

SKILLS, TECHNOLOGY AND GROWTH

IS ICT THE KEY TO SUCCESS?

PART I: AN ANALYSIS OF ICT IMPACT ON FRENCH GROWTH

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TABLE of CONTENTS

SUMMARY	3
ABSTRACT	4
RéSUMÉ LONG	5
RéSUMÉ COURT	6
Introduction	7
1. Methodology	8
1.1. The analysis framework	8
1.2. Capital services	10
1.3. Labour services	13
2. Results	15
2.1. Labour	15
2.1.1. Data and analysis	15
2.1.2. The evolution of labour quality in France	17
2.2. Capital	20
2.2.1. Investment series	20
2.2.2. Price series	21
3. Growth accounting	23
3.1. Contributions of ICT to the growth of the French economy	24
3.2. The average hourly labour productivity	28
Conclusion	30
Bibliography	32
APPENDIX	34

SUMMARY

This paper aims at assessing the contribution of ICT to growth in France at the macro-level. It is a first step towards a thorough identification of the sources of growth across industries, that will help understand more properly the importance of the contribution of ICT to overall productivity in the ICT-using- and producing industries in France. On the labour side, we also evidence the role played by hours worked by stressing the contributions of various factors to the labour quality and the way they intervene in explaining the labour productivity change in the period 1995-00.

The results obtained for France are compared to some big countries, and namely the United States, that provides a useful reference although sometimes a little bit tricky, when the distance between Europe and the USA is considered in terms of economic cycles.

By applying the Jorgenson's method to implement the growth accounting and the one of P. Schreyer from the OECD to assess price series, our estimates of the contribution of ICT to the French growth of value added happen to be slightly higher (0.46% per year over 1995-00) than results obtained in other studies (around 0.35%). Though moderate, the French contribution is roughly comparable to the British one but it is far behind that of the U.S.. The grounds underlying this gap are to be investigated in ICT investment shares and not in growth rates of investment. ICT investment growth is indeed as much sustained in France as in the U.S., but the proportion of U.S. ICT investment in total investments is almost thrice as high as the French share (the share of ICT investments in value amounts to 24% of total investment in the U.S. and 10.5% in France).

The contribution of ICT to the hourly labour productivity growth accelerated quite strongly in 1995-00 over the previous period. This acceleration was indeed accompanied by an acceleration in the total factor productivity but not by an increase in the quality of the French labour. The latter has indeed increased regularly till the period 1990-95, namely thanks to the contribution of education. Over the last period, the fall in the quality of French labour is in sync with the rise in hours worked by less well-paid workers and namely young workers. But the latter will accumulate human capital over their life-time, and will then contribute to improve the labour quality, all the quicker they have graduated in school.

ABSTRACT

This paper aims at assessing the contribution of ICT to growth in France at the macro-level. On the labour side, we also evidence the role played by hours worked by stressing the contributions of various factors to the labour quality and the way they intervene in explaining the labour productivity change in the period 1995-00.

One of the reasons why France lags behind the U.S. in terms of ICT contribution to growth is that although ICT investment growth is as much sustained in France as in the U.S., the proportion of U.S. ICT investment in total investments is almost thrice as high as the French share.

The contribution of ICT to the hourly labour productivity growth accelerated quite strongly in 1995-00 over the previous period. This acceleration was indeed accompanied by an acceleration in the total factor productivity but not by an increase in the quality of the French labour. The latter has indeed increased regularly till the period 1990-95, namely thanks to the contribution of education. Over the last period, the fall in the quality of French labour is in sync with the rise in hours worked by less well-paid workers and namely young workers. But the latter will accumulate human capital over their life-time, and will then contribute to improve the labour quality, all the quicker they have graduated in school.

Keywords: Information & communication technologies, growth accounting, labour quality, capital services.

J.E.L.: J21, J23, J31, L63, O47.

RÉSUMÉ LONG

Ce papier tente d'évaluer la contribution des TIC à la croissance en France au niveau macro-économique. Il n'est qu'une première étape et les développements ultérieurs porteront sur l'identification des sources de la croissance au niveau sectoriel, et sur la contribution des TIC à la croissance de la productivité du travail dans les secteurs producteurs et utilisateurs de TIC. Nous mettons l'accent dans ce papier sur le rôle de la qualité du travail dans l'évolution de la productivité, notamment sur la période 1995-00 et repérons les facteurs qui favorisent ou au contraire détériorent cette qualité.

Les résultats que nous obtenons pour la France sont comparés à quelques grands pays, notamment les Etats-Unis, qui fournissent une référence utile bien que parfois trompeuse étant donné la distance séparant les Etats-Unis de l'Europe en termes de cycles économiques.

En appliquant la méthode de Jorgenson afin de réaliser la comptabilité de la croissance et celle de P. Schreyer de l'OCDE pour estimer les séries de prix, notre évaluation de la contribution des TIC à la croissance française de la valeur ajoutée est un peu plus élevée (0,46% par an sur 1995-00) que les résultats obtenus dans d'autres études (environ 0,35%). Bien que modérée, la contribution française est comparable à la contribution britannique mais reste bien en retrait de celle des Etats-Unis. Les raisons de cet écart sont à rechercher dans les parts de l'investissement et non dans son taux de croissance. En effet, les taux de croissance de l'investissement en TIC sont aussi soutenus en France qu'aux Etats-Unis mais la proportion des investissements américains dans les investissements totaux est près de trois fois plus élevée que la part française (la part en valeur des investissements en TIC s'élève à 24% de l'investissement total aux Etats-Unis contre 10,5% en France).

La contribution des TIC à la croissance de la productivité horaire s'est sensiblement accélérée entre 1990-95 et 1995-00. Cette accélération, qui se double d'une accélération de la productivité totale des facteurs ne s'est pas accompagnée d'une amélioration de la qualité du travail. Celle-ci a régulièrement augmenté en France jusqu'à la période 1990-95, grâce à la contribution de l'éducation. Cependant, sur la dernière période, la baisse de la qualité du travail français est concomitante à la hausse des heures travaillées des catégories de travailleurs moins bien rémunérés, en particulier les jeunes travailleurs. Mais ces derniers accumuleront du capital humain et contribueront à améliorer la qualité du travail d'autant plus vite qu'ils sont diplômés.

RÉSUMÉ COURT

Ce papier tente d'évaluer la contribution des TIC à la croissance en France au niveau macro-économique. Nous mettons l'accent sur le rôle de la qualité du travail dans l'évolution de la productivité, notamment sur la période 1995-00 et repérons les facteurs qui favorisent ou au contraire détériorent cette qualité.

L'une des raisons pour lesquelles la France reste en retrait des Etats-Unis quant à la contribution du capital TIC à la croissance est à rechercher non pas dans les taux de croissance de l'investissement en TIC qui sont similaires dans les deux pays mais dans les parts de l'investissement en TIC, la part américaine dans les investissements totaux étant près de trois fois plus élevée que la part française.

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Mots-clés: Technologies de l'information & des communications, comptabilité de la croissance, qualité du travail, services du capital.

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IS ICT THE KEY TO SUCCESS?

AN ANALYSIS OF ICT IMPACT ON FRENCH GROWTH

Johanna Melka and Laurence Nayman¹

INTRODUCTION

The slowdown of American growth in 2001 might convey the view that ICT is only a myth. However, the works on information technologies are not outdated in so far as the slowdown in the U.S. is attributed to a decrease in ICT investment and to a depletion of productivity gains. The issue of the contribution of ICT is then still on the hot line.

The stylised facts about the U.S. are now well established in the literature (Jorgenson & Stiroh, 2000; Oliner & Sichel, 2000; Jorgenson, 2001) whereas uncertainties as to what extent Europe lags behind the U.S. persist. As a matter of fact, few country studies related to ICT in Europe are available for lack of data.

For Europe, Van Ark et alii. (2002) evidenced that real investment and capital services increased in Europe at the same pace as in the U.S.. The gap with the U.S. is to be measured in terms of structure as the shares of ICT in total investment and capital service flows have been roughly half to two thirds of the U.S. level throughout 1980-2000. Moreover in their study, ICT capital service flows would explain 0.70% of the real average annual GDP growth in the United States, 0.37% in Europe and 0.27% in France over the period 1995-2000, what lies below the 0.36% found by Cette, Mairesse and Kocoglu, (2001) for the business sector in France. For the U.K., figures lie at a higher level, 0.57% over 1994-98 (Oulton, 2001), suggesting some variance across European countries.

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This paper aims at assessing the contribution of ICT to growth in France at the macro-level. It is a first step towards a thorough identification of the sources of growth across industries, that will help understand more properly the importance of the contribution of ICT to overall productivity in the ICT-using- and producing industries in France. At the macro-level, we assess how large the French productivity lag is. On the labour side, we evidence the role played by hours worked by stressing the contributions of various factors to the labour quality and the way they intervene in explaining the labour productivity change in the period 1995-00. A bracket of estimates for the total factor productivity will then be provided given the calculation carried out for the labour quality using alternatively skills by occupation or education cross-classified with other characteristics.

The results obtained in the growth accounting framework will be compared to some big countries, and namely the United States, that provides a useful reference although sometimes a little bit tricky, when the distance between Europe and the USA is considered in terms of cycles.

1. METHODOLOGY

The method initiated by Dale Jorgenson is used in order to assess the contribution of ICT to growth. After a presentation of the analysis framework (section 1.1), the methodologies used to build the capital and labour services will be described (sections 2 and 3).

1.1. The analysis framework

The accounting method used to assess the contribution of the new economy to growth and labour productivity in France is standard. The methodology applied is the one of Jorgenson and Griliches (1967) whose objective consists in tracing how the quality of inputs evolves with the scope of enhancing the possible substitution schemes between factors of production.

The function of production is assumed to be:

$$Y_t = F(K_t, L_t, T) \quad (1)$$

where: X_t expresses a vector of inputs, K_t capital services, L_t labour services, T total factor productivity.

In the translog production function (*transcendental logarithmic production function*), production is an exponential function of the logarithms of inputs.

$$Y_i = \exp \left[\begin{array}{l} \alpha_0^i + \alpha_X^i \ln X_i + \alpha_K^i \ln K_i + \alpha_L^i \ln L_i + \alpha_T^i \ln L_T + \frac{1}{2} \beta_{XX}^i \ln(X_i)^2 + \beta_{XK}^i \ln X_i \ln K_i \\ + \beta_{XL}^i \ln X_i \ln L_i + \beta_{XT}^i \ln X_i * T + \frac{1}{2} \beta_{KK}^i \ln(K_i)^2 + \beta_{KL}^i \ln K_i \ln L_i + \beta_{KT}^i \ln K_i * T \\ + \frac{1}{2} \beta_{LL}^i \ln(L_i)^2 + \beta_{LT}^i \ln L_i * T + \frac{1}{2} \beta_{TT}^i * T^2 \end{array} \right]$$

T (time) represents technical progress, the α and β coefficients being the respective weights of labour and capital in production.

