furniture and IT equipment" which we used in the measurement of IT capital contains other types of asset. We set the share of IT capital in this item at 50%, on the basis of information derived from the national accounts. Moreover, in order to reconstitute the series for capital at replacement cost based on information recorded at historic cost, it is necessary to make assumptions concerning the service lives of IT capital and certain approximations linked to the fact that investment series are not available. Finally, it should be noted that the calculations we have made, like all growth accounting studies, are based on a set of a theoretical hypotheses (constant returns to scale, perfect competition on product and factor markets). In particular, we impute a share of the productive factor combination to IT that is based on the share of the remuneration of IT capital in value added.

In what follows, we first set out the theoretical framework suited to the measurement of the contribution of computerisation to growth, followed by a description of the data we have used. We then present our results, first regarding the contribution to growth made by the diffusion of IT in the whole of the economy, then singling out the NICT producer sectors and the sectors that use these technologies. Finally, we examine the heterogeneity of the diffusion of IT within the user sectors.

Part 1: 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) and has been used by, among others, Carré, Dubois and Malinvaud (1972) in the case of France. Similarly, evolutions in prices can be approximated using the evolutions in the prices of the different production factors. 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 to the evolution in prices.

The theoretical framework used to decompose growth is based on a production function $Y = A_t F\left(X_1, \ldots, X_K\right)$ which relates production to the various factors. Growth accounting consists of decomposing growth in output on the basis of the differentiated form of this function:

$$\begin{aligned} d\log Y &= \sum_k \frac{\partial \log F}{\partial \log X_k} d\log X_k + d\log A_t \\ &= \sum_k \varepsilon_k^F d\log X_k + d\log TFP \end{aligned}$$

where ε_k^F represents the elasticity of output to factor *k*. The contribution of factor *k* to growth is then defined simply by $\varepsilon_k^F d\log X_k$. The unexplained portion $d\log A_t = d\log TFP$ 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[2].

On the assumption of constant returns to scale $\left(\sum \varepsilon_k^F = 1\right)$, it can be shown that the evolution of prices can be decomposed in similar fashion using the evolution in prices of inputs, the elasticities of production to each of these factors and a residual term that can also be interpreted as the TFP growth rate[3]:

$$d\log P = \sum_k \varepsilon_k^F d\log P_{X_k} - d\log TFP$$

The contribution of the price of factor *k* to the evolution in prices is then defined simply as $\varepsilon_k^F d\log P_{X_k}$.

On the assumption of perfect competition on the product and factor markets, the elasticity of production is measured simply by the share of the remuneration of factor *k* in value added: $\varepsilon_k^F = \pi_k$[4]. It is therefore a simple matter to determine the contribution of each factor to growth insofar as one can measure the share of its remuneration in value added.

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[2] Certain types of productivity gains, such as those related to organisational change, seem in fact difficult to attribute to a particular production factor. There would therefore seem to be room, conceptually, for autonomous technical progress even if the services provided by all the production factors were perfectly measured.

[3] The decomposition of the evolution in prices is closely linked to that of the growth in value added, which also brings in the price indices for the production factors and value added for the calculation of growth rates.

[4] On the assumption of perfect competition, the producer maximises his profits by equating the marginal productivity of each of his inputs to their respective costs, so that the shares of the inputs in value added correspond to the elasticities of output in relation to the inputs:

$$A_t F_k' = \frac{P_k}{P} \Rightarrow \varepsilon_k^F = \frac{A_t F_k' X_k}{A_t F} = \frac{P_k X_k}{PY} = \pi_k$$

The interest of these two approaches, known as primal and dual, 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 (Hall (1988), Roeger (1991), Klette et Griliches (1996), Crépon, Desplatz and Mairesse (1999)). 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 widely used. Growth accounting is an exercise regularly carried out for the standard production factors (see, in particular, Accardo, Bouscharain and Jlassi (1999) for a very comprehensive approach in the case of France). This approach is the one used in all the studies that have attempted to measure the contribution of computerisation to growth (see Oliner and Sichel (2000) and Jorgenson and Stiroh (2000) for the United States; Heckel (2000)[5] and Cette et al. (2000b) for France). On the other hand, we know of no study that has attempted to determine the impact of the evolution in IT equipment prices on the price evolution, either in France or the United States.

The theoretical framework for growth accounting was applied here, taking the usual hypotheses (competition on product and factor markets, constant returns to scale) and introducing a relatively large number of production factors. As regards labour, three skill levels $\left(L_i\right)$ were distinguished; as regards capital, we also examined its heterogeneity by introducing nine different types of asset $\left(K_i\right)$, including IT capital. We then broke down growth in the following manner:

$$\Delta \log(Y) = \sum \pi_{L_i} \Delta \log L_i + \sum \pi_{K_i} \Delta \log K_i + \Delta \log TFP \quad (1)$$

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.

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

$$\Delta \log(P) = \sum \pi_{L_i} \Delta \log P_{L_i} + \sum \pi_{K_i} \Delta \log P_{K_i} - \Delta \log TFP \quad (2)$$

Among all these components, we paid particular attention to the contribution made by IT: $\pi_{K_{INF}} \Delta \log K_{INF}$ for the growth in activity and $\pi_{K_{INF}} \Delta \log P_{K_{INF}}$ for the evolution in prices.

Using the primal approach, it is also possible to obtain a decomposition of the growth in labour productivity. By taking the overall workforce *L*, the direct sum of the numbers of the various categories of employee, the growth in labour productivity can be decomposed using the following formula:

[5] This study in fact takes a stage further Heckel (2000), in which the contribution of IT capital was estimated at different levels of aggregation. But there are several notable differences between the two. First, the prices in the new INSEE national accounts base (base 95) were available for use. Moreover, the labour factor was introduced, enabling us to calculate the TFP growth rate. We also carried out the dual decomposition, i.e. for the evolution in prices. Finally, the growth accounting was carried out distinguishing the NICT producer sectors from the others.

$$\Delta \log(Y/L) = \sum \pi_{L_i} \Delta \log L_i / L + \sum \pi_{K_i} \Delta \log K_i / L + \Delta \log TFP$$
$$= \pi_L \sum \tilde{\pi}_{L_i} \Delta \log L_i / L + \sum \pi_{K_i} \Delta \log K_i / L + \Delta \log TFP$$

where $\tilde{\pi}_{L_i} = \pi_{L_i} / \sum \pi_{L_i}$ represents the share of the remuneration of employees in category *i* in the total remuneration of labour and π_L the share of the remuneration of labour in value added. The magnitude $\sum \tilde{\pi}_{L_i} \Delta \log L_i / L$ can then be interpreted as the evolution in the average quality of labour. The magnitudes $\pi_{K_i} \Delta \log K_i / L$ correspond to the evolution in capital-intensity for each of the types of asset and reflect the substitution of the different types of asset for labour. We looked more specifically at the contribution made by IT capital: $\pi_{K_{INF}} \Delta \log K_{INF} / L$. This measures the repercussions of a change in IT equipment per head on growth in labour productivity.

Part 2: The data used

Exploitation of the various sources of tax data enabled us to build up a very comprehensive sectoral database distinguishing IT capital from other assets at a refined sectoral level. In this way we were able to examine in detailed fashion the role played by IT over the period 1984-1998, taking into account both the heterogeneity of production factors and that of the productive factor combination as between different sectors.

The decomposition of growth is a fairly classical exercise. However, the studies available for France generally ignore the heterogeneity of capital assets. This represents a major difference compared with studies made, for example, in the United States, where it is usual to distinguish more than 50 forms of investment goods (see Stiroh (1998)). In fact, there is very little information in France regarding the different types of asset. In this study, we have tried to take advantage of the information available in company accounts to allow for this heterogeneity. This information enabled us to distinguish between nine types of asset, one of them being IT capital.

We have used data for companies subjected to the BRN (normal real profit) tax regime for the period 1984-1998. This gives a very large sample of firms, averaging (before clean-up) 600,000 a year. 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 (box 2.1). These data were then aggregated at various levels and, when necessary, deflated using the price indices in base 95 of the national accounts. However, the index for the prices of investment in IT equipment used for the construction of the IT capital series was partly based on the American index produced by the Bureau of Economic Analysis, which is calculated using long-period hedonic methods (box 2.2).

The measurement of the heterogeneity of capital

In the company accounts, IT capital is included in the item for fixed assets entitled "office equipment, furniture and IT equipment". In addition to computers, this item includes other office equipment (typewriters, telephone handsets, etc.) and furniture (desks, chairs). We therefore took only a fraction of this item in measuring the stock of IT capital, this fraction being estimated at 50% on the basis of national accounts data relating to investment in each of the assets included in this item at aggregated level. This fraction was also assumed to remain constant over the period of our study, given that it remains stable at aggregated level (box 2.3). Our results are nevertheless heavily dependent on the evaluation of this share[6] and on its homogeneity as between different sectors of the economy[7].

This measure is not available for all the tax returns. Detailed information on fixed assets is obtained in quasi-exhaustive fashion for the larger firms and by sampling for the others. Fixed scales for the breakdown into detailed (2-digit) sectors were constructed using these detailed data in order to break down the broader item of fixed assets which is available for all the tax returns and which includes not only the "office equipment, furniture and IT equipment" item but also items corresponding to general installations, transport material and reusable packaging materials[8].

We introduced a correction to take account of the fact that the fixed assets are valued in company accounts at historic (acquisition) cost. This correction makes it possible to

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[6] It was shown in Heckel (2000) that the contribution of IT to growth is relatively sensitive to the share of IT in the "office equipment, furniture and IT equipment" item, by allowing this to vary between 50% and 75%.

