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Convergence of Firm-Level Productivity, Globalisation, Information Technology and Competition: Evidence from France

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Abstract
Studies of firm-level data have shown that there is a huge dispersion of productivity across firms even when industries are narrowly defined. So there is a significant opportunity for the least productive firms to catch up to the most productive. The formers' convergence could therefore constitute an important part of productivity growth at the macroeconomic level. This article sheds light on this convergence process in the 1990s and the 2000s in France and on some of the factors which can explain it. Productivity convergence was stronger for labour productivity than for total factor productivity. But most importantly the speed of convergence has slowed during the course of the 1990s, a fact which is explained principally by the acceleration of the productivity of firms on the technological frontier. Three possible explanations of these stylised facts are considered: globalisation, information technology, and competition. Globalisation and information technology may have benefited the most productive firms more and the growth of competition may at the same time have stimulated the productivity of firms at the frontier while discouraging the convergence of the least productive firms.

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Data: FiBEn database, maintained by the Banque de France

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1. Introduction

The growth of labour productivity (output per head) began to fall in France in the 1990s, dropping from an annual average rate of 2.2 per cent in the 1980s to 1.4 per cent in the 1990s and 1.0 per cent in the 2000s. At the same time studies of firm-level data have shown that there is substantial dispersion of productivity across firms even within narrowly defined industries (for example Baily et al., 1992 and Oulton, 1998 and 2000) and even across different establishments within the same firm (Griffith *et al.*, 2007, who ascribe this in great part to differences in the quality of management).

Several studies have shown that this dispersion gives rise to a convergence process amongst firms which partly explains the growth of productivity at the macro level. Apart from the impact of random shocks, the least productive firms tend to catch up to the most productive, either by increasing capital intensity, or by copying the latter's organisational methods, or by adopting their technology. This convergence has been demonstrated for British data (Oulton, 1998 and Griffith *et al.*, 2002) and for Japanese data (Nishimura *et al.*, 2005), even after allowing for the impact of the selection process by which the least productive firms tend to disappear.

In France convergence plays a much more important role and the entry-exit process a correspondingly smaller one than is the case in other countries. In fact, productivity growth within surviving firms explains the bulk of aggregate productivity growth in France during the 1990s (Crépon and Duhautois, 2004). The within-firm component of productivity growth arises either from the growth of productivity of firms at the frontier or from convergence of less productive firms. It is this latter process which this article seeks to describe and explain. The speed of convergence, to be estimated by several different methods, can be defined as the year by year reduction of the gap between the productivity level of a given firm and a target level.

Competition is one of the factors suggested by the theoretical literature as a determinant of the speed of convergence.[1] Principal-agent theory suggests that competition has ambiguous effects on productivity convergence. It enables shareholders to evaluate better the effort of managers of firms by improving the comparability of their results (Nickell *et al.*, 1997), to raise managerial effort by an increased risk of bankruptcy (Holmström, 1982), and to raise the

[1] See Ahn (2002) for a review of the literature.

return to the productivity gains resulting from cost reduction via a higher elasticity of demand (Willig, 1987). On the other hand, competition also lowers the return to effort by reducing margins and can therefore lower the incentive towards convergence (Scharfstein, 1988). This idea has also been applied by Aghion *et al*. (2005) to the return to investment in innovation.

This article examines the impact of competition on productivity convergence but also considers more topical factors such as the impact of globalisation (via the acceleration of exports), and of information and communication technologies (ICT). The FiBEn database maintained by the Banque de France will be the principal source. In the next section three stylised facts about productivity convergence in France in the 1990s will be set out. In the third section three possible explanations of these stylised facts will be considered.

Box 1

THE FIBEN DATABASE

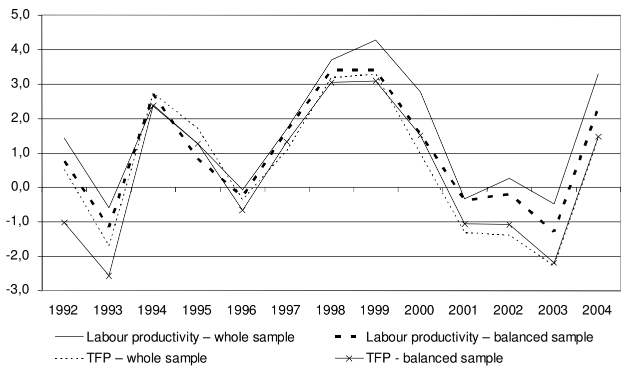
The FiBEn database maintained by the Banque de France is the principal data source used in the present study. It gathers data derived from the fiscal returns of some 282,000 firms that existed in France between 1991 and 2004, of which 45,000 firms were present during the whole period. It covers the whole of the market sector although industry is covered better than services.