The necessary conditions underlying the producer equilibrium imply that the shares in value of inputs are equal to the elasticities of production to these factors, that the returns to scale are constant and product and factors markets are perfectly competitive.

The equation (2) can be transformed as follows:

$$\Delta \ln Y = \bar{v}_{K,t} \Delta \ln K_t + \bar{v}_{L,t} \Delta \ln L_t + \Delta \ln A_t \quad (3)$$

Δ : first difference,

$\bar{v}_{K,t}$ is the average share of capital in domestic income, and $\bar{v}_{L,t}$ is the average share of labour in income.

$$\bar{v}_{K,t} + \bar{v}_{L,t} = 1,$$

A: is total factor productivity (T in equation 2).

The contribution of each factor of production to growth is determined from equation (3). The contribution of a factor of production to growth is equal then to the product of the rate of growth of the volume of this input (in including the evolution of quality of this factor of production) by the share of its return in value added.

Similarly, it is possible to assess the contribution of each type of capital to growth.

The average labour productivity by hours worked

By changing equation (3), the contribution of factors of production to growth of the average hourly labour productivity can be expressed in the form:

$$\Delta \ln y_t = \bar{v}_{K,t} \Delta \ln k_t + \bar{v}_{L,t} (\Delta \ln L_t - \Delta \ln H_t) + \Delta \ln A_t \quad (4)$$

with:

$$y_t = \frac{Y_t}{H_t} ; k_t = \frac{K_t}{H_t}$$

where H represents the volume of hours worked.

Growth of the average hourly labour productivity can then stem from:

- The “capital deepening”, or substitution of capital for labour, involved by a capital accumulation,
- The improvement of the labour quality defined as the difference between the rate of growth of the weighted labour input and hours worked,
- Growth of total factor productivity.

1.2. Capital services

The construction of capital services (or the like) involves that the efficiency of each type of asset is taken into account.

In that respect, each type of asset i at time t can perfectly be substituted for another asset i at time $t-1$. Actually, it is assumed that data on investment at constant prices allow for differences in the performance of the various assets. It means that price series used to deflate the investment series at current prices reflect the efficiency of assets.

The specificity of the approach assumed by Jorgenson and Griliches (1967) relies upon the construction of the asset rental prices, i.e. the cost of capital, that reflects the cost of using the asset at a given point of time. This cost embodies the price that will be paid by an agent to use the asset (put for rent).

First step: construction of a productive stock of capital: the permanent inventory method.

According to this method, the capital stock is defined as the weighted sum of past investments. The weights are defined by the relative efficiency of capital assets of different ages.

The capital stock for the asset i at time t is defined as:

$$K_t = \sum_{\tau=0}^{\infty} d_{\tau} I_{t-\tau}$$

where K_t is the capital stock (of a given asset) at time t , d_t represents the efficiency of capital at age τ relative to the efficiency of a new capital good bought at time $t - \tau$.

It is then necessary for the follow-up of our study to know the pattern acknowledging the loss of efficiency. For our part, the rate of depreciation we chose is the geometric one, as a constant rate of depreciation according to the works of Hulten and Wykoff (1981) seems to be a good approximation of the Box-Cox rates (see Jorgenson and al., 1987, p.119).

The capital stock is defined as:

$$K_{i,t} = K_{i,t-1}(1 - d_i) + I_{i,t} = \sum_{\tau=0}^{\infty} (1 - d_i)^{\tau} I_{i,t-\tau}$$

with:

d : geometric rate of depreciation,

I : investments at constant prices.

τ : age of capital.

2nd step: construction of the rental price of capital services (or cost of capital).

Our next objective is to construct costs of capital in the same way as Jorgenson (1987).

The cost of capital is equal to the cost of financing the asset i minus the loss or gain in capital.

$$c_t = p_{t-1}(r_t + d_t) - (p_t - p_{t-1})$$

p_t : price of the asset at time t ,

r_t : rate of return of capital.

The first term reflects the cost of financing the asset i with $p_{t-1}r_t$ being the opportunity or the financial cost borne at the time of the acquisition of the asset,

$p_{t-1}d_t$: the cost related to the declining efficiency of the asset since its acquisition.

The second term points to the gain or the loss in capital generated by the reselling of this asset after use.

The rental price of capital services is equivalent thus to the price of using the asset during a given period of time, under the consideration of its declining efficiency during this period and its reselling at the end of the period, and not to its acquisition price.

Which rate of return must be chosen?

To compute the cost of capital, the alternative between external rates of return (ERR) such as the long rates on government bonds and an internal rate of return (IRR) comes forth.

The internal rate of return is calculated from the following accounting identity:

Income from capital = Gross value added (GVA) – labour compensation.

Capital income is then defined by the national accounts (NA). Symmetrically, as capital income is the product of the capital stock in volume and the price of capital, the rate of return can be deduced from the following formula:

$$\text{Income from capital} = c_t K_t = p_{t-1} \left(r_t + d_t - \frac{p_t - p_{t-1}}{p_{t-1}} \right) K_t$$

The choice of a IRR or a ERR reveals numerous drawbacks. If a ERR is adopted, the cost of capital used as a weight (the average share of each component in the value of property compensation) to estimate capital services, is determined externally. As a result, income from capital defined by the product of the cost of capital and the capital stock is different from capital income defined in the national accounts.

As for the IRR, its use implies that the function of production has constant returns of scale and that markets are perfectly competitive. Moreover, with an internal rate of return, the cost of capital can turn to be negative, whereas it is not the case for the ERR.

In spite of this drawback, the IRR will be chosen in order to keep consistency in the accounting framework.

3rd step: construction of the aggregate index of capital services.

The aggregate index of capital services for all assets is assumed to be a translog function of individual capital services (Jorgenson, 1987). The index of aggregate capital is defined by:

$$\Delta \ln K_t = \sum_k \bar{v}_k \Delta \ln K_k^t$$

The weights are given by the average shares of each asset type in total property compensation:

$$\bar{v}_k = 0.5(v_{k,t} + v_{k,t-1})$$
$$v_{k,t} = \frac{c_{k,t} K_{k,t}}{\sum_i c_{k,t} K_{k,t}}$$

where c_k is the cost of capital of each asset k .

Labour services are constructed along the same lines as capital services. Their purpose consists in retracing the evolution of the quality of labour. After a short presentation of the way labour services must be constructed, the method used to set the quality indices, which participate in the evolution of the labour input quality, will be described. The distinction between labour services and hours worked must be acknowledged to account for quality.

1.3. Labour services

Following the works of Jorgenson (1987, 2000, 2001), changes in the composition of labour must be considered as an essential component of the labour volume. Actually, the services generated in an hour by an engineer are different in terms of output than those produced by another category of labour. Hours worked must be disaggregated according to their different characteristics in order to account for the quality in labour services. If this disaggregation is not performed, neither substitution between the different inputs nor the growth of productivity can be identified.

Jorgenson's method (1987) is replicated to construct a constant quality index of labour volume with a translog function. The growth rate of the index of labour input, i.e. the labour services, is a weighted average of the growth rates of its components.

Methodology

Labour services are measured by the growth rate of total hours worked in the economy weighted by the share of compensation of each individual characteristic of labour in total labour compensation. Each component is weighted by its marginal product under the neo-classical hypothesis according to which labour is compensated at its marginal productivity.

$$\Delta \ln L = \sum_l \bar{v}_{Ll} \Delta \ln H_l$$

with L , labour services, H , hours worked and v , the weight, the overstrike stands for an average. The weight bears on the share of compensation of each characteristic in total compensation and is computed with a Törnqvist index, where $P_l L$ is compensation related to the considered characteristic:

$$v_l = \frac{P_l^L L_l}{\sum P_l^L L_l}$$

$$\bar{v}_{Ll} = 0,5 * [v_{Ll}(t) + v_{Ll}(t-1)]$$

For each characteristic of the labour force (for example, gender, age, occupation, etc.), the growth rate of hours worked weighted by the compensation share of the considered category is computed to get first-order partial indices. For instance, the first-order index computed over gender is the sum of hours worked by women and men weighted by the corresponding compensation of women and men. Then, the different characteristics are combined with each other to get second-order, 3rd-order, 4th-order and 5th-order indices. At the second order, two characteristics are combined (gender and age for example, or gender and qualifications, etc.) and so on. The last order will constitute the labour services.

Contributions to labour quality

The ratio of labour services computed on the different orders to the growth rate of hours worked (that are not weighted) is designed to measure the quality of labour input. The index of quality is the constant that allows hours worked to be transformed into flows of labour services. It gives the measure of the contribution of substitution between components of the labour input relative to the volume of hours worked.

$L_L = Q_L * H$, or:

$Q_L = L_L / H$, L being labour services, product of Q_L , the quality of labour and H , non weighted hours worked.

$$\Delta \ln Q^L = \sum_l \bar{V}_{Ll} \Delta \ln H_l - \Delta \ln H$$

If components of hours worked grow at the same pace, the index of quality of labour Q_L remains unchanged. The index of quality increases when components generating the most labour services – workers whose marginal product is high – grow faster than the other characteristics. On the contrary, it decreases when the least efficient hours worked grow faster than the others.

Contributions to the growth of the quality index allow changes in the composition of hours worked by each characteristic to be captured. Contributions of the different characteristics to the growth of the quality index are computed from the partial indices and hours worked.

Partial first-order indices of labour input differentiated relative to the growth rate of hours worked indicate the contribution of the characteristic to the growth of the index of labour quality. Partial second-order indices of labour input differentiated against the growth rate of

hours worked reflect the interaction between two characteristics excluding the effect of all others. This calculation is continued till the last order.

2. RESULTS

Results on the evolution of the labour quality in France and the specificities of the labour and French investment markets over the last twenty years will be first displayed before addressing the issue of the contribution of ICT to growth.

2.1. Labour

A short presentation of the data will be followed by an analysis of the labour force. Then, our results related to the evolution of the French labour quality will be discussed.

2.1.1. Data and analysis

Data

Detailed data on employment, hours worked and labour compensation by type come from two sources: the D.A.D.S. and the labour force surveys. The Déclarations Annuelles de Données Sociales (D.A.D.S.) is a form filled in by employers that cover 15 million people. Till 1992, one wage-earner out of 25 was included in the sample operated by the INSEE. Afterwards, the operation of the database is exhaustive. Hours worked before 1993 have been deduced from the wages duration provided in the D.A.D.S. Years 1981, 1983 and 1990 that are not available in the D.A.D.S. have been interpolated and the year 1999 extrapolated forward. The ratios calculated in this database have been applied to the series of employees, hours worked, and labour compensation, found in the national accounts in order to remain consistent with the growth accounting framework.