[7] Adopting the same share as in the "office equipment, furniture and IT equipment" item for all the sectors does not introduce any bias in our measurement of IT capital at aggregated level. On the other hand, it leads to underestimation of this stock in sectors where the share is high and overestimation in sectors where it is low.

[8] We made various attempts at ex post adjustment of this information to allow for the fact that the information used to calculate the fixed scales 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 box 2.3 for further details).

move from the stock measured at historic cost to the stock measured at current prices. This is a function of the average service life and inflation rate for the asset in question (box 2.3). The more standard "perpetual inventory" method, which is normally preferred, was not used in this case in that it deals with investment flows and requires the use of long series that were not available to us (the information we used from company accounts goes back no further than 1984).

The other assets that the tax returns enabled us to break out were treated in the same manner. In all, there were nine types of asset, which we have re-grouped in three aggregates: the first comprises construction, buildings and general installations; the second brings together technical installations, transport equipment, office equipment and furniture, as well as reusable packaging; the third corresponds to IT equipment.

Measuring the heterogeneity of the labour factor

In order to take account of the heterogeneity of the labour factor, we used a different source of individual data, namely the DADS (annual declarations of social data made by firms). These declarations show for each employee in the sample his remuneration and his occupational category. Using this information we built up sectoral 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. Having in this case, too, only a sample of employees, we built up fixed breakdown scales at a detailed sectoral level, making it possible to break down the sectoral workforces as well as the total wage bills (box 2.3).

Measuring the share of the remuneration of each of the factors

In all these decompositions, determining the share of the remuneration of each factor in value added is an important stage. The principle we adopted to measure the share of the remuneration of the various factors consisted of breaking down the share of wages in value added (before tax) among the various forms of labour, with the residual shared out between the various types of fixed assets *pro rata* to the share in the total cost of capital[9].

We chose to break down the totality of the residual portion of value added in order to estimate the share of the remuneration of each of the capital elements rather than measure their remuneration directly (using the formula for usage cost) since this is the approach most commonly adopted, notably by Jorgenson. In theory, according to the supporting model, 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 the absolute cost of each capital element, but only a measure representing the relative costs of each of them[10]. Even so, breaking down the residual portion of wages in value added between the various forms of capital in all probability leads to an overestimation of the share of each of the forms of capital in question, for at least two reasons. First, if the firms apply a mark-up on their overall cost, the residual portion to be broken down between the various forms of capital is too large. Second, if certain factors are not observed, such as the intangible assets, the distribution of their remuneration between the various forms of capital will be incorrect.

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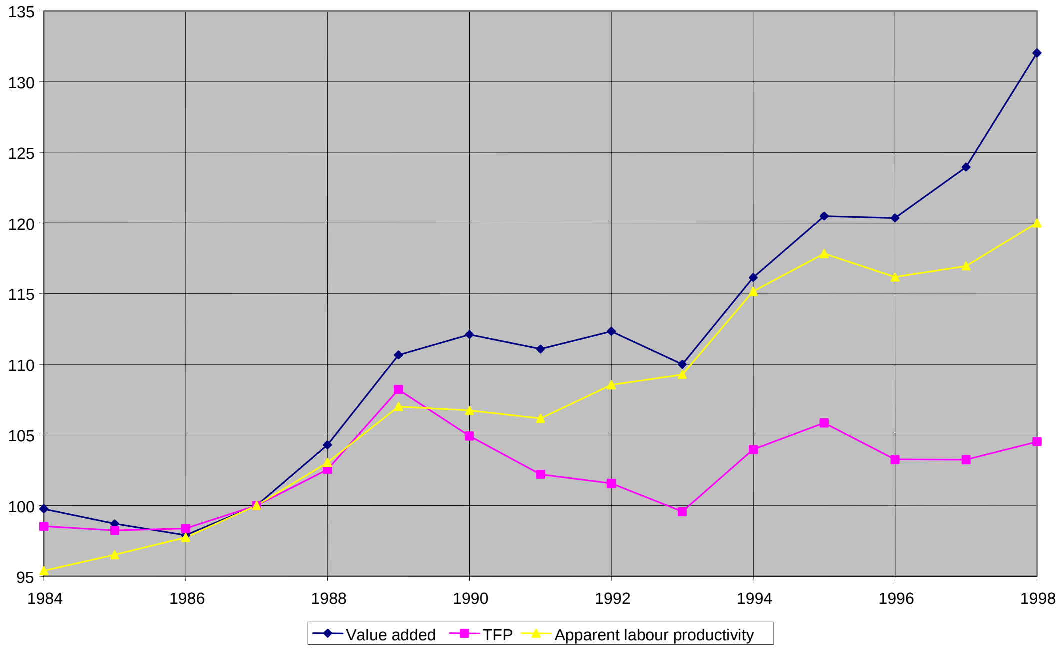
[9] To be more precise, our aggregation procedure determines the overall share of the remuneration of labour in value added α_L and its breakdown between the three skill levels $\tilde{\pi}_{L_i} = w_i L_i / \Sigma w_l L_l$. The share of each skill level of the labour factor is then defined by $\pi_{L_i} = \alpha_L \tilde{\pi}_{L_i}$. The share of the global remuneration of capital, defined as the complement to unity of the total labour share, is then broken down between the nine types of asset *pro rata* to the share in the total cost of capital $\tilde{\pi}_{K_i} = c_{K_i} K_i / \Sigma c_{K_l} K_l$. The cost of capital is defined according to the Jorgenson formula, i.e. $c_{K_i} = p_{K_i}\left(1-\left(1-\delta_{K_i}\right)\left(1+\Delta p_{K_i}/p_{K_i}\right)/1+r\right)$. The share of the remuneration of each type of asset being considered is then $\pi_{K_i} = \left(1-\alpha_L\right)\tilde{\pi}_{K_i}$

[10] The underlying reason for this choice is that the relative shares $\tilde{\pi}_{K_i}$ (defined in the previous footnote) are better measured than the shares in total costs. In fact, the relative shares will not be biased in the event of a multiplicative and identical measurement error regarding the remuneration of each of the forms of capital.

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 graph 2.1 shows, TFP, the residual portion of this decomposition, 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.

Graph 2.1: Evolutions in value added, apparent labour productivity and TFP over the period 1984-1998



Note: For all three series 1987 = 100. Coverage: non-financial non-farm enterprises. Evaluations made using data from tax date for firms subject to the BRN regime.

For our decomposition, we therefore chose a long period (1987-1998). 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 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 utilisation 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 NICT. The theoretical framework we adopted makes it possible to analyse the long-term determinants of growth and the evolution in prices. It seems difficult, therefore, to identify a change in trend by comparing periods as short as these. This is why we have not shown a decomposition for the second half of the 1990s.

Part 3: Contribution of it capital to growth in value added and in prices: aggregated evolutions

The past ten years have seen a rapid accumulation of IT capital by firms. This explains why, despite the still marginal role it plays in the productive factor combination, IT capital has made a major contribution to growth in value added. Over the period 1987-1998, the accumulation of IT capital has made a contribution of 0.3 of a point to growth, which itself is put at an annual average of 2.6%. At the same time, the use of this factor has made it possible to keep down production costs and hence the price rise. The decline in the price of computers made a negative contribution of 0.3 of a point to the 1.4% annual average price rise over the period. Moreover, the marked build-up in IT equipment has made a substantial contribution to the growth in labour productivity.

Production factors

In 1998, the remuneration of IT capital represented 1.8% of value added. This share has steadily increased, despite pro-cyclical fluctuations. In 1984, for example, it was only 1.2%. This evolution reflects the growing importance of IT in the productive factor combination.

However, this share remains very small in relation to the other production factors (table 3.1). One finds here the familiar conclusions regarding the respective overall positions of labour and capital, with labour accounting for roughly two-thirds of value added. The highest skill level represents a little over half the share of the remuneration of labour and the lowest level roughly one-sixth. Technical installations account for a little under two-thirds of the remuneration of capital, "buildings, construction and general installations" one-third and the remuneration of IT capital only 5%.

Table 3.1: Production factors over the period 1987-1998

	Share of value added	Annual factor growth rate (volume)	Annual growth rate of factor costs
Labour	68.2%	1.4%	2%
of which: Growth in numbers employed		*0.9%*	
Improvement in labour quality		*0.5%*	
Unskilled	9.5%	-0.6%	0.7%
Skilled	23.5%	0.4%	3.0%
Highly skilled	35.1%	2.8%	2.5%
Capital	31.8%	3.7%	-0.3%
Building, constr., gen. install'ns	10.5%	1.3%	1.4%
Technical installations	19.6%	3.8%	0.0%
Information technology	1.7%	19.4%	-15.1%

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

The stock of IT capital rose very strongly in volume in the period 1987-1998, with an annual growth rate put at almost 20% (table 3.1). There were two main causes. The first is related to the massive increase in purchases of computers by firms, made possible by the fall in prices. However, looking beyond this quantitative aspect, the increase in volume emerging from our calculation incorporates the effects of the improved performance of computers, since we are using a hedonic price index (box 2.2) and this plays a central role in this connection. The hedonic method consists essentially of deducting from the change in unit prices a component corresponding to the improvement in quality obtained by users. The price index we use is therefore calculated at constant quality. As computer performance has improved considerably in the past 20 years, the fall in the price of computers has been very marked throughout the period (see Cette, Kocoglu and Mairesse (2000a) for a more comprehensive discussion of the hedonic method). The growth rate in IT capital therefore reflects the sharp increase in the services provided by increasingly powerful computers.