Inclusion in the database is a function of size (sales, debt levels) but some firms which meet the criteria are nevertheless absent: for example if a firm is not obliged to publish accounts or if it does not voluntarily send its fiscal return to the Banque de France. At the end of the period the database contains 80% of all employees and 90% of the employees of very large firms (those with more than 500 employees).

The number of firms in the database has grown more rapidly than has the population of firms in France; 98,359 firms were in the database in 1991 and 155,770 in 2004. This is mainly due to inflation because the size criterion for inclusion in the database is nominal sales. The growth of the included firms was particularly strong at the beginning of the 1990s and led to an increase in the share of small enterprises: enterprises with less than 20 employees constituted 50% of the sample in 1992 and this grew to 58% in 1997 and to 60% in 2004. This leads to a potential bias in the estimates. To verify the robustness of the results, we have also done the estimates using the balanced sample;[2] the numerous controls that we have used (dummy variables for sector, year, sector and year, region) also reduce the size of the bias. Another factor suggesting that the impact of the bias is limited is the similarity between the productivity growth rates in the whole and the balanced samples (see Chart A).

The 10th productivity decile is composed of firms which are on average slightly older than in the sample as a whole (the median age is one year higher) and appreciably larger (their sales are 50% higher in the case of labour productivity and 10% higher in the case of TFP). Very young and above all very small firms are under-represented in the 10th decile. For labour productivity, the 10th decile includes the largest firms, which is not the case for TFP.

Chart A
The growth of productivity



Source: FiBEn, Banque de France

[2] The balanced sample is not completely free from bias, since the firms present at the beginning of the period initially have a probability of one of surviving at least 12 years, but this probability declines as time goes on.

Box 2

MODELLING AND ESTIMATING CONVERGENCE

Convergence amongst firms is modelled in the same way as convergence amongst countries (for example, Barro (1991)):

$$\Delta q_{it} = \beta q_{i,t-1} + \mathbf{X}_{it}\varepsilon + u_{it} \tag{1}$$

where q_{ijt} is the log of productivity (labour or TFP) of the *i*th firm in year *t*, $\mathbf{X}_{it}$ is a vector of exogenous control variables, ε is a vector of parameters, and u_{it} is an error term.

The control variables include dummy variables for sector, year, region, and for the interaction of sector and year. For each sector and each year, convergence can therefore be towards different productivity levels since some sectors are more intensive in physical or human capital than others. Regional dummies are also included in order to allow for the effects of varying distance from raw materials and to export markets, and also for geographical clustering effects.

In the model of equation (1), there is convergence if $\beta < 0$: within a given sector and in a given year, firms converge towards a common productivity level (β convergence). This does not necessarily imply that productivity dispersion declines (σ convergence) due to the presence of the error term u_{it}. Equation (1) can be rewritten in the form of a test of the stationarity of productivity growth at the firm level:

$$q_{it} = (1+\beta)q_{i,t-1} + \mathbf{X}_{it}\varepsilon + u_{it}$$

The model of equation (1) can thus be considered alternatively as a test of the persistence of productivity shocks: if $\beta < 0$, the effect of shocks gradually disappears.

An alternative formulation of convergence has been employed, for example by Griffith et al. (2002):

$$\Delta q_{it} = \beta(q_{i,t-1} - q_{jt}^{F}) + \gamma \Delta q_{jt}^{F} + u_{it}$$

where q_{jt}^{F} is the productivity level of firms which are on the frontier. Here firms are supposed to converge towards the productivity level of frontier firms which is itself growing (Δq_{jt}^{F}). Equation (1) is a generalisation of this hypothesis since frontier effects are captured by the interaction of sectoral and year dummies.

The model of equation (1) rests on strong assumptions: convergence is linear and occurs at the same rate in all years. The model can be modified to test these hypotheses by introducing some variable z_{it} interacted with lagged productivity to test its impact on the speed of convergence.