A second source has been used in order to get skills by education: the labour force surveys that cover households. The poll rate of this survey amounts to 1/300. As wages are not available before 1982, the period under review spans 1982-2001 in that database. The database has been wiped out in order to fit in the same field definition as the D.A.D.S.. Ratios are calculated on the distribution of total hours and wages on gender, age and degrees relative to total hours and wages summed on gender and age. These ratios are then applied to the D.A.D.S. database. We mean to keep the highest consistency by maintaining a common distribution by gender and age (the one of the D.A.D.S.). Moreover, the integration of degrees in the D.A.D.S. will help catch discrepancies between both databases.

In the D.A.D.S. database, we could so far separate out five characteristics: gender (2 : men, women), age (4 : <25 years old, 25-34, 35-54, >54), occupation (3 : very skilled, skilled and non skilled), the belonging to an ICT sector or not (2), the status (2 : full-time or part-time job). Age brackets have been cut off that way in order to be comparable with the results obtained by Jorgenson in the framework of the KLEMS project. The very skilled entail engineers, technicians and managers (23, 34, 35, 37 and 38 of the CS occupation classification); The skilled ones cover skilled white and blue collars (43, 46, 47, 48, 54, 55 and 62, 63, 65, 67 of the CS); the non-skilled gather the other observations. By distinguishing five types in the labour force, we can sum up 31 partial indices over 96 categories ($2*4*3*2*2$).

In integrating degrees in the D.A.D.S., we include six extra dimensions: graduates, university or professional degree (A level +2), A level (high school or professional), professional high school degree (CAP, BEP or this level), school leaving certificate (B.E.P.C.), no degree or C.E.P. The quality of labour when calculated with gender, age and degrees entail 48 ($2*4*6$) categories.

Analysis

Figures 4 to 16 presented in the appendix display the hourly labour compensation and hours worked from 1976 to 1999 in the D.A.D.S. database. Regressions are run against two sets of dummies: labour compensation values per hour are first regressed on gender, age, occupation, belonging to an ICT sector or working full/part-time and then only on gender, age and education. This means that labour compensation values per hour are corrected for differences of other characteristics, i.e the latter are maintained constant. These regressions allow to retrieve the mean with a confidence interval. Next to all results are very significant with a confidence interval below 1%.

It is found that occupation, belonging to an ICT sector, status and gender being equal, labour compensation per hour of the oldest (over 54 years old) relative to the ones of the youngest (under 25 years old) surge dramatically from 1992 on. This could exemplify the accumulation of human capital over the whole working life, though Crépon and alii. (2002) show that older workers are overpaid relative to their marginal productivity.

The gap in the hourly wages between the very skilled and the non skilled in terms of occupation widens by about 4% whereas this gap remains stable between the very skilled and

the non-skilled workers. In terms of education, graduates are paid 1.5 times as much as bachelors and people with no degree receive a third less than bachelors.

Men keep on being better paid than women in spite of a rise in their wages by about 11% between the beginning and the end of the period. Even if this hardly reflects productivity differences between men and women, the fact that unskilled women are overpaid relative to their marginal productivity balances roughly the fact that skilled women are underpaid (Crépon et alii, 2002). This is confirmed by graph 15: in terms of education, hourly wages of graduated women reached a trough in the 1991-95 period at 75% of the wages of graduated men and have gone up afterwards by some 7 points of percentage. In comparison, women with O'level are better paid.

The people employed by the ICT industries are relatively better paid but the gap between both ICT and non ICT sectors is not significant.

In terms of hours worked, women, the very skilled, the employees in the ICT industries and those working part-time are those whose worked hours have risen more steeply.

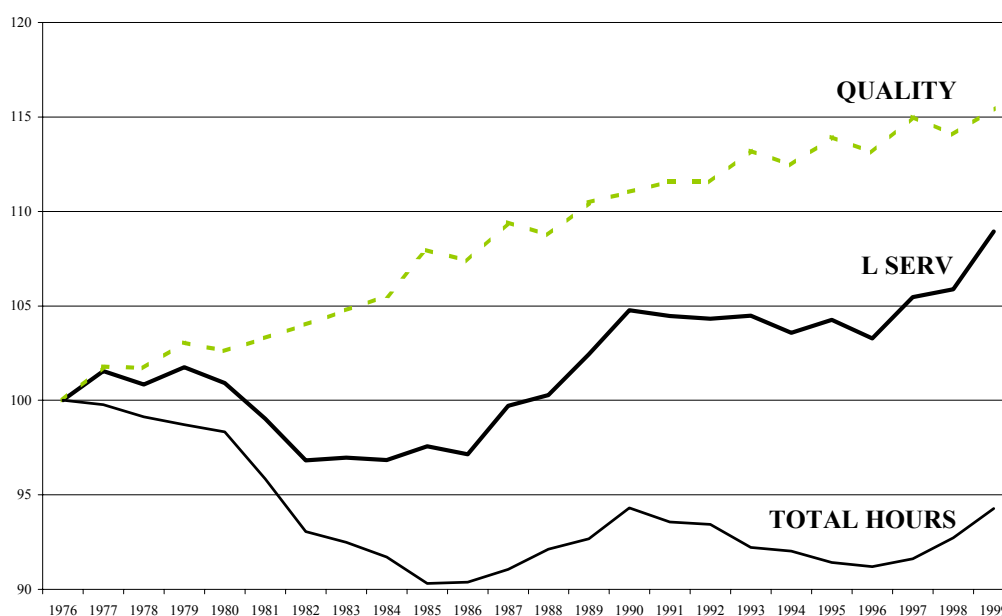
Skills and age should play as an engine in the changes intervening in the quality of labour. Results on the quality of French labour over 1980-00 will be displayed in the light of the stylised facts as described above and will be compared with figures obtained for the United States.

2.1.2. The evolution of labour quality in France

Figure 1 shows the indices of labour volume (labour services), quality and non-weighted hours worked, computed on gender, age, occupation, ICT and full-time characteristics since 1976. Quality has increased steadily since 1976 and has experienced a slowdown at the end of the period on account of hiring of younger employees. Labour services globally follow the trend of hours worked but the quality effect hampers labour services to fall further. The rise in hours worked at the end of the period contributes more than the declining quality index to the growth of labour services. Computed on gender, age and education, the profile of the curves are very similar to the first batch since 1982.

Graph 1: Convergence of labour input, quality and hours worked indices

In %



Note: 1999 is extrapolated with figures from the labour force surveys.

Source: D.A.D.S. and National Accounts, INSEE.

Information provided by the figure are corroborated by table 1. Differences in quality between both surveys, the D.A.D.S. and the labour force surveys are highlighted. Results are reported for the period 1982-99. The first line relates to the above-mentioned results of the D.A.D.S. including all characteristics but education. Quality 2 refers to quality when calculated on gender, age and education. At last, quality 3 is computed directly from the labour force surveys on gender, age and education. It is worth being noted that education must be a strong stimulus to the quality of labour: figures are highly positive throughout the period as evinced by the comparison of quality 1 and quality 2.

As shown in table 2, the growth in labour services is above all due to the rise in the quality of labour over the whole period 1982-99, as non-weighted hours worked evidence a small contribution. However, the breakdown in sub-periods allows to make out between the 1990-95 period when hours worked contributed very negatively and the 1995-2000 one when the quality of labour fell back due to the rise in total hours worked.

Contributions to the labour quality show that skills and age loom large in this context, the latter characteristic playing a major role in the deterioration of quality over 1995-99 due to the decrease in unemployment of the youngest. The contribution of education remains strong and has been ever growing over the whole period.

The findings of Jorgenson for the United States (table 3) contrast noticeably with those of France, hours worked and quality contributing positively to labour services throughout all periods. It is worth noting that the hiking of unskilled labour in the US over 1995-99 has an adverse effect on labour quality. The volume of total hours worked being large in the United States relative to France, the French quality index of labour outpaces the American one.

Table 1: Comparison of labour quality in the D.A.D.S. and labour force surveys, annual average, in %

	1982-99	1982-90	1990-99	1990-95	1995-99
QUALITY:					
1: D.A.D.S.	0.62	0.82	0.44	0.52	0.33
2: D.A.D.S.-LFS	0.84	1.04	0.66	0.78	0.52
3: LFS	0.89	0.74	1.02	1.08	0.95

Note: Year 1999 is extrapolated with figures from the labour force surveys.

Quality 1. D.A.D.S.: gender, age, occupation, belonging to an ICT sector, full- or part-time job,

Quality 2. Ratios from Labour Force Surveys applied to D.A.D.S.: gender, age, education,

Quality 3. Labour Force Surveys: gender, age, education.

Source: D.A.D.S. labour force surveys, National Accounts, & authors' calculations.

Table 2: Contributions to quality, annual average, in %

	1982-99	1982-90	1985-95	1990-99	1990-95	1995-99
QUALITY	0.84	1.04	0.80	0.66	0.78	0.52
GENDER	-0.02	0.00	-0.04	-0.04	-0.06	-0.02
AGE	0.23	0.44	0.22	0.04	0.26	-0.24
EDUCATION	0.64	0.60	0.62	0.68	0.62	0.75
Σ						
INTERACTIONS	-0.01	0.00	0.00	-0.01	-0.04	0.02
LH	0.08	0.17	0.12	0.00	-0.62	0.77
L	0.92	1.21	0.92	0.66	0.16	1.29

Note: L= labour services, LH= non-weighted growth rate of hours worked. Quality=L-LH.

Source: D.A.D.S. labour force surveys, National Accounts, & authors' calculations.

Table 3: Results from Jorgenson on services and labour quality in the USA

	1980-85	1985-95	1990-95	1995-99
QUALITY	0.41	0.54	0.66	0.25
LH	1.37	1.55	1.22	2.45
L	1.78	2.09	1.88	2.70

Source : Jorgenson & Ho (1999 & revised 2001)

Labour services and the quality of labour will be an input in the value added and productivity growth accounts presented further.

2.2. Capital

We will proceed first to a short analysis of the evolution of the ICT price and investment in volume in France and then we will display the results for France of the growth accounts and contrast them with those of other O.E.C.D. countries over the period 1980-00.

2.2.1. Investment series

Data

Out of six assets three are ICT assets (hardware, software and communication equipment); the three other categories are non-residential structures and buildings, transport equipment and other machinery. We use statistics released by the I.N.S.E.E. The underlying hypotheses are shown in tables 10 and 11.