As regards the other factors of production, the standard results are found: capital has increased much faster than labour over the period 1987-1998. The annual growth rate in numbers employed is put at 0.9%. This masks very different tendencies at different skill levels. The numbers of the highly skilled have risen steeply (by 2.8% annually), whereas the numbers of the unskilled have declined. This tendency is reflected in an improvement in the quality of the labour factor (+0.5%).

Decomposition of growth

The decomposition of growth at aggregate level is shown in table 3.2. For annual average growth of 2.6% over the period 1987-1998, the contribution of labour as a whole is 1 point and that of capital 1.2 points. The residual portion, corresponding to TFP gains, is 0.4%.

IT capital has made a substantial contribution to growth. We estimate it to be 0.3 of a point per year, on average, equivalent to almost a third of that of capital as a whole. It is therefore relatively high, especially in view of the small share of computers in the productive factor combination. This is due to the very rapid increase in volume of this production factor. The volume of the two other capital asset groups has risen much less rapidly, so that their contributions to growth are of a comparable order of magnitude.

Our evaluation of the contribution of IT capital to growth is distinctly higher than that shown by other studies using French data (box 3.1), which give estimates ranging between 0.1 and 0.2 of a point. This difference stems mainly from differences in the valuation of the IT share of the factor combination, which in turn reflects differences in the basic information used. As for the evolution of IT capital, all the studies using French data find a very marked accumulation during the past fifteen years, of the order of 20% a year.

Estimates using American data give much higher contributions, ranging between 0.2 and 0.6 of a point during the 1990s. They also seem to indicate a much more rapid accumulation of IT equipment during the second half of the 1990s, resulting in large part from a more rapid fall in the deflators used in the studies (see box 3.1 for more detail).

To arrive at a quantitative estimate of the surplus related to the accumulation of IT capital, one can compare the actual growth with what the growth would have been had IT capital increased at the same rate as other capital goods[11]. With the same notations as in part 1, the surplus can then be written:

$$\pi_{K_{INF}}\left(\Delta \log K_{INF} - \Delta \log K_{OTHER}\right)$$

where $\Delta \log K_{OTHER}$ is the growth rate of the other capital goods. This growth rate can be evaluated at 2.9% a year. The growth differential between IT capital and other forms of capital is then 16.6%, which, given the 1.7% share of IT in value added, leads to a substantial growth surplus, amounting to 0.3 of a point over the period 1987-1998. This calculation of the surplus is obviously very simplistic. In particular, if IT capital had indeed grown at the same rate as the other capital goods, there would certainly have been less substitution between IT capital and other capital goods, so that the latter would have grown faster than was in fact the case.

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[11] The growth rate for the other capital goods is defined as the mean of the growth rates, weighted by their relative elasticities (Divisia index).

Table 3.2: Decomposition of growth over the period 1987-1998

	Value added	Prices
Growth rate	2.60%	1.44%
Contribution from labour	0.97%	1.64%
Unskilled	-0.07%	0.07%
Skilled	0.08%	0.71%
Highly skilled	0.96%	0.85%
Contribution from capital	1.19%	-0.07%
Bdg, constr., gen. install'ns	0.12%	0.15%
Technical installations	0.74%	0.02%
Information technology	0.32%	-0.25%
TFP growth rate	0.44%	0.12%

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

The TFP gains obtained are low by comparison with those shown by other studies. For example, Accardo et al. (1999) find TFP gains of the order of 0.8% (annual average) over the period 1990-1997[12]. Apart from what can be imputed to differences in the data used, this differential may originate from the fact that we distinguish IT capital from the other factors of production.

As defined in the theoretical growth accounting framework (see equation (1)), the growth rate of capital is a Divisia index of the growth rates of each of the constituent elements, the weights being the relative shares of each of them in the total cost:

$$\Delta \log\left(K^{DIV}\right) = \sum \pi_{K_i} / \pi_K \, \Delta \log K_i = \sum \left(c_{K_i} K_i \Big/ \sum c_{K_j} K_j\right) \Delta \log K_i \qquad (3)$$

On the other hand, when no distinction is made between the capital goods, the growth rate can be approximated by a Divisia index having as weights the shares of the capital elements in the total stock:

$$\Delta \log\left(K^{TOT}\right) = \Delta \log\left(\sum K_i\right) \approx \sum \left(K_i \Big/ \sum K_j\right) \Delta \log K_i \qquad (4)$$

In practice, the usage costs for IT capital are much higher than for other capital goods because of its rapid depreciation and the sharp fall in the price of computers[13] so that the weight corresponding to the growth rate of IT capital is less high in this second definition. Not distinguishing IT capital from other capital goods produces an overall growth rate of capital that is lower as a result of the high usage cost of IT capital compared with other capital goods[14]. The TFP growth rate is therefore higher when the heterogeneity of capital goods is ignored.

One can obtain an idea of the scale of the differences between these two definitions by

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[12] This magnitude corresponds to the estimates of TFP obtained when the authors take no account of the skills structure of labour.

[13] To give an order of magnitude, a usage cost is calculated corresponding to 100 francs invested in IT capital and 100 francs invested in another capital good with an interest rate of 10%: $c_{KINF} K_{KINF} \approx (r + \delta - \Delta p / p) p K_{KINF} = (0.1 + 0.2 + 0.135)100 = 43.5$ $c_{KOTH} K_{OTH} \approx (0.1 + 0.1 + 0.01)100 = 19$

[14] Note, moreover, that using a single deflator for all the capital goods leads to a considerable underestimate of the growth rate of IT capital because of the very rapid fall in the price of computers. The error made by using a common deflator for IT capital and other capital goods therefore helps to amplify the underestimation of the growth rate of the capital aggregate to a substantial extent.

repeating the decomposition of growth in two ways: first, without distinguishing IT capital from office equipment and furniture; second, by making no distinction between capital goods. When IT equipment and office equipment and furniture are brought together, the TFP gains rise substantially, from 0.44% to 0.48%. When the heterogeneity of different capital goods is totally ignored, the growth rate of IT capital falls substantially in equation (4), being mixed in with a large number of goods with substantial weights, the result being that the TFP gains rise from 0.44% to 0.71%. These figures are very close to the ones generally obtained in studies making no distinction between various types of capital.

The fact that the TFP gains are considerably reduced when the heterogeneity of production factors is taken into account is a classic conclusion. For example, the measure of the TFP growth rate in Accardo et al. (1999) is highly sensitive to the correction introduced by the authors to take account of the heterogeneity of the labour factor, changing it from +0.8% to -0.5% for the period 1990-1997.

Decomposition of the evolution in prices

Table 3.2 shows a decomposition of the evolution in the price of value added as a function of the evolution in the costs of various factors and the TFP gains. According to our calculations, the spread of computers has helped to moderate inflation to a substantial extent, by holding down the rise in production costs. In fact, the cost of IT capital has fallen by an annual average of more than 15% over the period 1987-1998 (table 3.1). Despite the small share of IT capital in the productive factor combination, the result is a substantial negative contribution evaluated at 0.3 of a point, compared with overall price growth of 1.4%[15].

Total factor costs are shown to grow on average by 1.6%. This rise is explained by that of labour costs, which contribute 1.6 points to the rise in total factor cost. The total cost of capital makes a contribution that is generally negative, this being related to the fall in the cost of IT capital, on the one hand, and the slow rise in the cost of other forms of capital, on the other.

As in the primal decomposition, the automatic decline in prices linked to the evolution of the cost of IT can be defined by:

$$-\pi_{K_{INF}}\left(\Delta\log P_{K_{INF}} - \Delta\log P_{K_{OTHER}}\right)$$

where $\Delta\log P_{K_{OTHER}}$ represents the evolution in the cost of the other capital goods. Given the small share of IT in the productive factor combination and the small rise in the prices of other capital goods, this magnitude is not substantially different from the contribution to the price rise. If the price of IT had risen at the same rate as those of other capital goods, inflation would have been 1.7% instead of the 1.4% observed. The fall in the price of computers has therefore made an appreciable contribution to keeping the overall price rise down.

Decomposition of the growth in labour productivity

The preceding results can also be used to calculate the contribution of IT capital to the growth in labour productivity, which rose by 1.7% on average over the period 1987-1998 (table 3.3). Of this growth, 0.3 of a point is explained by the rise in IT capital per head. The contribution of the rise in overall capital-intensity is 0.9 of a point and most of this is

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[15] The TFP evaluated using the dual approach (0.1%) is appreciably smaller than that obtained with the primal approach (0.4%). This difference between the TFP evaluations in the two approaches has been frequently reported and commented on. Roeger (1991) shows that it can be explained in terms of imperfect competition on product markets.

related to technical installations (0.6 of a point). Finally, the labour productivity gains are also linked to an improvement in the quality of labour (0.4 of a point) and to TFP gains (0.4 of a point).

Table 3.3: Decomposition of growth in apparent labour productivity over the period 1987-1998

Value added growth rate	2.60%
Growth in numbers employed	0.91%
Growth in apparent labour productivity	1.69%
Improvement in labour quality	0.36%
Contribution from capital intensity	0.88%
Building, constr., gen. install'ns	0.03%
Technical installations	0.55%
Information technology	0.31%
TFP growth rate	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.