The linearity hypothesis implies that convergence is symmetric: the productivity of firms which are above the long run level[3] falls at the same rate as the productivity of firms which are below it grows. But it might be thought that the process is asymmetric: the speed of convergence may be less rapid for firms that are above the long run level since they can benefit from their innovations over a run of years, while firms below the long run level are under greater pressure to converge (eg due to the threat of bankruptcy). To test this hypothesis of non-linearity, two methods have been employed:

1. The dummy variables for the productivity deciles of firms have been used as indicators of lagged productivity levels.
2. The decile dummies have been interacted with lagged productivity levels, which assumes that convergence is linear within each decile. The decile dummies are defined by sector and not at the whole economy level, which means that firms are converging towards a long run productivity level which is sector-specific, and not towards a common, whole economy level.

Under the first method:

$$\Delta q_{it} = \sum_{k=1}^{9} \delta_k D_{i,t-1}^k + \mathbf{X}_{it}\varepsilon + u_{it} \tag{2}$$

Here $D_{i,t-1}^k$ is a dummy variable equal to one if the ith firm belongs to the kth decile in year t-1 and zero otherwise. In this model the δ_k coefficients should be interpreted as the growth rate of firms in the kth decile relative to that of firms in the 10[th] decile which is chosen as the reference:

$$\delta_k = E(\Delta q_{ijt} \mid D_{it}^k = 1, \mathbf{X}_{it}) - E(\Delta q_{ijt} \mid D_{it}^{10} = 1, \mathbf{X}_{it})$$

If there is convergence, all the δ_k are positive and decreasing in k.

Under the second method:

[3] In the long run, from equation (1), the productivity level converges to $-\mathbf{X}_{it}\varepsilon / \beta$.

$$\Delta q_{it} = \sum_{k=1}^{9} \beta_k D^k_{i,t-1} q_{i,t-1} + \mathbf{X}_{it}\varepsilon + u_{it} \tag{3}$$

Here β_k is the speed of convergence of a firm in the *k*th decile.

The second hypothesis, invariance of the speed of convergence over time, can be tested by estimating the model separately for each year.

Finally, to test the impact of some variable z_{it} on the speed of convergence, an interaction term is introduced into equation (1):

$$\Delta q_{it} = \beta_0 q_{i,t-1} + \beta_1 q_{i,t-1} z_{i,t-1} + \beta_2 z_{i,t-1} + \mathbf{X}_{it}\varepsilon + u_{it} \tag{4}$$

The speed of convergence of the *i*th firm in year *t* is then $\beta_0 + \beta_1 z_{i,t-1}$. If $\beta_1 > 0$ then the speed of convergence is decreasing in z_{it} and if $\beta_1 < 0$ then it is increasing in z_{it}.

Identification and estimation

The model is identified if there exists a stationary representation of productivity of the form:[4]

$$q_{it} = \frac{f_i}{-\beta} + \sum_{k=0}^{t} (1+\beta)^k v_{i,t-k} \tag{5}$$

The term f_i represents the unobserved heterogeneity of firms. It is assumed constant over time. The term v_{it} represents transitory shocks to firm-level productivity. The assumptions about the distribution of the shocks are similar to those of Arellano and Bond (1991), Arellano and Bover (1995), and Blundell and Bond (1998). The firm-level shocks are assumed independent of all the control variables:

$$H_1: \quad E(f_i \mid \mathbf{X}_{it}) = 0$$

In the same way, the transitory shocks are assumed independent of all the controls, in every year:

$$H_2: \quad E(v_{it} \mid \mathbf{X}_{it}) = 0, \forall t, \forall i$$

The unobserved characteristics of firms are assumed independent of the transitory shocks, conditional on the control variables:

$$H_3: \quad E(f_i v_{it} \mid \mathbf{X}_{it'}) = 0, \forall t, \forall t', \forall i$$

The transitory shocks are assumed independent over time, conditional on the control variables:

[4] To simplify the notation in equation (5), we ignore the control variables here.

$$H_4: \quad E(v_{it}v_{is} \mid \mathbf{X}_{it'}) = 0, \ \forall s \neq t$$

Following Arellano and Bond (1991), we assume that the initial value of productivity is uncorrelated with subsequent transitory shocks:

$$H_5: \quad E(q_{i1}v_{it} \mid \mathbf{X}_{it'}) = 0, \ \forall t > 2$$

Following Arellano and Bover (1995) again, we impose a second initial condition by assuming that the firm-level fixed effects are uncorrelated with the initial growth of productivity:

$$H_6: \quad E(f_i \Delta q_{i2} \mid \mathbf{X}_{it'}) = 0$$

Using equation (5), we can rewrite equation (1) in the form

$$\Delta q_{it} = \beta q_{i,t-1} + f_i + u_{it}$$

Under the assumptions just set out, it is now clear that lagged productivity is an endogenous variable since it is correlated with the unobserved firm-level heterogeneity f_i. More precisely, it can be shown that the ordinary least squares estimator overestimates the coefficient β while the firm-level fixed effects estimator underestimates it, whether in levels or first differences.