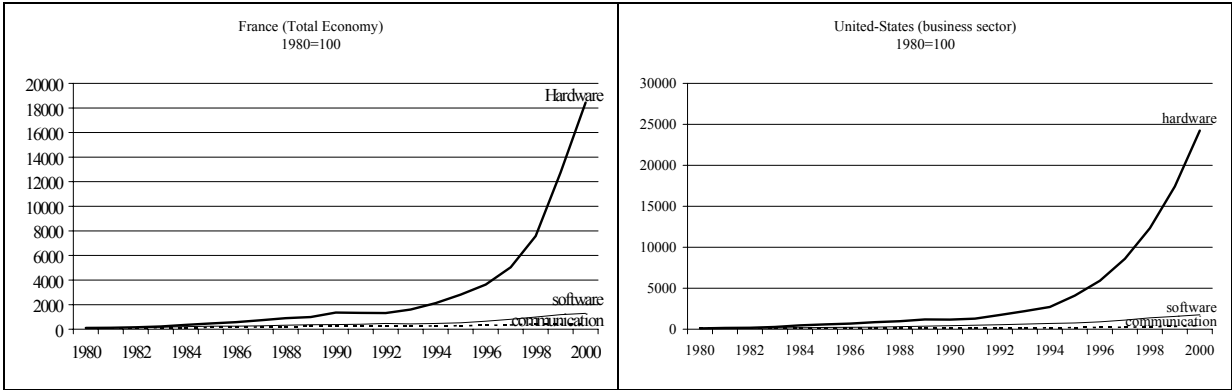
Analysis

The growth in investment in ICT at constant prices has dramatically surged over the last twenty years, due namely to the strong increase in hardware equipment with an annual pace of 30% over the period 1980-00, as investments in software grew at the same time by 14% and those in communication equipment increased by only 8%. Moreover, the growth in investments has mainly taken place over the last five years (1995-00).

When comparing the evolution of ICT investments in volume in the United States and in France², it comes forth that ICT investment growth in France was about the same as in the United States in the second half of the decade. Over 1995-00, the growth rate of French investment in hardware and software (46% and 20% respectively) even topped the American one (43% and 18% respectively). Conversely, the growth rate of investments in communication equipment in France (10%) featured a substantial difference with that of the United States that posted 18%.

Another difference is worth being emphasised: although the share in value of GFCF in GDP for the business sector in France is the same as the American share (17%) in 2000 (see table 12), the share of ICT investment in France (2%) notched quite under the American level (4%), what can amount to substantial differences in terms of catch-up in a growth accounting framework.

Graph 2: Evolution of French and American ICT investments



Source: INSEE, BEA and CEPII, authors' calculations.

2.2.2. Price series

Data

By applying the methodology suggested by Jorgenson, efficiency and substitution between assets can be taken into account. To do so, it is assumed that prices reflect the evolution of efficiency and then the quality of assets. Nonetheless, statistical offices have been

² It deals with the business sector in the United States and with total economy in France when the comparison is made on volumes and both on the business sector when the comparison relates to investment in value.

constructing hedonic price series only for a short time. In France, the I.N.S.E.E. constructs such time series only for hardware.

Two ways of settling the price matter can be contemplated in order to make prices consistent:

- either use American ICT prices corrected for 50% of the exchange rate. This method is chosen by Cette, Mairesse and Kocoglu [2002]. With this correction, it is assumed that half of ICT equipment is imported.
- Or construct new price series by applying the method elaborated by Schreyer [2000] which consists in applying the difference between non ICT equipment prices and ICT prices prevailing in the USA to French prices of non ICT equipment.

The second methodology suits us better. As a matter of fact, applying a correction for the exchange rate by 50% to American prices of hardware and software over the whole period seems to be arbitrary. The evolution of French hardware imports points to a significant change in the share of investments in imports over time. Thus, assuming that this share is constant and identical for hardware and software is a strong hypothesis.

The Schreyer's method appears to be more relevant in so far as the gap between American prices of ICT and non ICT equipment fluctuates throughout the period and is different according to the type of ICT equipment. By applying this method to obtain the French price series for the different types of ICT equipment, the evolution of non ICT equipment in France is taken into account.

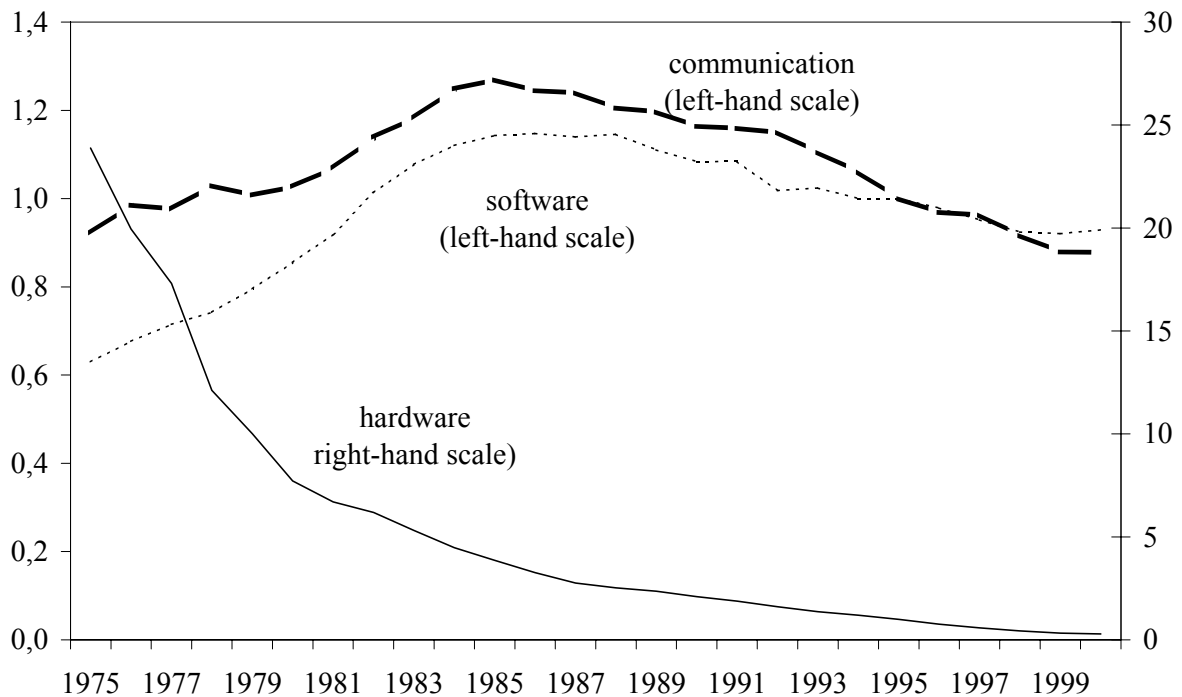
Nonetheless, these two price series (the BEA's and the Schreyer's ones) will be used alternatively in order to emphasise the differences that arise in the results on ICT contribution to growth.

Analysis

Firstly, the method used to construct price series greatly influence the increase in ICT investment prices, as could be expected.

We also notice a strong divergence in the evolution of ICT prices by type of asset. Hardware prices fall very steeply over the period 1980-00, whereas software and communication equipment prices increase.

Graph 3: Growth of ICT prices (calculated with the Schreyer's method)



Source: BEA, INSEE and CEPII, authors' calculations

Let's now turn to the results related to the ICT contribution to the French growth. To do so, results based on estimates using U.S. hedonic prices for hardware and software investments will be compared to estimates that result from the calculation of new price series with the method applied by Schreyer. We will contrast our results with those of Cette, Mairesse and Kocoglu, and then we will compare the contribution of ICT to the French growth with the ones of other O.E.C.D. economies. Lastly, we will focus on the contributions of capital substitution for labour and quality of labour to the average hourly labour productivity in France.

3. GROWTH ACCOUNTING

As ICT growth accounting studies are few in Europe compared to the United States, the contribution of ICT to the French growth and to the average hourly labour productivity is a useful exercise that should be completed later by econometrics on total factor productivity (TFP) in order to assess the relevant factors explaining it. In this section, the emphasis will be brought on the evolution of the French labour quality and its role in the impact of the spread

of ICT on the performances of the French economy. Labour services and the quality of labour shown below result from the calculation that integrates education³.

3.1. Contributions of ICT to the growth of the French economy

Several issues could be mooted following our estimates of the contribution of ICT to the growth of the French economy. The choice of price series which is crucial is one of them. The contribution of ICT to the growth of the French economy is over- or underestimated according to the price series used (see table 12 in Appendix).

Leaning on estimates run with the price series resulting from the Schreyer's method (table 4), the contribution of ICT to growth is limited to 0.32% per year over the period 1990-99, and 0.46% per year over 1995-99. Nonetheless, even if the contribution of ICT is limited, it has dramatically increased relative to the contribution of other equipment goods. Over 1995-00, ICT goods and services have the most contributed to growth, along with the labour services. The contribution of labour services to growth is noticeably strong over the period. Moreover, it can be spelt out that if we had applied non weighted total hours worked instead of labour services, the contribution of labour to growth would have been twice as less important.

The strongest contribution brought to the growth of ICT investment is chiefly carried out by hardware, and in a lesser extent by software. ICT equipment goods explain about 46% of the contribution of capital to the growth of value added (24% being attributable to hardware, 14% to software and 8% to communication equipment) over 1995-99. The weakness of the contribution of communication equipment points to a sluggish investment effort over that period. In terms of acceleration, hardware and software investments have nearly doubled their contribution between 1990-95 and 1995-99. Meanwhile, the contribution of non residential structures has kept falling back throughout the period.

³ The quality of labour that includes education being above the estimate excluding education, the contribution of labour to the French growth with labour services including degrees will necessary be higher than the one excluding degrees.

Table 4: Contributions to the average annual growth of gross value added (in %)
(ICT prices assessed with the Schreyer's method)

	1980-99	1980-90	1990-99	1990-95	1995-99
GVA	2.09	2.57	1.66	1.09	2.37
Capital services	1.13	1.27	0.99	0.98	1.01
<i>Total ICT:</i>	0.31	0.30	0.32	0.21	0.46
Hardware	0.16	0.16	0.17	0.11	0.24
Software	0.08	0.07	0.09	0.04	0.14
Communication	0.07	0.07	0.07	0.06	0.08
Non-residential structures	0.50	0.56	0.45	0.56	0.32
Transport	0.07	0.07	0.08	0.06	0.10
Other equipment	0.25	0.37	0.14	0.16	0.12
Labour services	0.64	0.84	0.45	0.11	0.88
Non weighted labour	-0.05	-0.04	-0.06	-0.48	0.46
TFP (with labour services)	0.32	0.45	0.21	0.00	0.49

Source: CEPII, authors' calculations.

These results suggest to focus on the growth of total factor productivity, which in theory accounts for changes in the structure of the economy, say, technical progress.

Analysis of total factor productivity

The total factor productivity is calculated as a rest over the sum of the different contributions of inputs. Thus, the more our estimation of the contribution of factors of production (capital, labour) is accurate, that is to say accounts for the improvement in the quality of labour and capital, the weakest the total factor productivity. Nonetheless, in this accounting framework of growth, the economic fluctuations of the degrees of utilisation of factors of production are not included. Therefore, any reversal in the cycle will impact on total factor productivity.