Part 4: Contribution to growth in the producer and user sectors

The contribution of computerisation to growth in the economy is not due solely to its diffusion in the user sectors. For some authors (Gordon (2000)), the impact of this diffusion is even negligible, with most of the contribution reflecting the existence of substantial TFP gains in the sectors producing the new-technology goods. It is therefore useful to repeat the preceding analysis separately for the NICT producer sectors and the other sectors, which we shall call the user sectors. In this approach, one examines the role of IT as production factor through diffusion effects in the user and producer sectors and as the product of the production process via the productivity gains in the producer sectors[16].

The NICT producer sectors are not limited to sectors producing specifically IT capital goods. They also include several service sectors. We have adopted the same definition as Berthier (2000) who classifies the NICT producer sectors into three branches:

- The IT branch

  manufacture of office machines and IT equipment
  wholesaling of office machines and IT equipment (services)
  IT activities (services)

- The electronic 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)

- The telecommunications branch

  manufacture of broadcasting and transmission equipment (telephones)
  telecommunications

The share of these sectors in total value added within the coverage of our study was relatively stable from 1987 to 1998, averaging 7.6% over this period. Using national accounts data, Berthier (2000) puts these sectors' share of total value added at 4.8%, which is compatible with our own evaluation, since the coverage we have chosen is more restricted than Berthier's, including only non-farm non-financial private sectors, whose weight in total value added (estimated using national accounts data) is 64% on average over the period in question. This result is therefore approximately the same for the NICT sectors as Berthier's when this difference is taken into account (0.64*7.6% = 4.9%).

Within the NICT producer sectors, that of computer services is the largest in terms of value added, accounting on average for 25% of the value added of all NICT producer sectors in the period 1987-1998. Next comes the manufacture of computers, with 19%. The French productive system is therefore fairly well placed for the production of IT services as well as for computers.

Our results show that the TFP gains in the producer sectors have been very substantial: 5.2% taking the primal approach and 5.8% taking the dual approach over the period 1987-1998. These values are very close to the ones obtained by Accardo et al. (1999) for the electric and electronic equipment construction sector (TFP growth rate of 6.0% over the period 1990-1997), branches which include, inter alia, the three NICT producer sectors with the largest TFP gains in our own study[17]. The productivity gains in the NICT

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[16] Note that we do not confine our analysis to sectors producing IT equipment, but also consider sectors producing other forms of NICT. A complete approach would examine the role of NICT (and not simply IT equipment) as production factor. However, no data are available concerning the other NICT goods and services used by firms.

[17] The sector concerned is that of the manufacture of IT equipment and office machines, the manufacture of electronic components and the manufacture of reception apparatus as well as the sector of recording and reproduction.

producer sectors made a substantial contribution to growth at aggregate level over the period 1987-1998: 0.4 of a point out of total growth of 2.6%. The diffusion of IT has also made a substantial contribution, which we put at 0.3 of a point. All things considered, TFP gains and diffusion of IT explained 0.7 of a point of the 2.6% growth in the period 1987-1998. Similarly, the overall contribution of computerisation to the evolution in prices over the period is substantial, being put at -0.7 of a point out of the modest annual average rise of 1.4% in the period. Here again, two-thirds can be imputed to evolutions originating in the producer sectors.

Distinguishing the producer and user sectors resulted in no modification in the contribution of the accumulation of IT capital to growth (0.3 of a point) compared to the evaluations for the economy as a whole (see Part 3). On the other hand, it made it possible to put a figure on the contribution of productivity gains in the producer sectors (0.4 of a point).

Production factors

Table 4.1 compares the characteristics of the producer sectors and the user sectors. The shares of the remuneration of each factor in value added differ between the two. The producer sectors are much more intensive users of highly skilled manpower and of IT than the user sectors.

The production factors have grown more in the producer sectors. However, contrary to what one might have expected, the accumulation of IT capital was slightly less rapid than in the user sectors. It is the technical installations and the skilled labour that were responsible for most of the factor growth in the producer sectors. It will also be noted that in these sectors there was a considerable fall in unskilled labour (3.3%).

Table 4.1: Factor shares and their growth rates in the producer and user sectors

	Factor shares		Factor growth rates (volume)		Factor cost growth rates	
	Users	Producers	Users	Producers	Users	Producers
Labour	67.9%	72.7%	1.35%	2.63%	2.4%	2.3%
of which: Growth in numbers employed			*0.86%*	*1.71%*		
Improvement in labour quality			*0.49%*	*0.92%*		
Unskilled	9.9%	4.7%	-0.52%	-3.25%	0.7%	0.4%
Skilled	24.0%	17.1%	0.36%	0.56%	3.0%	2.1%
Highly skilled	33.9%	50.9%	2.65%	3.88%	2.5%	2.6%
Capital	32.1%	27.3%	3.67%	4.60%	-0.2%	-1.1%
Bdg, constr., gen. install'ns	10.8%	6.5%	1.38%	-1.34%	1.4%	2.6%
Technical installations	19.8%	17.5%	3.70%	4.48%	0.0%	0.1%
Information technology	1.5%	3.3%	19.90%	16.73%	-15.1%	-14.9%
Growth rates in value added or prices			2.13%	8.28%	1.91%	-4.32%

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

Decomposition of growth and of the price evolution

Table 4.2 shows the decomposition of growth in value added and in prices in the producer sectors and the user sectors. A striking result is the importance of the TFP gains in the producer sectors. These amounted to 5.2% according to the primal approach, and to 5.8% in the dual approach. This is in sharp contrast to the TFP gains in the user sectors, which were of the order of 0.1% under the primal approach and even negative in the dual approach. This means that it was mainly productivity gains that enabled the producer sectors to expand more rapidly and to reduce their prices to a great extent.

Table 4.2: Contribution of IT to growth in value added and in prices in the producer and user sectors

	Decomposition of growth in value added		Decomposition of growth in prices	
	Users	Producers	Users	Producers
Growth rates in value added or prices	2.13%	8.28%	1.91%	-4.32%
Labour	0.90%	1.89%	1.63%	1.62%
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	1.18%	1.24%	-0.06%	-0.18%
Bdg, constr., gen. install'ns	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	0.05%	5.15%	-0.34%	5.76%

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

Another important difference concerns the role of IT, which is systematically more important in the producer sectors than in the user sectors, the contribution being twice as large in the former. This means that the contribution of the accumulation of IT capital to growth was 0.3 of a point in the user sectors and almost 0.6 of a point in the producer sectors. Similarly, the contribution to the evolution of prices of the cost of IT capital is –0.2 of a point in the user sectors and –0.5 of a point in the producer sectors.

Table 4.3 shows the contribution of IT and the new technologies to overall growth in the economy. In the user sectors, the contribution of IT to growth is defined, as previously, on the basis of the share of the remuneration of IT capital in value added and the growth rate of IT capital. On the other hand, in the producer sectors, it is appropriate to add the TFP growth rate since it represents the substantial technical progress achieved in the field of new technologies. One can then determine a global contribution of computerisation to growth by summing the various components, weighted by the share of these two groups of sectors in total value added. The total contribution to growth can then be written:

$$\sigma^U\left(\pi^U_{K_{INF}}\Delta\log K^U_{INF}\right)+\sigma^P\left(\pi^P_{K_{INF}}\Delta\log K^P_{INF}+\Delta\log TFP^P\right)$$

where σ^U et σ^P represent the respective shares of the user and producer sectors in total value added $\left(\sigma^U+\sigma^P=1\right)$. One then arrives at a contribution to growth that is very substantial, amounting to 0.7 of a point, out of growth of 2.6%. An important portion of this contribution corresponds to the TFP gains in the producer sectors (0.4 of a point). Even so, the contribution of the diffusion of IT capital is by no means negligible, since, taking all sectors together, it amounts to 0.3 of a point, only slightly less than the contribution of the TFP gains achieved in the producer sectors.

This means that, while the effects of the diffusion of IT capital are twice as large in the producer sectors (0.55 of a point as against 0.3), singling them out from the user sectors does not alter the contribution of the accumulation of IT capital to growth. This results from the limited share of total value added in the producer sectors within the coverage of our study (7.6%). On the other hand, despite this low share of value added, the producer sectors make a substantial contribution to growth as the result of the very high productivity gains enjoyed by these sectors.

In the same way, one can define the total contribution of computerisation and the new technologies to the evolution in prices by:

$$\sigma^U\left(\pi^U_{K_{INF}}\Delta\log P^U_{K_{INF}}\right)+\sigma^P\left(\pi^P_{K_{INF}}\Delta\log P^P_{K_{INF}}-\Delta\log TFP^P\right)$$

According to our calculations, the total productivity gains achieved in the producer sectors reduced the price rise by 0.4 of a point, with the fall in the cost of IT capital resulting in a moderation of inflation by 0.3 of a point. The computerisation process and technical progress in the NICT field are therefore seen to have reduced inflation substantially, by 0.7 of a point, compared with inflation of 1.4% over the period 1987-1998.

Table 4.3: Overall contribution and additional growth due computerisation over the period 1987-1998

	Value added	Prices
Growth rate	2.60%	1.44%
Overall contribution	0.71%	-0.69%
Users (92.4% of VA)	0.28%	-0.21%
Producers (7.56% of VA)	0.43%	-0.47%
of which: IT	*0.04%*	*-0.04%*
TFP	*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.