On the other hand, from the assumptions one can derive a set of moment conditions which allow the model to be identified:

$$E(q_{i,t-s}\Delta u_{it}) = 0, \ \forall t \geq 3, \forall s \geq 2$$

$$E(u_{it}\Delta q_{i,t-s}) = 0, \ \forall t \geq 3, \forall s \geq 2$$

These assumptions permit the identification of the model by using the twice lagged first differences of productivity as instruments for the lagged productivity level $q_{i,t-1}$, following the strategy of Arellano and Bover (1995).

Box 3

The main variables

The following variables were used:

- *Real value added (VA).* Nominal value added (NVA) deflated by the sectoral price index (at the NES36 level, ie two-digit level). The unavailability of price indexes at the firm level may lead to bias in the estimates.
- *Labour input (L).* Average number of employees, full time equivalents (FTE), including temporary employees. The data in the fiscal return is supposed to be full time equivalents. The employment data has been adjusted for temporary employment on the basis of the proportion of the wage bill devoted to the latter. However, the adjustment is minor.
- *Capital input (K).* Real capital services, estimated by the method of Bond *et al.* (1997).
- *Labour productivity (LP).* VA/L. Output per head, not output per hour, even though the workers are measured as full time equivalents.
- *Wage bill (WB).* The total of salaries, social contributions, profit sharing, and payments to workers not employed by the firm.
- *Share of labour (α).* WB/NVA
- *Total factor productivity (TFP).* Growth rate of real value added minus the weighted sum of the growth rates of the inputs: $\Delta \ln(VA_{it} / L_{it}) - [1-(1/2)(\alpha_{it} + \alpha_{i,t-1})] * \Delta \ln(K_{it} / L_{it})$, where i denotes the firm and t the year.

The database of firms is liable to contain some outlying values, due to the large number of observations and the method of collection. In order to avoid distorting the estimates, extreme values have been removed using the following criteria: if the value in logs of a variable (TFP, LP, ...) is greater than the value of the third quartile plus three times the interquartile gap or is less than the first quartile minus three times the interquartile gap (Tukey's method, as recommended by Kremp (1995)).

A simple way of measuring the speed of convergence

Convergence in productivity at the firm level implies that the productivity of firms with low productivity at *t*-1 grows more rapidly between *t*-1 and *t* than that of firms with higher productivity. In order to test the convergence hypothesis and estimate its speed, a simple model in which the growth of productivity between *t*-1 and *t* depends on the level of productivity at *t*-1 can be employed. If the coefficient β attached to the productivity level at *t*-1 is significantly different from zero and negative, then convergence exists. In addition, the higher the absolute value of β, the faster is the speed of convergence. The parameter β therefore characterises the process of convergence. The model can be made richer in two ways. On the one hand, adding a set of control variables enables us to study conditional rather than absolute convergence. On the other hand, the assumption that convergence is linear can be relaxed by allowing the speed to vary between deciles of the productivity distribution. The model is estimated by the Generalised Method of Moments (GMM).

Using output per employee rather than output per hour as the productivity measure can lead to a biased estimate of the convergence speed. This will be the case if hours per employee are growing at a different rate in high productivity firms compared to low productivity ones. During the period under study, changes in the regulations covering the length of the working week may have led to this kind of bias. (the loi Robien of 11 June 1996, the lois Aubry I and II of 13 June and 20 January respectively). From 1996 to 1999 the impact of these measures was limited (2,300 Robien agreements signed between June 1996 and June 1998, 13,000 Aubry I agreements between June 1998 and December 1999) and hours worked per employee did not change much between 1992 and 1999 according to INSEE. On the other hand, in two years — 2000 and 2002 — there were very marked falls in hours worked per employee. These were the years when the two lois Aubry caused most firms to reduce working hours, according to the ACEMO enquiry. In addition, it may well be that these laws cause a bias in the estimated speed of convergence since firms with more than 20 employees had to reduce working hours from 1 January 2000 while the rest had to from 1 January 2002. On the whole the evidence presented here suggests an increase in productivity dispersion in 2000, particularly when measured by the standard deviation, but no corresponding reduction in 2002. Nevertheless, the stylised facts identified in this section are observed through the whole period and changes in 2000 are the continuation of trends observed in the 1990s. In addition, the very rapid GDP growth observed in France in 2000 (+4.1%) may also have contributed to the changes seen in that year.