It is thus difficult to make out in the growth of the total factor productivity what share is attributable to economic fluctuations or to structural changes. Cette, Mairesse and Kocoglu [2002] assess that the contribution of total factor productivity to growth of value added would be explained by more than 30% by the favourable economic prospects over 1980-00.

By analysing the results of the contributions of factors of production to growth, it appears that total factor productivity fluctuates along the same lines as the economy. ICT capital and labour services show very large contributions to growth. This result can be somewhat associated with a bias towards technical change, a more skilled labour meeting the requirements of ICT changes. Moreover, the TFP contribution is quite strong over 1995-99, contrasting with the preceding period which includes a year of recession. These different contributions can then reflect a possible structural change over the period 1995-99.

International comparison

Few studies besides those by Cette et al. [2001, 2002] and Cholecchia et al. [2001] have used an accounting framework including ICT. It is neither easy to compare our results with these studies in so far as the mapping is different. Contrary to our work based on the aggregate economy, the studies mentioned above assess the contribution of ICT to growth for the business sector. Results are compared in table 10 (in appendix). We apply the same method as Cette et al. and our results are quite close. Although we do not use the Schreyer's method who takes hyperbolic depreciation rates while we apply geometric ones, our results are also relatively similar.

Table 5 presents our results against the findings of Colecchia et al. for 9 other O.E.C.D. countries. As a difference, Colechia and Schreyer, as already mentioned, use their own method.

In relative terms, when dividing the contribution of each asset by growth of value added, the ICT **relative** contribution is less strong in the United States than the one of Japan over 1995-00. ICT equipment goods and services explain 34% of the Japanese growth whereas they account for 19% of the American one, 18% of the German and Italian ones. The relative contributions of ICT to the French and Canadian growth (O.E.C.D. results) amount to 12%. Surprisingly, ICT does not contribute as much in Finland with a relative share of only 3.5% over 1995-00.

In absolute terms, the contribution of ICT to growth is then quite stronger in the United States than in Japan (0.86% and 0.38% respectively over the period 1995-99). Investment in Japan was less sustained than in the United States. If the Japanese investment effort had equalled the one in the U.S., the impact of ICT should have been quite huge as well in absolute as in relative terms.

As for France, its contribution is closer to that of the United Kingdom. In other studies [Oulton (2001), Van Ark, (2002)], the French contribution sets at a lower level than the one of UK (about 0.57%).

Altogether, it pops up from this comparison that the contribution of ICT to growth in France is stronger with our series and our method. This difference can be explained by a steeper fall in IT prices when the prices resulting from the Schreyer's method are used rather than prices from the B.E.A. corrected for exchange rates.

Table 5: International comparison

		Australia	Canada	Finland	France	France(Our)	Germany	Italy	Japan	UK	USA
GVA	80-85	3.39	2.66	2.80	1.48	1.85	1.13	1.54	3.31	2.59	3.35
	85-90	3.79	2.90	3.42	3.46	3.13	3.59	3.04	5.14	3.90	3.31
	90-95	3.37	1.79	-0.70	0.97	1.09	2.22	1.4	1.33	2.12	2.64
	95-99	4.72	4.09	5.62	2.60	2.37	1.73	1.93	1.10	3.48	4.43
	95-00	4.64	4.20		2.81	2.48	2.06			3.55	4.40
OCM& C	80-85	0.24	0.25	0.21	0.13	0.22	0.18	0.21	0.16	0.16	0.36
	85-90	0.34	0.24	0.30	0.17	0.23	0.23	0.23	0.23	0.25	0.32
	90-95	0.37	0.21	0.17	0.16	0.17	0.24	0.18	0.25	0.23	0.29
	95-99	0.53	0.39	0.46	0.23	0.32	0.28	0.29	0.36	0.42	0.61
	95-00	0.53	0.43		0.25	0.31	0.30			0.43	0.62
Software	80-85	0.05	0.04	0.07	0.05	0.06	0.03	0.02	0.02	0.02	0.07
	85-90	0.12	0.09	0.12	0.05	0.07	0.04	0.08	0.07	0.04	0.11
	90-95	0.12	0.09	0.07	0.02	0.04	0.06	0.02	0.06	0.04	0.14
	95-99	0.13	0.12	0.16	0.10	0.14	0.07	0.07	0.02	0.05	0.25
	95-00	0.15	0.13		0.10	0.11	0.07			0.04	0.25
Total	80-85	0.29	0.30	0.28	0.18	0.29	0.20	0.23	0.18	0.18	0.44
	85-90	0.46	0.33	0.42	0.22	0.30	0.27	0.31	0.30	0.29	0.43
	90-95	0.48	0.30	0.24	0.18	0.21	0.30	0.21	0.31	0.27	0.86
	95-99	0.66	0.51	0.62	0.33	0.46	0.35	0.36	0.38	0.47	0.86
	95-00	0.68	0.57		0.35	0.42	0.38			0.48	0.87

Note: OCM & C: office & computer machinery; communication equipment. Total = OCM & C + software.

Source: Colecchia and Schreyer (2001)

In other respects, the growth of average hourly labour productivity in France must be considered to be contrasted with the American trend over the last ten years. How large is the magnitude of the accumulation of ICT capital is a question that is worth being examined.

3.2. The average hourly labour productivity

The growth of average hourly labour productivity slows down noticeably over 1995-99 (table 6). This phenomenon can be explained in part by the French policy regarding the

reduction in social contributions upon the low wages and the employment of young people. Started in 1993, these measures have been further fostered from 1995 on. These measures have led to a significant slow-down of labour quality, on account namely of a negative contribution of age to quality. Let's spell out that if education would not have been included in the estimation of labour quality, then the contribution of labour quality to labour productivity growth should have been negative over 1995-99 (-0.15 instead of 0.42).

The growth of the average hourly labour productivity can be explained by the substitution of capital for labour ("capital deepening") and the improvement of the labour quality that both have a positive impact on the growth of average hourly labour productivity.

A substitution of capital for labour has a positive impact on labour productivity as it makes workers more productive. An alternative explanation may be the skill-biased technological change. Thus, any increase in the substitution of capital for labour should improve the quality of labour. That what can be drawn from table 6.

The contribution of capital deepening to the hourly labour productivity increases in relative terms between 1982-90 and 1990-99. Over the period 1990-95, the substitution of capital for labour and the quality of labour explain more than 67% and 33% respectively of the hourly labour productivity growth.

Over 1995-99, the growth of the total factor productivity explains about 29% of the increase in labour productivity. The contribution of "capital deepening" to growth falls from 67% to 47%, along with the contribution of labour quality from 33% to 24%. Possibly in spite of a strong capital accumulation in ICT over this period, the contribution of capital deepening is less strong than over the previous period as it is not accompanied by an increase in the quality of labour.

Table 6: Growth sources of average hourly labour productivity (in %)

(ICT prices assessed with the Schreyer's method)

	1982-99	1982-90	1990-99	1990-95	1995-99
Average hourly labour productivity	2.15	2.60	1.75	1.80	1.69
Capital deepening	1.13	1.26	1.02	1.21	0.78
of which, ICT:	0.31	0.30	0.32	0.23	0.44
Hardware	0.16	0.16	0.17	0.12	0.23
Software	0.08	0.07	0.09	0.05	0.14
Communications	0.07	0.07	0.07	0.06	0.08
Quality of labour	0.69	0.89	0.51	0.59	0.42
TFP	0.32	0.45	0.21	0.00	0.49

Note: ICT refers to hardware, software and communication.

Sources: CEPII, authors' calculations.

CONCLUSION

Assessing the contribution of ICT to growth can turn out to be a tricky exercise as the results are conditioned by the series quality and namely the price series.

The contribution of ICT to the French growth of value added remains moderate. It is comparable to the British contribution (about 0.45% per year over 1995-99) but it is far behind that of the United States. The grounds underlying this gap are to be investigated in ICT investment shares and not in growth rates. ICT investment growth is indeed as much sustained in France as in the U.S., but the proportion of U.S. ICT investment in total investments is almost thrice as high as the French share (the share of ICT investments in value amounts to 24% of total investment in the U.S. and 10.5% in France).

The contribution of ICT to the hourly labour productivity growth can also entail an improvement of the labour force quality and produce an increase in the efficient combination of input. The acceleration of ICT capital deepening between 1990-95 and 1995-00 was accompanied indeed by such a rise in the total factor productivity but not by an improvement in the labour quality. The quality of the French labour has increased regularly till the period 1990-95. Over the last period, the fall in the quality of French labour is in sync with the rise in hours worked by less well-paid workers and namely young workers. But the latter will accumulate human capital over their life-time, and will then contribute to improve the labour

quality. What is heartening is the strong contribution of education to the labour quality, maybe testifying that labour costs for young graduates has fallen further as the general education level has hiked up.