Decomposition of the growth in labour productivity

The decomposition of growth in terms of labour productivity shows that the sectors producing the new technologies have been much more dynamic than the user sectors. The growth rate for value added for the producers is over 8% for the period 1987-1998, compared with only 2.1% for the user sectors (table 4.4). This growth is above all the result of a major improvement in labour productivity in the producer sectors, itself linked to the very high TFP growth. This confirms that the producer sectors have for some time been benefiting from the technical progress achieved in the field of new technologies, which has enabled them to increase their workers' productivity substantially. Moreover, the decomposition of growth also reveals that the NICT producer sectors have been more dynamic in terms of employment. The growth rate in numbers employed in these sectors was 1.7%, compared with 0.9% for the user sectors. Only the most highly skilled workers, however, have benefited from this dynamism of employment, as the numbers employed at the other two skill levels stagnated or fell in the producer sectors (table 4.1).

Table 4.4: Decomposition of growth in apparent labour productivity over the period 1987-1998

	Users	Producers
Value added growth rate	2.13%	8.28%
Growth in numbers employed	0.86%	1.71%
Growth in labour productivity	1.28%	6.57%
Improvement in labour quality	0.33%	0.66%
Contribution from capital intensity	0.89%	0.75%
Bdg, constr., gen. install'ns	0.04%	-0.20%
Technical installations	0.55%	0.46%
Information technology	0.29%	0.49%
TFP growth rate	0.05%	5.15%

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

Part 5: Diffusion of it at sectoral level

The contributions of IT to growth and to lower prices are substantial, both in the producer sectors as a group and in the group consisting of the sectors using the new technologies. Nevertheless, one cannot conclude that the diffusion of IT has affected all sectors in the economy. In fact, our data at refined (2-digit) sectoral level for the user sectors shows that the bulk of the diffusion effects are concentrated in a few sectors making particularly large contributions.

The weights of the factors in the productive factor combination as measured by the shares in value added vary widely from one sector to another. They remained relatively stable over the period 1984-1998. For each factor, the share of the total variance explained by inter-sectoral differences is in fact very large, being close to 90% (table 5.1). Only 10% of this variance results from variations over time.

Table 5.1: Shares in value added of the different production factors over the period 1984-1998 (user sectors)

	Mean	Standard deviation	Inter variance	Intra variance
Labour	68.5%	17.5%	92.8%	7.2%
Unskilled	10.7%	8.3%	91.8%	8.2%
Skilled	24.5%	11.7%	95.8%	4.2%
Highly skilled	33.3%	12.7%	92.7%	7.3%
Capital	31.5%	17.5%	92.8%	7.2%
Bdg, constr., gen. install'ns	10.9%	8.4%	89.2%	10.8%
Technical installations	19.2%	14.2%	94.9%	5.1%
Information technology	1.4%	1.1%	86.9%	13.1%

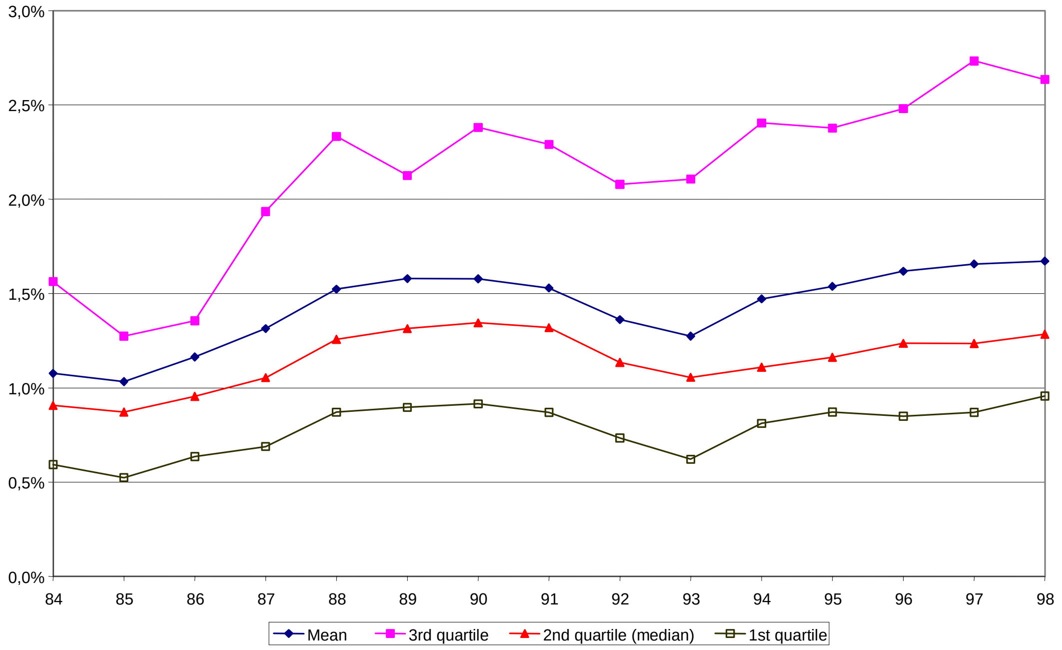
Note: Annual average changes. Coverage: non-financial non-farm enterprises. Evaluations made using data from tax returns by firms subject to the BRN regime.

IT capital is the production factor whose share of value added has varied most over time, with the average rising from 1.2% in 1984 to 1.8% in 1998 (graph 5.1). 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, moreover, that the dispersion of this share increases over time, with the interquartile difference widening from around 0.9% in 1984 to 1.6% in 1998. This shows that IT usage remains marginal in a large number of sectors. In fact, in 1998, 50% of the sectors recorded an IT share that was less than 1.3% and for 25% of them the share was less than 1.0%. Graph 5.1 also shows that IT can be used intensively: in 25% of sectors, the IT share exceeds 2.6%. Finally, it should be noted that the distribution of the share of IT is highly skewed (the median is much lower than the mean), highlighting that the use of IT is confined to a small number of sectors.

Graph 5.2 shows the share of IT capital in value added in 1998 in relation to its 1984 share. It will be seen that there was a general tendency for the share to rise. However, the graph, again highlighting the heavy concentration of the distribution of shares at the lower end of the scale, shows that sectors which used IT only to a small extent in 1984 have increased their recourse to IT only marginally in the course of these 15 years. On the other hand, the share of IT has risen sharply in sectors that were already using this tool[18].

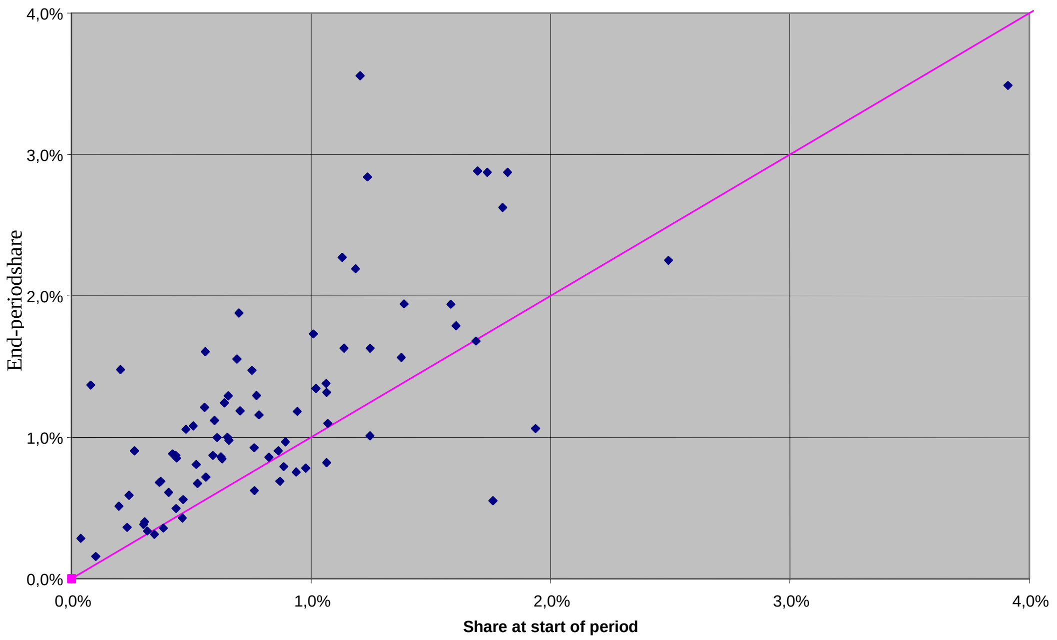
[18] Except at the two extremes, where the share has remained more or less constant; the sectors of "publicity and market research" (4%) and "mail and delivery services" (2.5%).

Graph 5.1: Evolution in the distribution of the share of IT capital over the period 1984-1998 (user sectors)



Note: This graph shows a number of different statistical representations of the distribution of the share of IT in value added: the mean, with each sector weighted by its value added, as well as the three quartiles. Coverage: non-financial non-farm enterprises, excluding NICT producer sectors.