2. Three stylised facts

Based on the various versions of the model of convergence (see Box 2), the following three stylised facts emerge:

- The productivity of firms converges, whether productivity is taken to be labour productivity or total factor productivity, but there is one notable difference. The convergence of labour productivity occurs through catch-up by lagging firms, while convergence of TFP occurs through a regression to the mean by leading firms.
- The speed of convergence falls over the estimation period (1992-2004) while productivity dispersion increases.
- This reduction in the speed of convergence derives from an increase in the relative growth rate of productivity in the highest productivity firms.

"Bottom-up" convergence in labour productivity, "top-down" convergence in TFP

The first finding is of a significant degree of convergence (β-convergence) in both labour productivity and TFP, in both the total and the balanced sample,[5] and with controls for sector, region and year, and for sector and year interacted (see Table 1). For the median firm in the first (lowest) productivity decile, half the gap with its "target" level of productivity is eliminated in less than four years, both for labour productivity and for TFP.[6]

Because of shocks, this finding of convergence on an annual basis might not be valid for longer periods. Nevertheless, over five years the coefficient of convergence is still found to be significant and close to what would be expected in the absence of shocks ($-0.68 \approx 1-(1-0.2)^5$): see Annex 1.

[5] The similarity of the estimated coefficient of convergence in the two samples is evidence that selection bias has only a limited effect.

[6] The "target" level of productivity differs between each sector, each region and each year. So we are talking here of an average speed of convergence.

As explained in Box 2, the speed of convergence could depend on the level of productivity in a non-linear fashion, contrary to what we have assumed up to now (see equation (1)). To see if this is actually the case, we consider the annual transition matrix between productivity deciles (see annex 2). This matrix shows the distribution of firms by decile in one year (the rows) by the decile in the following year (the columns).

The transition matrix demonstrates substantial inertia in the distribution since nearly 70% of firms either stay in their current decile or move into an immediately adjacent one. This inertia is greater for TFP than for labour productivity as reflected also in the lower β for labour productivity in the regressions of Table 1: the share of firms remaining in the same decile as in the preceding year (the diagonal) is uniformly higher for TFP, with the sole exception of deciles 9 and 10. But most importantly, the form that convergence takes differs between labour productivity and TFP. Convergence is "bottom-up" in the case of labour productivity, with the less productive firms catching up with the better ones, while for TFP it is "top-down", with the most productive firms regressing to the mean. In fact, averaged over the whole period, 62% of firms in the first decile for labour productivity in one year were still there in the next, compared to 82% for TFP.

Another way of quantifying this stylised fact is to model annual productivity growth as a function of the initial level of productivity, but with the convergence speed allowed to vary across deciles. The convergence coefficients β for each decile (equation (3) of Box 3) are thus estimated separately from the firms in each decile. The relation between the speed of convergence and the initial productivity level confirms our previous finding (see Table 2):[7]

- For labour productivity, the speed of convergence falls in three steps. The coefficient for the lowest decile is algebraically the smallest (-0.18 using Generalised Least Squares (GLS), ie a rapid rate of convergence). Then for the next 5 deciles the coefficient is about -0.13; for the last four it is about -0.07.
- For TFP, the speed of convergence rises in a roughly linear way with the decile number, so that the higher is a firm's productivity level, the more does its growth rate suffer (β becomes increasingly negative, going from -0.03 for the first decile to -0.11 for the tenth).

[7] The results for labour productivity using GMM are not significant for deciles 5, 6 and 7, due to the difficulty in finding good instruments for the interaction terms between decile and productivity (productivity level times decile number, see equation (3) of Box 3).

This suggests that for labour productivity the convergence process acts through a relative increase in capital intensity: the least productive firms catch up with the others by investing in physical capital or by shedding labour. For TFP by contrast, it seems to be difficult for firms to stay on the technological frontier, as is shown by both the annual growth regressions and the five-yearly ones (see Annex 1).