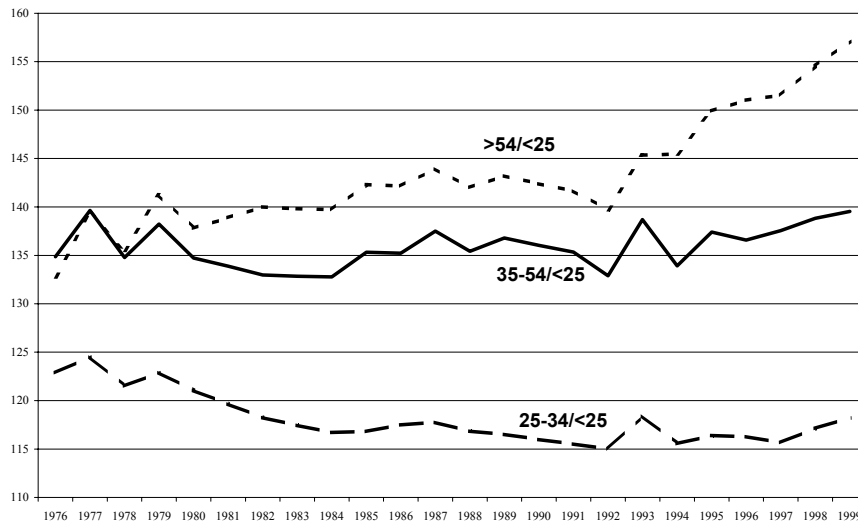
Bibliography

- Ark, B. van, J. Melka, N. Mulder, M. Timmer, and G. Ypma (2002); "ICT Investment and Growth Accounts for the European Union, 1980-2000", Final report on ICT and Growth Accounting for the DG Economics & Finance of the European Union, June.
- Autor, D. H., L. F. Katz and A. B. Krueger (1998); "Computing Inequality: Have Computers Changed the Labour Market", *Quarterly Journal of Economics*, CXIII-4, November, pp. 1169-1214.
- Berman, E., J. Bound and S. Machin (1998); "Implications of Skill-Biased Technological Change: International Evidence", *Quarterly Journal of Economics*, CXIII-4, November, pp. 1245-1280.
- Caselli, F. and J.W. Coleman (2001); "Determinants of Technology Adoption: the Case of Computers", *American Economic Review*, Papers and Proceedings, forthcoming.
- Cette, G., J. Mairesse and Y. Kocoglu (2000); "Les technologies de l'information et des communications en France: diffusion et contribution à la croissance", *Economie et Statistique*, n°339-340 –9/10, pp.117-146.
- Cette, G., J. Mairesse and Y. Kocoglu (2001); "Croissance économique et diffusion des TIC : le cas de la France sur longue période (1980-2000)", *Revue Française d'Economie*, n°3 vol.XVI, pp.155-192.
- Cohen, D and M.Debonneuil (2002), "Nouvelle Economie", CAE, documentation française.
- Colecchia, A. and P. Schreyer (2001), "ICT Investment and Economic Growth in the 1990s: Is the United States a Unique Case? A Comparative Study of Nine OECD Countries, STI Working Paper, 2001/7, OECD, Paris.
- Crépon, B. and T. Heckel (2000); "La contribution de l'informatisation à la croissance française: une mesure à partir de données d'entreprises", *Economie et Statistique*, n°339-340, pp.93-115.
- Daveri, F. (2001); "Information Technology and Growth in Europe", mimeo.
- ECB (European Central Bank) (2001); "New Technologies and Productivity in the Euro Area," *Monthly Bulletin*, July, pp. 37-48.
- Eurostat (1999); "Volume Measures for Computers and Software", Report of the Task Force, June.
- Eurostat Data Shop Handbook (2000); "The Input – Output Tables", Luxembourg.
- Gimm, T., B. R. Moulton and D.B. Wasshausen (2002); "Information Processing Equipment and Software in the National Accounts", conference on Measuring Capital in the New Economy, Federal Reserve Board.
- Green, F. A. Felstead and D. Gallie (2000); "Computers Are Even More Important Than You Thought: An Analysis of The Changing Skill-Intensity of Jobs", Centre for Economic Performance, Discussion paper 439, January.
- Hollanders, H. and H. Meijers (2001); "Quality Adjusted Prices and Software Investments: The Use of Hedonic Price Indexes", mimeo Maastricht University.
- Hulten, Ch. R. and F. C. Wyckoff (1981); "The Measurement of Economic Depreciation " in *Depreciation, Inflation and the Taxation of Income from Capital*, Ed. Ch. R. Hulten, Urban Institute Press.
- Jalava, J. and M. Pohjola (2001); "Economic Growth in the New Economy: Evidence from Advanced Economies", mimeo UNU/WIDER.
- Jorgenson, D.W. (2001); "Information Technology and the US Economy", *American Economic Review*, vol.91, March, pp.1-32.
- Jorgenson, D.W. and K.J. Stiroh (2000); "Raising the Speed Limit: US Economic Growth in the Information Age", *Brookings Papers on Economic Activity*, vol.2.
- Ho, M.S. and D.W. Jorgenson (1999); "The Quality of the US Work Force, 1948-95", Harvard University mimeo.
- Jorgenson, D.W. and Griliches Z. (1967); "The explanation of productivity change", *Review of Economic Studies*, vol.34, n°3, July, pp.249-283.
- Machin, S. and J. Van Reenen (1998), "Technology and Changes in Skill Structure: Evidence from Seven OECD Countries", *Quarterly Journal of Economics*, CXIII-4, November, pp. 1215-1244.

- Moch, D. (2001); "Price Indices for Information and Communication Equipment Technology Industries – An Application to the German PC Market", *Discussion Paper, No. 01-20*, Centre for European Research (ZEW); Mannheim.
- Moch, D. and J. Triplett (2001); "*International Comparisons of Hedonic Price Indexes for Computers: A Preliminary Examination*" Prepared for NBER/CRIW Summer Institute meeting, July 30-31, 2001.
- Niiniinen P. (1999); "Computers and Economic Growth in Finland ", in M. Pohjola (ed.), *Information Technology and Economic Development*, WIDER/United Nations University, Oxford University Press, forthcoming.
- OECD (2000); "A New Economy? The Changing Role of Innovation and Information Technology in Growth", Paris.
- OECD (2000a); "Handbook on Quality Adjustment of Price Indexes for Information and Communication Technology Products", mimeo, Paris.
- Oliner, S.D. and D.E. Sichel (1994); "Computers and Output Growth Revisited: How Big is the Puzzle? ", *Brookings Papers on Economic Activity*, 2, pp. 273-317.
- Oliner, S.D. and D.E. Sichel (2000); "The Resurgence of Growth in the Late 1990s: Is Information Technology Story? ", *Journal of Economic Perspectives*, 14, pp.3-22.
- Oulton, N. (2001); "ICT and Productivity Growth in the United Kingdom", Working Paper, no. 140, Bank of England, July.
- Pilat, D. (2001) and F. Lee (2001); "Productivity Growth in ICT-Producing and ICT-Using Industries: a Source of Growth Differentials in the OECD? ", *STI Working Papers*, No. 4, OECD, Paris.
- Schreyer, P. (2000); "The Contribution of Information and Communication Technology to Output Growth: a Study of the G7 Countries", *STI Working Papers 2000/2*, OECD, Paris.
- Stiroh, K. (2001); "Information Technology and the US Productivity Revival: What Do the Industry Data Say?", *Staff Reports*, Federal Reserve Bank of New York, January, N°115.
- Wiel, H. van der (1999); "Sectoral Labour Productivity Growth: A Growth Accounting Analysis of Dutch Industries 1973-1995", CPB Netherlands for Bureau of Economic Policy Analysis, n°158.
- WITSA (2000); Digital Planet. The Global Information Economy.
- Wyckoff, A.F. (1995); "The Impact of Computer Prices on International Comparisons of Labour Productivity", *Economics of Innovation and New Technology*, 3, pp.277-293.

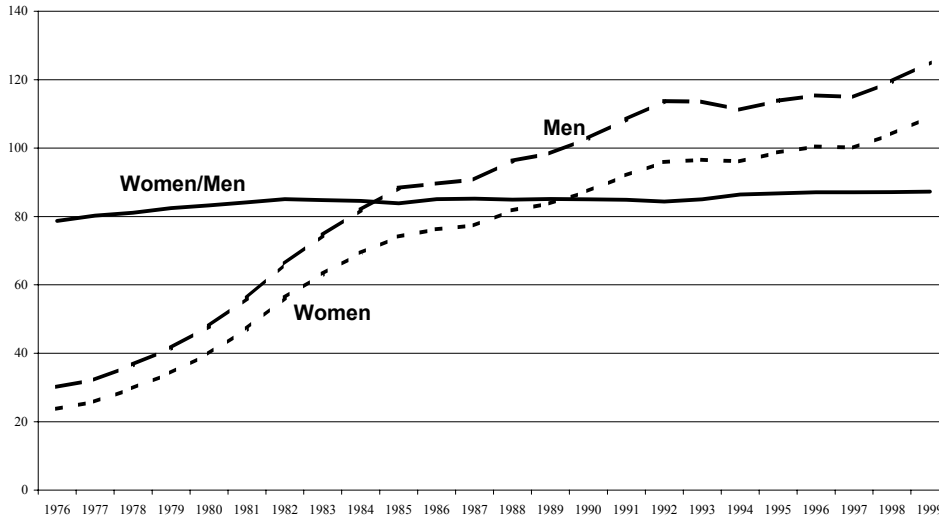
APPENDIX

Graph 4: Hourly wage by age bracket relatively to the youngest, *ceteris paribus* in %



Source: INSEE, D.A.D.S. and National Accounts; CEPII, authors' calculations.

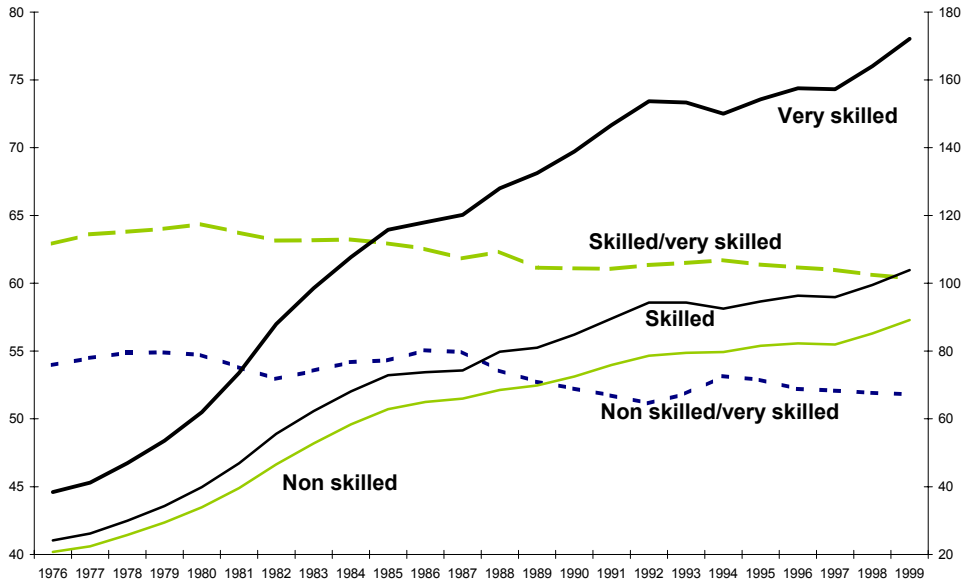
Graph 5: Women's/men's hourly wages, *ceteris paribus*, in %



Source: INSEE, D.A.D.S. and National Accounts; CEPII, authors' calculations.

Graph 6: Hourly wage by skills (occupation), *ceteris paribus*

In %, right-hand scale for relative variables



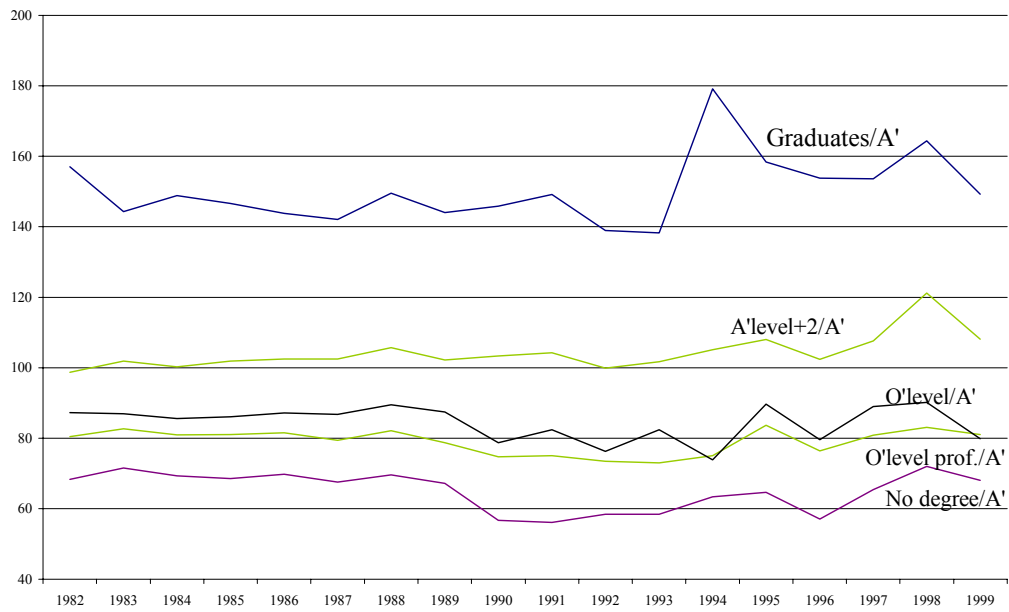
Source: INSEE, D.A.D.S. and National Accounts; CEPII, authors' calculations.