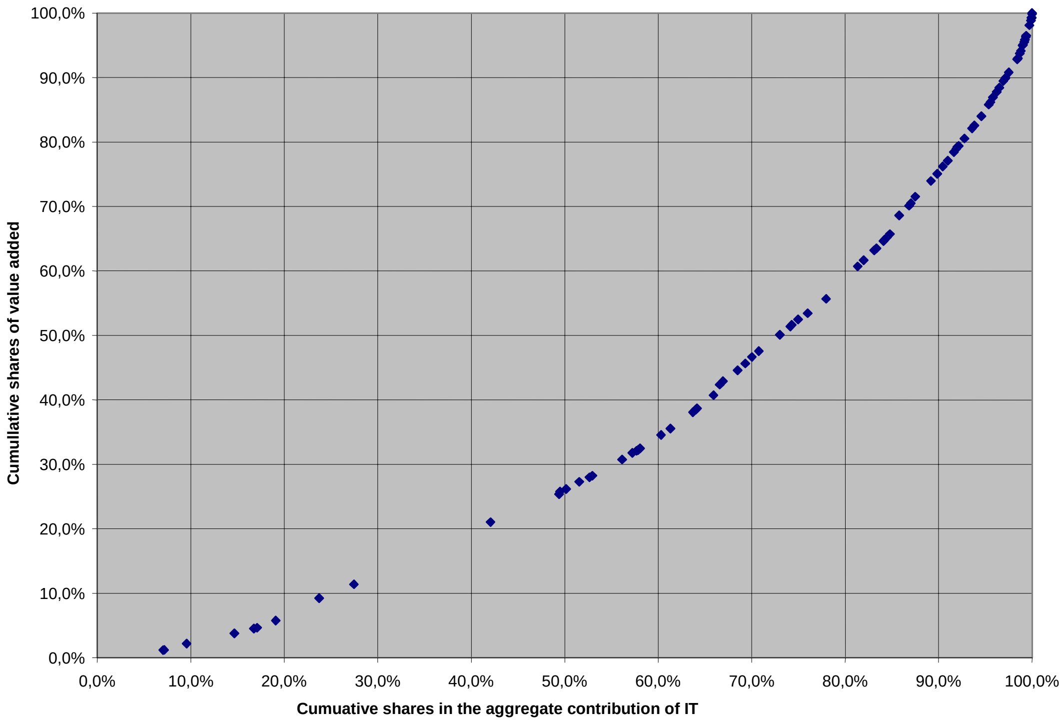
Graph 5.2: Evolution in the IT share between 1984 and1998 (user sectors)



Note: Each sector is represented on this graph by the share of IT in its value added at the start and end of the period. Coverage: non-financial non-farm enterprises, excluding NICT producer sectors.

Graph 5.3 shows on a cumulative basis the weighting of sectors in value added as a function of the cumulative weight of the sectors in the aggregated contribution to the growth in IT capital, when the sectors are ranked by decreasing order of intensity of recourse to IT. For example, the graph shows that 50% of the overall contribution of IT to growth took place in only 13 sectors (out of 90), accounting together for slightly over 25% of value added. 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. Most of the contribution of IT to growth is found in these sectors. In analogous fashion, it is shown that the contribution of IT to the evolution of prices is concentrated in the same sectors

Graph 5.3: Cumulative shares in value added as a function of the cumulative shares in the aggregate contribution of IT capital to growth (user sectors)



Note: To produce of this graph, the sectors were initially ranked in decreasing order of share of IT in value added. Each sector's share of aggregate value added was then calculated, as well as its share of the aggregate contribution of IT. It is the cumulative values of these two shares that are shown here. Coverage: non-financial non-farm enterprises, excluding NITC producer sectors.

Conclusion

In this study, we have attempted to evaluate the contribution of IT capital to growth, using company accounts. This source has enabled us to estimate the stock of IT equipment and, on various hypotheses, the contribution of the new technologies to growth. It should be borne 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 and makes it possible to have a better idea of the role of computerisation in our economy.

We find a much larger contribution of IT to growth than has been reported in the other studies using French data. This is mainly due to the data source used, which automatically gives a larger share to IT capital. In absolute terms, however, the role of IT in the productive factor combination remains small. Our analysis also makes it possible to quantify the impact of the diffusion of IT on costs and prices.

In line with Gordon (2000) and Oliner and Sichel (2000), we distinguish the NICT producer sectors from the others in order to measure the respective importance of the effects of IT diffusion and the effects related to gains in total productivity in the producer sectors. According to these authors, it would seem in fact that the NICT producer sectors made a particularly important contribution to American growth during the 1990s. Our results show that the diffusion of IT, as well as the total productivity gains in the producer sectors, made a substantial contribution to French growth over the period 1987-1998.

Lastly, we examine the sectoral heterogeneity of the diffusion of IT, finding that this remains confined to a small number of sectors.

In our study, we have isolated the two mechanisms by which computerisation 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. We find that both effects are substantial. Out of growth of 2.6% a year over the period 1987-1998, the overall contribution of computerisation is evaluated at 0.7 of a point, of which 0.4 corresponds to productivity gains made in the producer sectors and 0.3 to the diffusion effects.

References

Accardo, Bouscharain et Jlassi (1999) Le progrès technique a-t-il ralenti depuis 1990 ? Economie et statistique, N° 323

Berthier (1998) Prix du matériel informatique pour la rétropolation Note INSEE, DESE, N° 047/G420

Berthier (2000) L'impact de la production des nouvelles technologies de l'information et de la communication sur la croissance L'Economie Française, INSEE, Edition 2000-2001

Bouscharain (2000) Quelques précisions sur les évolutions de la productivité en France Note INSEE, DESE, N° 3/G221

Carré, Dubois et Malinvaud (1972) La croissance française Edition du Seuil 1972, Paris

Cette, Kocoglu et Mairesse (2000a) La diffusion des technologies de l'information et de la communication en France : Mesure et contribution à la croissance Miméo pour le CAE

Cette, Kocoglu et Mairesse (2000b) Les technologies de l'information et de la communication en France : Quelques considérations méthodologiques Economie et Statistique, A paraître

Cette, Kocoglu et Mairesse (2000c) L'Evaluation du capital en matériels informatiques et de sa contribution à la croissance sur la base des séries longues de la comptabilité nationale L'Economie Française, Edition 2000-2001

Crépon, Desplatz and Mairesse (1999) Estimating price cost margins, scale economies and workers' bargaining power at the firm level Document de travail INSEE, DESE, N° G9917

Duhautois (1999) Evolution des flux d'emplois en France entre 1990 et 1996 : une étude empirique à partir du fichier des bénéfices réels normaux (BRN) Document de travail INSEE, DESE, N° G9915

Fraumeni (1997) Evolution des flux d'emplois en France entre 1990 et 1996 : une étude empirique à partir du fichier des bénéfices réels normaux (BRN) Survey of Current Business, BEA, Volume 77 N°7

Gordon (1999) Has the new economy rendered the productivity slowdown obsolete? Miméo

Griliches (1971) Price indexes and quality change : studies in new methodes of measurement Federal Reserve Board, Harvard university press

Hall (1988), The relationship between price and marginal cost in the US industry Journal of Political Economy, N° 96

Heckel (2000) La contribution à la croissance du capital informatique L'Economie Française, INSEE, Edition 2000-2001

Jorgenson et Stiroh (2000) Raising the Speed Limit : US Economic Growth in the Information Age Mimeo pour l'OCDE

Lequiller (2000) La croissance comparée France-USA est-elle affectée d'un biais statistique ? Note INSEE, DESE, N° 92/G401

Klette et Griliches (1996) The inconsistency of common scale estimators when output prices are unobserved and endogeneous Journal of Applied Econometrics, N° 11

Manuel de Canberra (1999) Draft Manual on the Measurement of Capital Stock OCDE, mimeo

Moreau (1991) A price Index for microcomputers in France Document de travail INSEE, DSE, N° G9109

Oliner et Sichel (2000) The Resurgence of Growth in the Late 1990s : Are Computers the Story ? Journal of Economic Perspectives, A paraître

Roeger (1991) Can imprefect competition explain the difference between primal and dual productivity measures ? Journal of Political Economy, N° 103

Solow (1957) Technical Change and the Aggregate Production Function Review of Economics and Statistics, Vol N°39

Shreyer (2000) The contribution of information and communication technology to output growth : a study of the G7 countries STI Working paper 2000/2

Stiroh (1998) Computers, Productivity and Input Substitution Economic Inquiry, N° 36

Whelan (2000) Computers, Obsolescence and Productivity Federal Reserve Board, Paper 2000-6, February

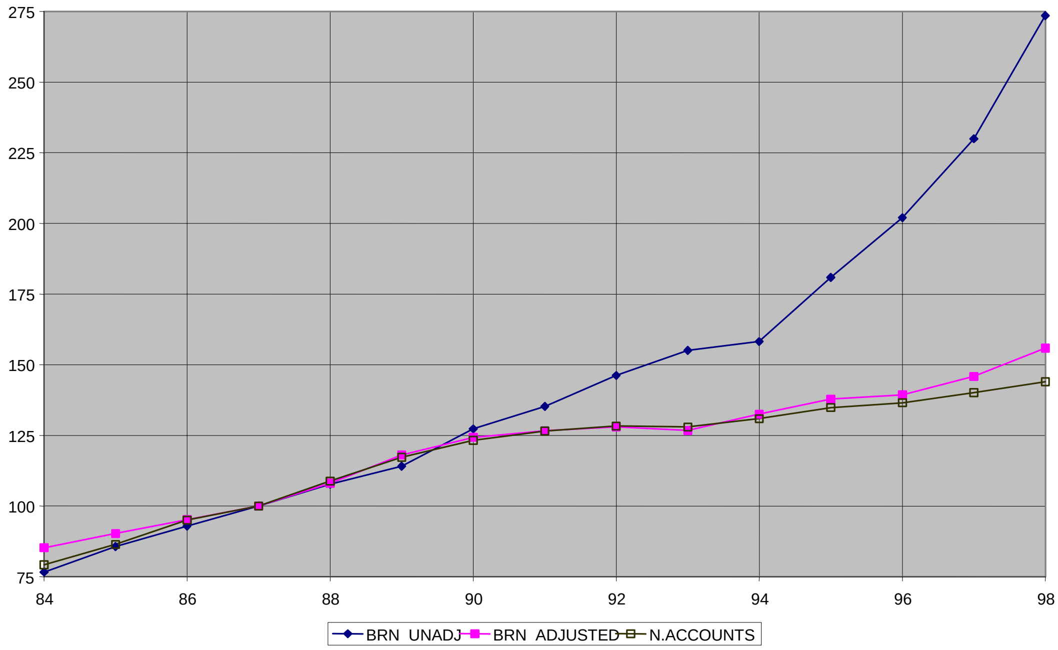
Box 2.1

The tax source

Information from tax returns has provided us with a measure of activity and of the utilisation 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% of taxable firms in terms of sales[19]. The data were examined for the period 1984-1998.