The decline in the speed of convergence and the increase in dispersion

Studying changes over time in convergence and productivity dispersion reveals a decline in the speed of convergence and an increase in various measures of dispersion between 1992 and 2004. This finding is not affected by whether we use the whole sample or the balanced sample) nor does it depend on the measure of dispersion (standard deviation, interquartile range or interdecile range divided by the median). Chart I shows the changes in the standard deviation between 1992 and 2004 for the whole and balanced samples. After a period of stability in the 1990s, the increase in dispersion was particularly marked after 2000.

Estimating β-convergence year by year (equation (1)) shows that the speed of convergence falls in the 1990s (Chart II). The decline in the speed is continuous in the 1990s; it flattens off from 2000 onwards for labour productivity but continues for TFP. This finding is robust since it applies to both the balanced and unbalanced samples and for different methods of estimation (GMM, GLS, Spearman rank correlation).

The fall in the speed of convergence derives from the performance of the most productive firms

By analysing the convergence process by year and by decile, we can see that the reduction in the speed of convergence derives from an increase in the growth rate of productivity in the most productive firms (those in the 10^{th} decile), relative to that of other firms. The δ_k coefficients measure the mean difference between the productivity growth rate in the *k*th decile, relative to the productivity growth rate in the highest decile. So convergence exists if these coefficients are positive and decrease as the decile number rises.

In fact, from Chart III, we see that:

- the δ_k are all positive and the curves are parallel, demonstrating convergence within each sample (growth is relatively higher, the lower the decile);
- the δ_k generally all fall over time, demonstrating that growth in the 10^{th} (reference) decile is rising relative to growth in the other deciles.

3. ICT, globalisation and competition

The features which marked the 1990s suggest several hypotheses for explaining the second and third of the stylised facts mentioned above, that is, the fall in the speed of convergence due to a relative increase in the productivity growth rate of the most productive firms. At the macroeconomic level, productivity growth has been marked by the impact of information and communications technology (ICT). It is possible that ICT has benefited most the firms which were already highly productive, owing to their greater capacity to profit from waves of innovation: the level of qualifications of their employees is higher, they have a greater capability to carry out organisational change, their existing technology is more productive, etc. One could equally well argue that new entrants, which are initially below the mean productivity level of their sector, might be better placed to take advantage of ICT since their organisation and their capital stock is new.

The second hypothesis considered in this article is that globalisation stimulated productivity growth, the mechanism being the rapid and prolonged growth of exports on the part of firms focused on markets abroad. Previous work has documented that exporting firms also have the highest productivity (Clerides and Tybout, 1998), since there are large fixed costs incurred in entering foreign markets. The issue is whether, in addition to this selection effect, there is also a positive effect of globalisation on productivity growth.

The final hypothesis involves competition. It is likely that competition in product markets increased during the 1990s, as a result of the policies of deregulation and growing openness to foreign competition. The time path of the OECD's indicators of product market regulation reflects the impact of these policies (Nicoletti and Scarpetta, 2005, covering seven sectors). However, the theoretical literature does not speak with one voice on the relation between competition and productivity (see above) and we cannot predict *a priori* the direction of the impact of strengthened competition on productivity convergence.

Information and communication technologies (ICT)

ICT played a major role in productivity growth in France in the 1990s via investment in ICT products and capital deepening. Cette *et al*. (2001) have shown that in the second half of the 1990s the contribution of ICT capital to French growth was more important than that of any other type of asset.

Studying the impact of the diffusion of ICT on productivity convergence raises various questions. First, is the diffusion of ICT biased towards leading firms, because of the high skill levels of their employees, because these firms are more agile, or because they are more sharply focused on new developments in technology?. Or is diffusion biased towards new entrants who can escape the restructuring costs which must be paid by older firms if they are to benefit fully from ICT?

To measure the diffusion of ICT, we employ the share of ICT in total profit at the industry level, which is available in EU-KLEMS (NACE 52). This share is calculated in the standard way as the sum of the shares of computers, software, and communications equipment. For each of these components, the share is the rental price multiplied by the stock, as a ratio to GDP. The rental price follows the standard Hall-Jorgenson formula.

In the absence of firm-level data, industry-level measures have been used. This limits the strength of any conclusions since it is not then possible to show that the most productive firms, whatever their sector or industry, have adopted ICT on a large scale. In order to test the robustness of our results to the potential endogeneity of this variable, the value of this variable in U.S. industries is also used (see Annex 3). This is to deal with the problem that causality may be from productivity to ICT intensity rather than the other way round.