Graph 7: Hourly wage by skills (education), *ceteris paribus*



Source: INSEE, D.A.D.S. labour force surveys and National Accounts; CEPII, authors' calculations.

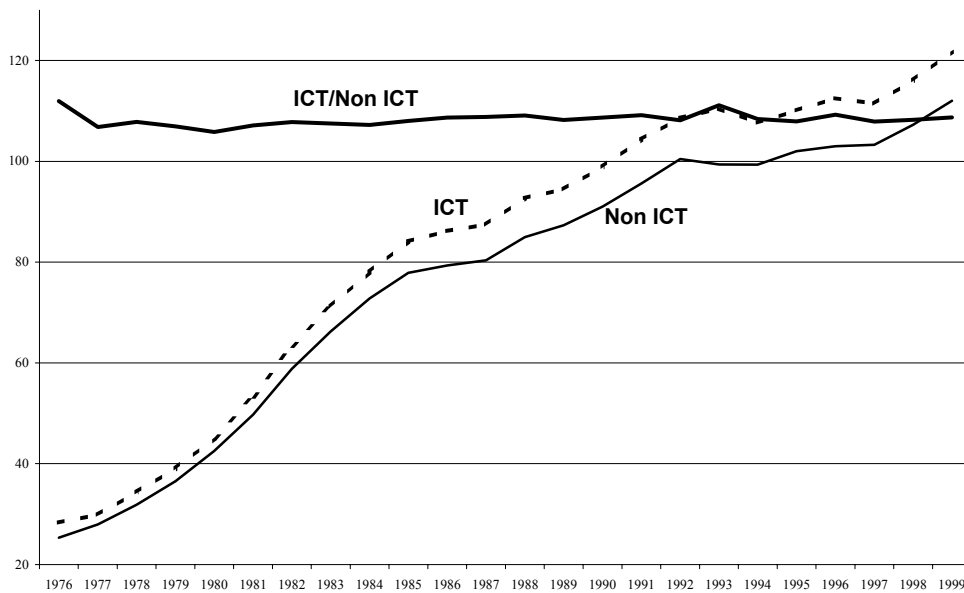
Graph 8: Hourly wage of women relative to men by skills (degrees)



Source: INSEE, D.A.D.S. labour force surveys and National Accounts; CEPII, authors' calculations.

Graph 9: Hourly wage in ICT and non ICT sectors, *ceteris paribus*

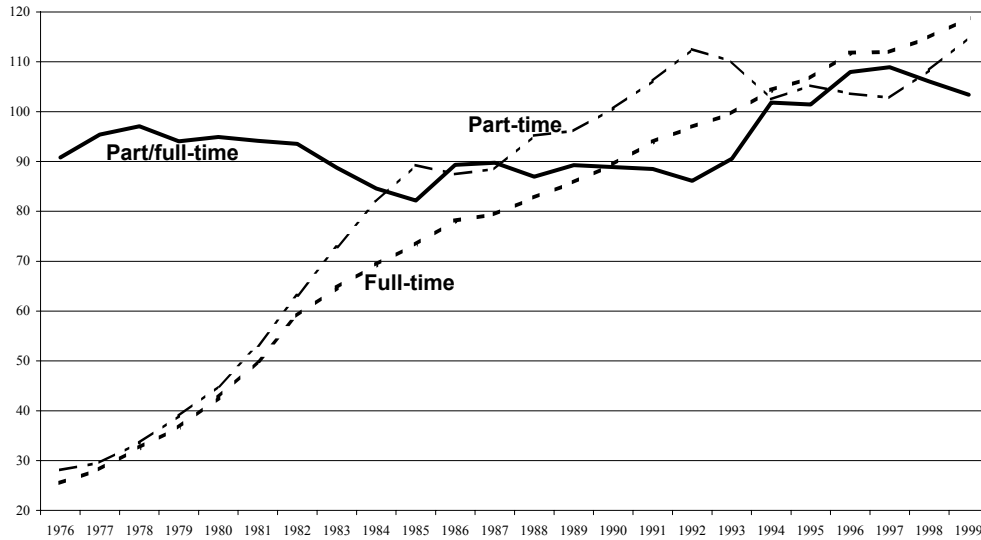
In %



Source: INSEE, D.A.D.S. and National Accounts; CEPII, authors' calculations.

Graph 10: Hourly wage of full/part time, *ceteris paribus*

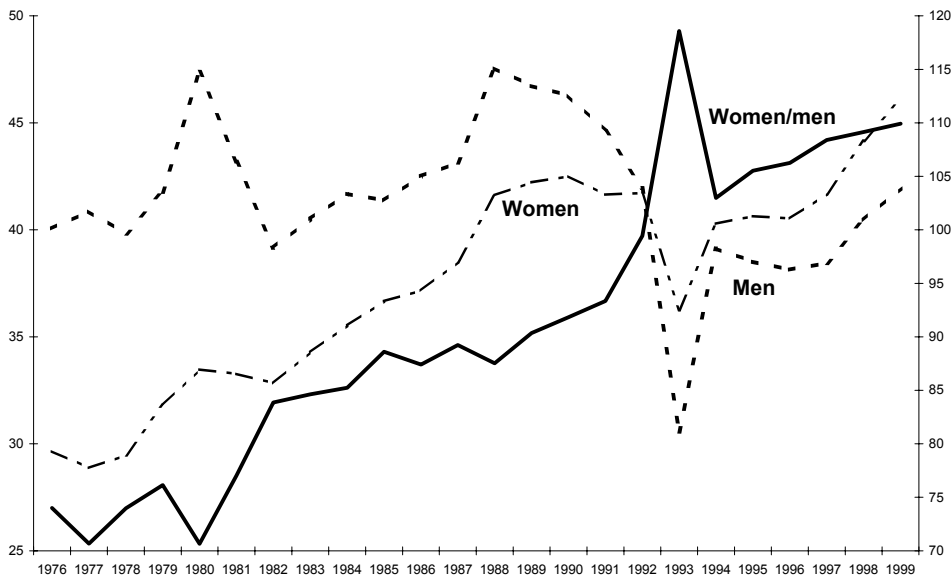
In %



Source: INSEE, D.A.D.S. and National Accounts; CEPII, authors' calculations.

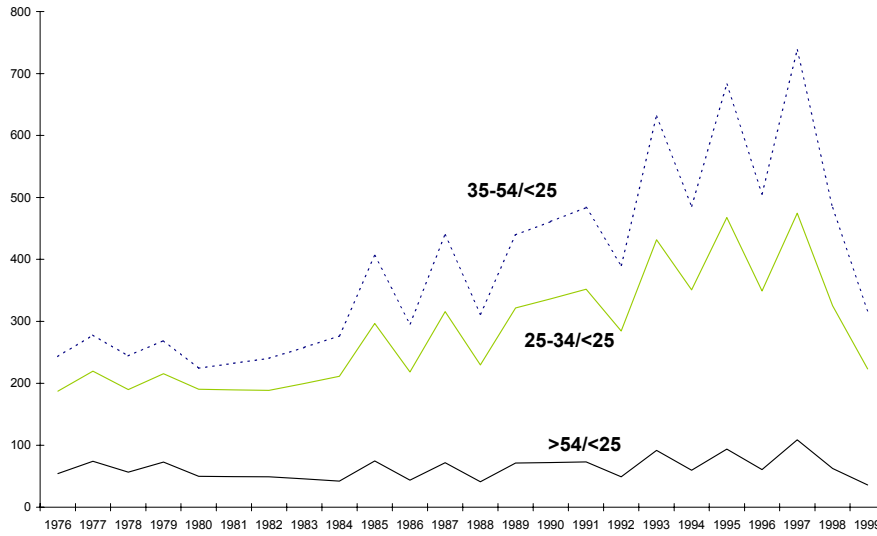
Graph 11: Total hours worked by women and men

In %, right-hand scale for relative variables



Source: INSEE, D.A.D.S. and National Accounts; CEPII, authors' calculations.

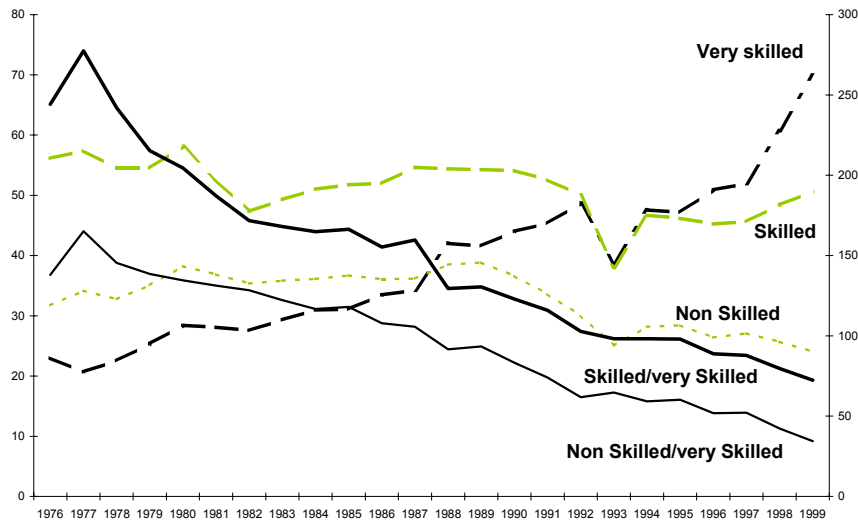
Graph 12: Relative total hours worked by age bracket, in %



Source: INSEE, D.A.D.S. and National Accounts; CEPII, authors' calculations.