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[20].

Evolution of value added



Note: This graph shows the evolution of value added before clean-up (BRN UNADJ) and after (BRN ADJUSTED), as well as the corresponding evolution drawn from the national accounts. For all three series 1987 = 100. Coverage: non-financial non-farm enterprises. Evaluations on the basis of tax returns by firms subject to the BRN regime.

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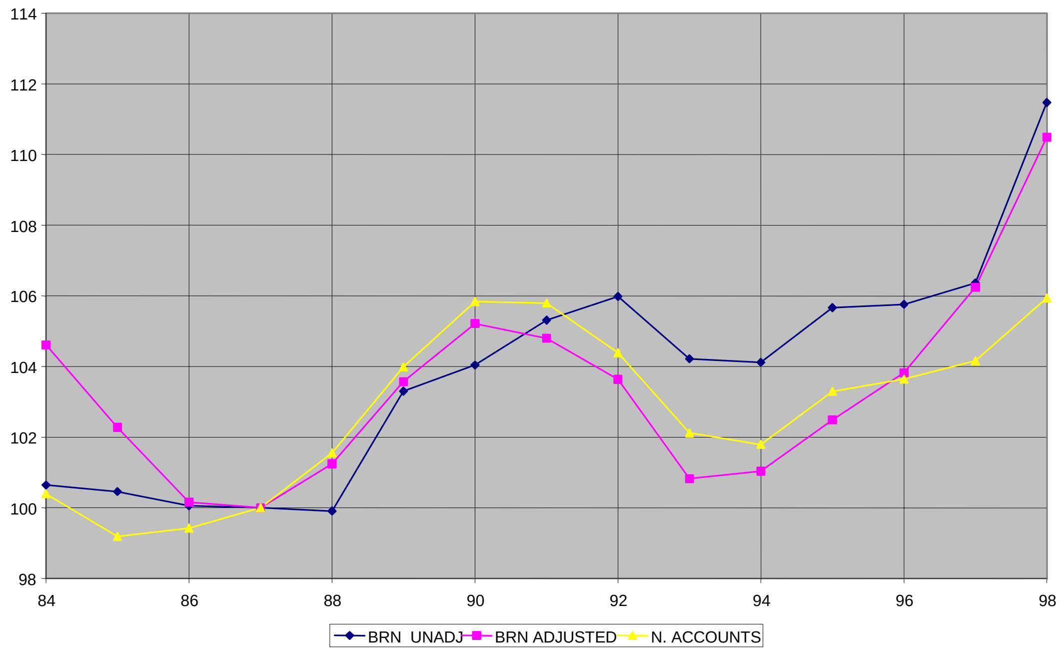
[19] The BRN regime applies to all firms with sales of more than 3.8 million francs. This tax regime accounts for roughly 95% of total sales of the so-called "BIC-IS" firms (firms subject to taxation of commercial profits and to corporation tax), which themselves correspond to 94% of the sales of all taxed firms. The figure of 95% was calculated in 1990, that of 94% in 1992.

[20] The way in which the data were cleaned up was largely inspired by the method followed by Duhautois (1999), whom we wish to thank here, stressing that he is not responsible for any errors we may have committed.

Following this stage, we have at our disposal a database of roughly 300,000 firms belonging to most sectors in industry and services [21]. The scale of the sample, as well as the aggregate evolutions attained (see graphs above and below) ensure the representativeness of this sample. The data are 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 IT user sectors from the sectors producing IT equipment and the new technologies in general.

Evolution of employment



Note: This graph shows the evolution of employment (numbers employed) before data clean-up (BRN UNADJ) and after (BRN ADJUSTED), as well as the corresponding evolution derived from the national accounts. For all three series 1987 = 100. Coverage: non-financial non-farm enterprises. Evaluations on the basis of tax returns by firms subject to the BRN regime.

[21] Note that banks and insurance companies have had to be excluded from the coverage of the study, despite the fact that they account, on average, for roughly 24% of the stock of IT capital at current prices for all sectors over the period 1984-1998. 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.

Box 2.2

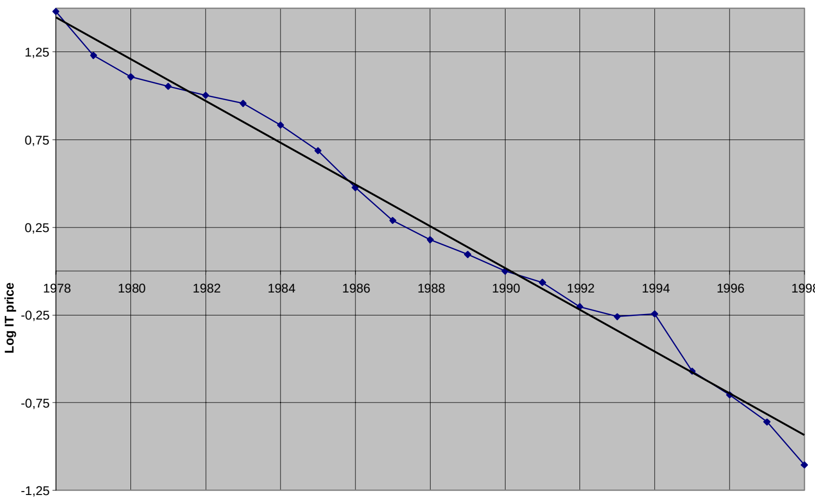
The IT equipment price index

The sector producing IT equipment has experienced substantial productivity gains in recent decades and, simultaneously, major price cuts. As a result, the price of investment in IT equipment fell by almost 13.5% a year over the period 1978-1998. On average, it halved every four years[22], whereas the price of technical installations rose at an annual average rate of 2.3% over the same period.

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 been compiling this type of index only since 1990 (Moreau (1991)). 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[23].

For the construction of capital series, it is necessary to have available a series of prices for IT capital covering a long period. We have 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[24] before 1990. It was then linked in to the national accounts index from 1990 on. The series thus obtained was then smoothed by taking a three-year moving average. The steep drop in prices of IT equipment in the past 25 years (see graph) therefore reflects 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% a year. This result is similar to that obtained by Cette et al. (2000c) for the period 1977-1997 (14.7%).

Evolution in the IT equipment price index between 1978 and 1998



Note: Log IT equipment price calculated on the basis of the national accounts index after 1990, and with the help of the BEA index prior to that date (see text above)). 1990 = 1. The graph also shows the straight-line trend for the whole of the period 1978-1998.

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22 Actually, according to the so-called “Moore's Law”, the price of computing power falls by half every 18 months. The price index we used does not fall as fast.

23 It would seem that from then on, the American price index has declined faster than the French. See Lequiller (2000) for further detail.

24 A dollar effect was added to the BEA index to take account of the predominance of the United States in the manufacture of computers. It is nevertheless assumed that exchange-rate variations are not entirely passed on into the prices of imported computers. This is why it was decided to add only part of the exchange-rate variations. See Berthier (1998) for further detail.

Box 2.3

Production factors: value, volume and cost

We separate out nine types of capital goods, assembled into three groups: IT capital, technical installations and construction. We also distinguish three skill levels for the labour factor. The series were all compiled on the basis of individual data, aggregated at various levels of classification.

Data concerning the labour factor

The data concerning the labour factor 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 the permanent 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 the first fortnight of October, so that the sampling ratio is 1/26. The information contained in the DADS relates to occupational category and remuneration. We used data aggregated at two-digit level.

Given the low sampling ratio, this information was used only to constitute the fixed scales for breaking 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 them we took three skill levels defined on the basis of the occupational category (CSP):

Skill level groups constituted using the DADS

	Occupational category
Unskilled	Unskilled white- and blue-collar workers (CSP N° 53, 55, 56, 67, 68, 69)
Skilled	Skilled white- and blue-collar workers (CSP N° 52, 54, 62, 63, 64, 65)
Highly qualified	Business heads, senior executives and intermediate (CSP N°2, 3, 4)

Note: Definition of the three skill levels based on occupational category.

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 selected 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 historic cost (KH) to current prices (KV). Expressed formally, one has:

$$KH_t = p_t I_t + \ldots + p_{t-T} I_{t-T}$$
$$KV_t = p_t I_t + p_t I_{t-1} + \ldots + p_t I_{t-T}$$

where *I* represents the investment flow in volume and *p* the corresponding price index. To move from one to the other, one uses the information contained in the stock of amortisation $AH_t = \left(p_{t-1}I_{t-1}...+Tp_{t-T}I_{t-T}\right)/T$. If one assumes that the price rise is constant and not too large, it is possible to make the following approximations to express capital at current prices:

$$\begin{aligned} KV_t &\approx p_t I_t + (1+\dot{p})p_{t-1}I_{t-1} + ... + (1+\dot{p})^T p_{t-T}I_{t-T} \\ &\approx KH_t + \dot{p}\left(p_{t-1}I_{t-1} + ... + Tp_{t-T}I_{t-T}\right) \\ &\approx KH_t\left(1+\dot{p}\left(T \times AH_t\right)/KH_t\right) \\ &\approx KH_t\ p_t/p_{t-a} \end{aligned}$$

where $a = T \times AH_t / KH_t$ can be interpreted as the average age of the capital. The adjustment to move from capital at historic cost to capital at current prices then 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 estimated on the basis of the amortised portion of the capital.