Building on equation (4), we estimate:

$$\Delta q_{it} = \beta q_{i,t-1} + \gamma (q_{i,t-1} ICT_{j,t-1}) + \delta ICT_{j,t-1} + \mathbf{X}_{it}\varepsilon + u_{it}$$

where q is the log of productivity (labour or TFP), measured as deviations from sector-year means, *ICT* is the share of ICT capital in profit in each sector, $\mathbf{X}$ is a vector of dummy variables for year, sector, and region, i indexes firms, j indexes sectors and t indexes years. The coefficient δ is expected to be positive: a higher share of ICT capital[8] leads to faster growth of productivity, either by raising ICT capital intensity or through various external effects linked to ICT. By contrast, γ could be either positive or negative. If γ is positive, this means that ICT diffusion slows down convergence; if γ is negative, the total coefficient on the lagged productivity level ($\beta + \gamma ICT$) is more negative in sectors where the ICT share is high, indicating faster convergence.

The estimates (see Table 3) show a positive relationship between the share of ICT and productivity growth: firms belonging to industries which are ICT-intensive have a productivity growth rate which is significantly higher on average than the other firms in the same sector. The interaction term is positive and significant: a firm which has higher productivity than the average for its sector grows more rapidly if it belongs to an ICT-intensive industry within that sector. Holding the ICT share constant at its mean level (12%), the interaction term reduces the speed of convergence by more than half for both labour productivity (from -0.9 to -0.5) and TFP (from -0.7 to -0.4). The considerable increase in the speed of convergence by comparison with the model of simple convergence, from -0.2 to -0.9 (see Table 1), shows that the increase in ICT intensity can explain an important part of the recent slowdown in the speed of convergence: the mechanism is productivity acceleration in high-productivity firms belonging to ICT-intensive industries.

These results remain significant, although weaker, when the ICT share and the interaction term are entered alongside the other explanatory variables which are considered below (the export share, the Lerner index and associated interaction terms: see Annex 6). Holding all three explanatory variables at their mean levels, ICT has the largest impact on convergence; it reduces the speed of convergence by almost a third for both labour productivity and TFP.

In order to see whether this reduction in speed is occurring because of a relative increase in growth amongst the leaders or a relative decline amongst the laggards, the following equation was estimated on each decile of the productivity distribution separately:

$$\Delta q_{it} = \beta q_{i,t-1} + \delta ICT_{j,t-1} + \mathbf{X}_{jt}\varepsilon + u_{it} \tag{6}$$

The ICT share has a significance and positive impact on productivity growth for firms which belong to the most productive decile and a weaker and insignificant impact for the least productive firms. This asymmetric impact is consistent with a reduction in the speed of convergence which is linked to ICT diffusion and which manifests itself as a relative increase in the growth rate of leading firms.

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[8] Given that sector dummies are included, we are talking here of the variation with respect to the sector mean over the whole period.

Globalisation

The rapid growth in new, emerging markets and the single European market have led to strong growth in exports: in France, the annual growth rate of exports rose from 4.2% in the 1980s to 7.0% in the 1990s. What effect did that have on productivity growth and which firms benefited the most?

Some arguments suggest a positive impact of exporting on productivity growth: if there are economies of scale at the firm level, or learning effects resulting from the entry into new markets,[9] or again a cyclical effect resulting from the fact that growth is faster in export markets than in the domestic market, which enables exporting firms to operate at full capacity while other firms have to cope with spare capacity.

A clear and positive relationship exists between the level of productivity and exporting at the firm level. However, it has been established that this relationship is mainly a selection effect (Clerides, Lack and Tybout, 1998; Bernard and Jensen, 1999): only the most productive firms can take on the fixed costs which must be incurred in entering a new market. The existence of a learning effect is still the subject of debate but recent work has confirmed it (Baldwin and Gu, 2003; Lileeva and Trefler, 2007 for industrial countries).

If these two effects (self-selection and learning by exporting) combine, this would help to explain the stylised fact that the fall in the speed of convergence is accompanied by a relative increase in the productivity growth rate of leading firms.

We therefore estimate equation (4) with the share of exports in value added at the sector level (NES 36) as the z_{it} variable. The results (Table 5) show that there is a positive relationship between measures of exporting and productivity growth. Given that exporting is largely confined to the most productive firms, this positive impact supports the intuition that globalisation is slowing down the convergence process.