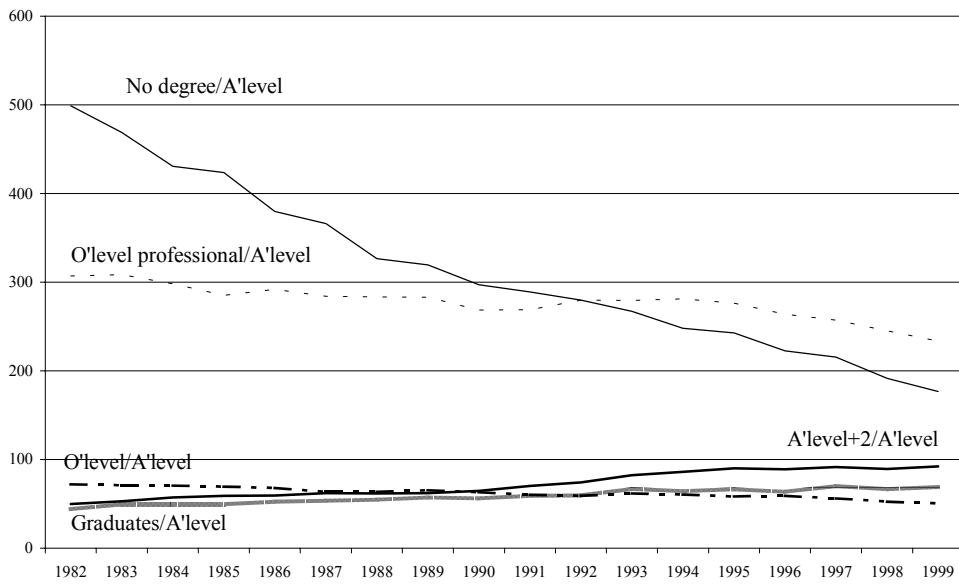
Graph 13: Total hours worked by skills (occupation)

In %, right-hand scale for relative variables



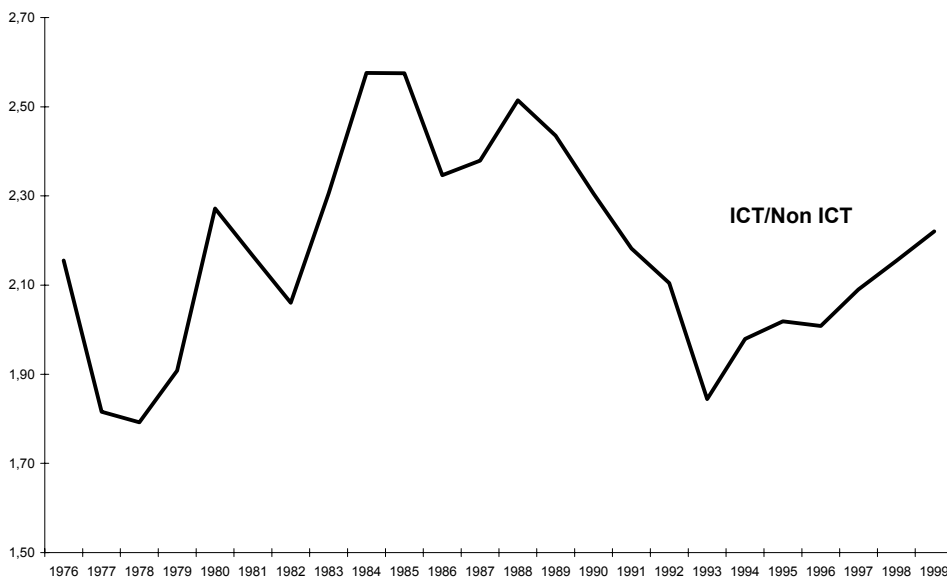
Source: INSEE, D.A.D.S. and National Accounts; CEPII, authors' calculations.

Graph 14: Total hours worked by skills (education)



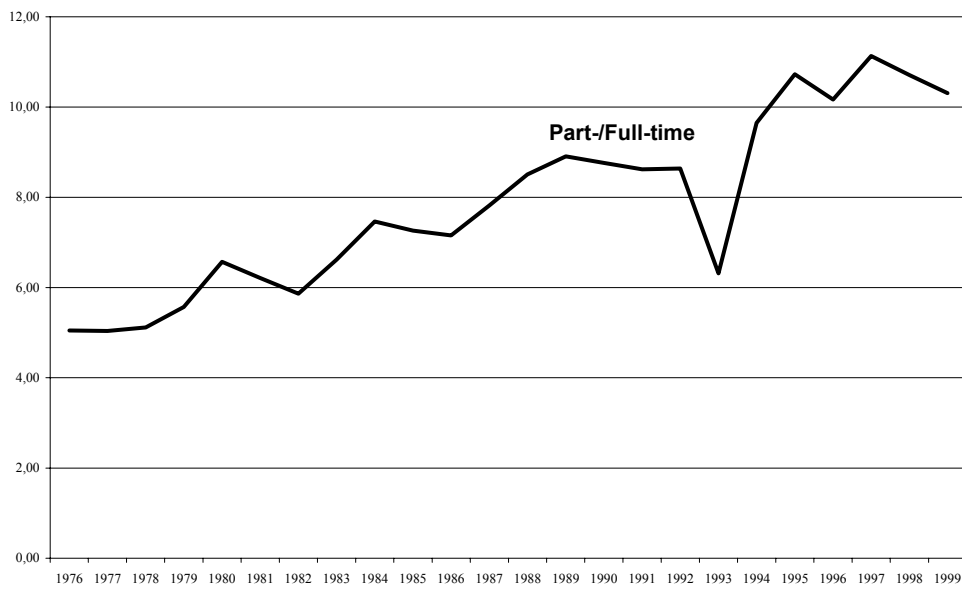
Source: INSEE, D.A.D.S. labour force surveys and National Accounts; CEPII, authors' calculations.

Graph 15: Total hours worked by ICT and non ICT sector, in %



Source: INSEE, D.A.D.S. and National Accounts; CEPII, authors' calculations.

Graph 16: Total hours worked by status (full/part-time), in %



Source: INSEE, D.A.D.S. and National Accounts; CEPII, authors' calculations.

Table 7: Hypotheses for the construction of capital stocks

Assets	Depreciation	Life time
Software	0.315	5
Hardware	variable	5
Communication	0.11	15
Non residential structures	0.028	60
Transport	0.1906	15
Other equipement	0.132	15

Source: O'Mahony and University of Groningen.

Table 8: Variable depreciation rates for computer equipment over 1980-2000

1980	0.222
1981	0.224
1982	0.227
1983	0.226
1984	0.231
1985	0.235
1986	0.239
1987	0.242
1988	0.242
1989	0.242
1990	0.243
1991	0.243
1992	0.243
1993	0.246
1994	0.250
1995	0.254
1996	0.261
1997	0.270
1998	0.279
1999	0.287
2000	0.295

Source: Marcel Timmer, University of Groningen.

Table 9: Contributions to average annual growth of value added (in %)
(BEA prices for hardware and software, INSEE prices for other assets)

	1982-99	1982-90	1990-99	1990-95	1995-99
GVA	2.09	2.57	1.66	1.09	2.37
Capital services	1.13	1.31	0.98	0.98	0.97
<i>Total ICT:</i>	0.27	0.25	0.29	0.18	0.40
Hardware	0.14	0.14	0.14	0.09	0.19
Software	0.08	0.06	0.09	0.05	0.14
Communication	0.05	0.05	0.06	0.04	0.08
Non-residential structures	0.47	0.62	0.54	0.58	0.34
Transport	0.07	0.07	0.07	0.06	0.10
Other equipment	0.22	0.37	0.25	0.16	0.12
Labour services	0.56	0.84	0.31	0.11	0.55
Non weighted labour	0.08	0.00	0.15	-0.71	1.10
TFP (with labour services)	0.39	0.42	0.37	0.00	0.85

Note: Hypotheses underlying capital services are the same as assumptions used for capital services with prices resulting from the Schreyer's method.

Source: INSEE series; CEPII, authors' calculations.

Table 10: Contributions to average annual growth of value added (in %)

	1980-00			1980-90			1990-00			1990-95			1995-00		
	cepii	cmk	CS	cepii	cmk	CS	cepii	cmk	CS	cepii	cmk	CS	cepii	cmk	CS
GVA	2.16	1.88		2.53	2.42		1.81	1.35		1.10	0.50	0.97	2.51	2.20	2.81
ICT	0.26	0.25		0.24	0.24		0.28	0.27		0.17	0.17	0.13	0.38	0.36	0.27
H	0.14	0.11		0.14	0.11		0.14	0.11		0.09	0.08		0.20	0.15	
S	0.07	0.08		0.06	0.07		0.07	0.08		0.04	0.05	0.02	0.11	0.09	0.08
C	0.05	0.06		0.04	0.05		0.06	0.07		0.04	0.05		0.08	0.09	
OCM&C	0.15			0.13			0.17			0.11		0.23	0.27		0.19
K	1.20		1.17	1.40	1.3		1.00	1.05		1.00	1.18	0.73	1.00	0.91	0.78
L	0.21	-0.47		0.24	-0.60		0.18	-0.34		-0.07	-0.83		0.44	0.15	
TFP	0.73	1.19		0.86	1.74		0.60	0.64		0.16	0.15		1.04	1.13	

Note : CEPII = total economy, calculations performed by using the price indices from the BEA for hardware and software, and price indices from INSEE for the other assets, Rental price calculated with an internal rate of return.

CMK (Cette, Mairesse, Kocoglu, 2002) = Business sector,

CS (Colecchia and Schreyer, 2001) = Business sector.

Results for OCM&C: office machinery + computer equipment + communication equipment, are calculated with the Schreyer's method in order to make results comparable with CS.

L: Labour services calculated on all characteristics except education.

Source: CEPII, authors' calculations.

Table 11: Sources of growth of the average annual hourly labour productivity (in %)
(BEA prices for hardware and software, INSEE prices for other assets)

	1982-99	1982-90	1990-99	1990-95	1995-99
Average hourly labour productivity	2.15	2.60	1.75	1.80	1.69
Capital substitution for labour	1.13	1.27	1.00	1.21	0.75
Of which, ICT :	0.26	0.24	0.28	0.19	0.39
Quality of labour	0.69	0.89	0.51	0.59	0.42
TFP	0.34	0.45	0.24	0.01	0.53

Note: ICT = OCM + software + communication.

Source: CEPII, authors' calculations.

Table 12: Share of current ICT investment in total investment and in GDP for France & the U.S. (Business sector)

	1980	1985	1990	1995	2000
% Investment in GDP					
France	20.5	17.2	19.0	15.4	16.9
United-States	17.3	17.0	14.6	15.0	17.4
% ICT in total investment					
France	4.0	6.4	6.2	6.9	10.5
United-States	10.1	13.9	16.1	18.7	23.8
% ICT investment in GDP					
France	0.8	1.1	1.2	1.1	1.8
United-States	1.7	2.4	2.3	2.8	4.1

Source: CEPII, authors' calculations.