This adjustment was applied to each of the capital goods making assumptions on service lives based on amortisation provisions (DAH). Assuming straight-line amortisation, then

$T = KH_t / DAH_t$ and one obtains as averages for the period:

Average service lives over the period 1984-1998

	Construction	General installations	Technical installations	Transport equipment	Office equipment, furniture and IT equipment	Packaging and miscellaneous
Average service life (years)	27	12	11	7	6	6

Note: Service lives calculated on the basis of amortisation on fixed assets (see text above). Coverage: non-financial non-farm enterprises. Evaluations on the basis of tax returns by firms subject to the BRN regime.

These service lives are close to those used for the French national accounts and normally adopted in company accounts. They are also similar to those usually applied in the United States (Canberra Manual (1999) and Fraumeni (1997)). Oliner and Sichel (2000), for example, use an average service life of five years for computers.

Breakdown of fixed assets between the different types of capital

For all firms subject to the BRN regime, the fixed asset accounts distinguish only 3 types of capital and this is not sufficient to isolate 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 equipment, furniture and IT equipment" (see table below), 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.

Tangible fixed asset accounts available for all firms subject to the BRN regime and available for a sample of them

Breakdown of the available fixed asset account	
All firms	For firms in the sample
Constructions	Construction on own land Construction on others' land General installations, fittings and arrangement of the constructions
Technical installations, industrial equipment and tools	Technical installations, industrial equipment and tools
Other fixed assets	General installations, miscellaneous fittings and arrangements Transport equipment **Office equipment, furniture and IT equipment** Miscellaneous re-usable packaging

Note: Detail of the tangible fixed asset items in the balance sheet contained in the tax returns.

This sample is virtually exhaustive as regards the larger firms, since it covers more than 90% of firms with more than 500 employees subject to the BRN regime (see table below). Small firms, on the other hand, are under-represented, only 2.5% 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% (historic cost). This is a consequence of the very 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.

Representativeness of the sample for which details of fixed assets are available

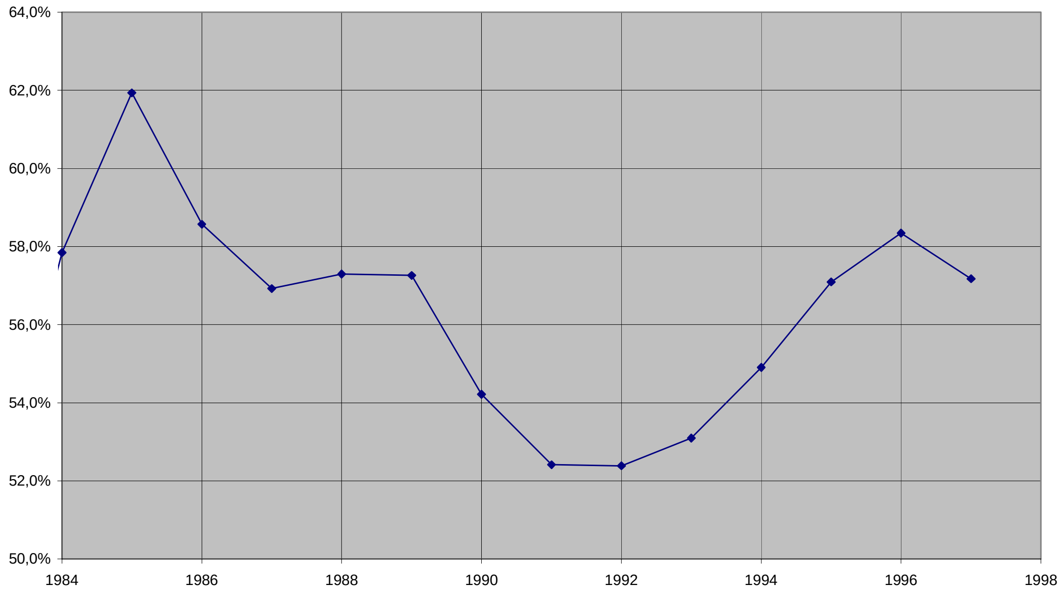
Number of employees	< 20	20 -100	100-500	>500	**Total**
$(KINF/KTOTAL)unadj.$	3.18	3.69	2.86	2.61	2.83
$(KINF/KTOTAL)adjusted$	2.97	3.66	2.97	2.62	2.98
Proportion of firms in the sample (%)	2.5	17.2	64.9	90.5	6.23

Note: The ratios were calculated using historic cost. Proportions are those of 1995. Coverage: non-financial non-farm enterprises. Evaluations on the basis of tax returns by firms subject to the BRN regime.

Share of IT capital in the "office equipment, furniture and IT equipment" item

The share of IT capital in the "office equipment, furniture and IT equipment" item is estimated to be 50% on the basis of the investment flows in the national accounts at aggregated level for each of the goods making up this item. The following graph shows that there has been little evolution during the period in question.

Share of IT equipment in the investment corresponding to the item "office equipment, furniture and IT equipment"



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

Cost and remuneration of capital goods

The cost and remuneration of the various types of capital good distinguished here were calculated on the basis of the usage cost formula (see Part 2 for the measurement of the share of each of the factors) which introduces the cost of financing and the rate of depreciation. The cost of financing was estimated at two-digit sectoral level on the basis of company data as the apparent interest rate (ratio of financial charges to debt). The depreciation rate was taken as the inverse of the service life of the asset.

Box 3.1

Contribution of IT capital to growth: lessons from other studies

The results of our study are comparable to those of several other studies based on the theoretical framework of decomposition of growth set out in Part 1. Our evaluation of the contribution of IT capital to growth is substantially higher than those of other studies using French data (Cette, Kocoglu et Mairesse (2000b) and Shreyer (2000)), which gave estimates ranging between 0.1 and 0.2 of a point (see table below)[25]. This difference stems mainly from differences in the evaluation of the share of IT in the productive factor combination, which Cette et al. put at 0.4%, whereas according to our calculations it is 1.7%. These differences partly originate from the use of different sources of information. The two studies mentioned are in fact based on national accounts data whereas our study uses the aggregation of individual company data. The studies nevertheless have in common that they highlight a relatively low level for the share of IT in value added and an upward tendency in this share, which also emerges from the data in the present study (graph 5.1).

Evaluations for France

	Cette, Mairesse & Kocoglu (2000b)			Shreyer (2000)*		
	1969-1979	1979-1989	1989-1999	1980-1985	1985-1990	1990-1996
Share of remuneration of IT capital	0.3	0.4	0.4	0.3	0.9	0.9
Growth rate of IT capital	37.4	27.7	24.4	N/A.	N/A.	N/A.
Contribution to growth made by IT capital	0.11	0.12	0.10	0.17	0.23	0.17

Note: Annual averages.

** Comprising not only IT capital but also communication equipment.*

All the studies using French data also reveal a very rapid build-up of IT capital in the past ten years, of the order of 20% a year. This is linked to the massive increase in firms' purchases of computers, made possible by the fall in prices, and to the improvement in computer performance, since we use a hedonic price index which plays a central role in this connection (box 2.2). It is mainly because of the very steep fall observed in the price of IT equipment that the growth rate in the services provided by computers is so rapid and the contribution so important.

Uncertainties regarding the evaluation of the IT share also emerge in the studies using American data (see table below). It is therefore a delicate matter to compare the absolute shares in the two countries. However, all studies, including our own, show the share to be rising, which reflects the growing importance of IT in the productive factor combination both in France and in the United States.

Estimates using American data are seen, in addition, to indicate 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 used in the studies. The fall in the index for the price of investment in IT equipment used by Jorgenson and Stiroh (2000) is around 15% for the period 1990-1995, fairly similar to our own conclusion (13.5% for the period 1987-1998). On the other hand, it reaches almost 30% for 1995-1998, which helps to increase the growth rate measured for IT equipment.

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[25] In fact, the evaluations by Shreyer (2000) relate to the contribution of IT capital, but also of telecommunications equipment. The contribution he would obtain for IT capital on its own (not available) would therefore seem very close to that arrived at by Cette et al. (2000b).

Evaluations for the United States

	Jorgenson & Stiroh (2000)			Oliner & Sichel (2000)		
	1973-1990	1990-1995	1995-1998	1974-1990	1991-1995	1996-1999
Share of remuneration of IT capital	N/A.	1.0	1.3	1.0	1.4	1.8
Growth rate of IT capital	N/A.	18	34	31	18	36
Contribution to growth made by IT capital	0.20	0.19	0.46	0.27	0.25	0.63

Note: Annual averages.

These very high estimates for the second half of the 1990s are, moreover, underestimated according to Whelan (2000). He shows that the estimates on the subject do not take account of the fact that the physical wear and tear in the case of computers is very small and that it is rapid technological obsolescence that induces firms to renew their IT capital stock. This leads him to higher estimates of the stock of IT capital and a larger contribution to growth, of the order of 0.82 of the period 1996-1998.