Given the correlation between exporting and the level of productivity, it is hard to obtain a significant coefficient on the interaction term, which is also difficult to instrument. The latter variable tends to reduce slightly the speed of convergence: for firms with the mean rate of exporting, the interaction term increases the coefficient of convergence by 0.02 on a base of -

[9] These effects do not necessarily apply when firms from advanced countries are entering emerging markets. However, some part of the increase in the growth rate of international trade stems from increased trade between advanced countries.

0.19 for both labour productivity and TFP. When the other determinants are included (see Annex 6), the interaction term remains positive and significant. With the export share set at its mean value, the effect on the speed of convergence is weaker than that of ICT, but comparable to that of competition (see below).

The FiBEn database records the share of sales abroad at the firm level. These data are relevant but may be endogenous.[10] We therefore used the mean rate of exporting over the whole period by each firm and a dummy variable for when a firm had more than 25% of their sales abroad. We are then able to estimate equation (4) without the interaction term $q_{i,t-1}z_{i,t-1}$, decile by decile (see Table 6). We find a positive impact of the exporting variables on the productivity growth rate of the leading firms. By contrast, the impact of the exporting variables on the least productive firms is negative. This could be explained by the fact that the productivity variables are measured as deviations from the sector (and year) means. The exporting firms from the lowest productivity deciles are found predominantly in sectors where exporting is common, so exporting does not raise their productivity growth relative to the average for their sector. In summary, these two effects combined, the positive impact on the productivity growth of the leaders and the negative impact on that of the least productive, both work to reduce the speed of convergence.

Competition

Although the theoretical literature does not speak with one voice, several empirical studies using British data (eg Nickell, 1996) have found a positive impact of competition on productivity. However, we do not have any *a priori* view on the effect of competition on convergence.

We estimate equation (4) with the product of a Lerner index and the productivity level as the interaction term. A Lerner index is used as the measure of the intensity of competition (see Box 4). When the index is high, competition is weak.

The direct impact of the lagged Lerner index on productivity growth is negative for labour productivity (more competition increases productivity growth) but it is positive for TFP. This finding is robust to the estimation method (GLS or GMM), to the choice of sample (whole or

[10] There are also doubts about the quality of the export data which may be badly reported (particularly with regard to the distinction between not “available” and “zero”). To test the robustness of these results, the estimates were also done for just exporters, with similar results.

balanced) and to the use of different instruments or controls (see Annex 4). By contrast, when all the determinants of convergence used in this study are included, the direct impact of the Lerner index is no longer significant for labour productivity when GMM is used (though it remains significant and of the same sign when GLS is used) and for TFP it remains positive though smaller.

Box 4

Measures of competition

Measuring competition leads to considerable difficulties. First, the degree of competition to which a firm is subject is endogenous and depends on its own conduct: a particular strategic choice (product differentiation, the threat posed by spare capacity) can *ex post* reduce competition. In addition, competition and market structure are in a dynamic relationship: fierce competition can lead to the survival of a small number of very productive firms.

The measures based on just market structure (such as the Herfindahl index or market share) are both endogenous and subject to the problem of distinguishing the market in which firms are operating (taking account of the international dimension, and the difficulty of matching a market to a statistical industry).

Measures based on profitability are preferred in this study as in Aghion *et al.* (2005). Under perfect competition profits should disappear. The existence of profit shows that competition, potential or actual, is less than perfect whether due to regulation, the nature of the market (natural monopoly) or because an innovation has conferred temporary monopoly power.

The Lerner index relates price to marginal cost. Prices and marginal costs cannot be directly observed, so the Lerner index is approximated by the ratio of revenues to average costs. Since the costs recorded in the firm's accounts depend on its financial structure, average costs are calculated using the firm's estimated capital stock and its inventories. On the revenue side profits can be captured by the employees as well as by the shareholders. In the absence of detailed knowledge of the qualifications of the workforce which would allow us to calculate the wage bill at market prices, two choices are open: (1) use value added which would imply that the whole of wages is profit; or (2) use operating surplus, which would imply that all profit accrues to shareholders. The two measures were tested and yielded similar results, so we present here only the results based on operating surplus.

The Lerner index used in this study takes the following form:

$$IL_{it} = \frac{RE_{it} - \alpha_i (K_{it} + S_{it})}{V_{it}}$$

where IL is the Lerner index, RE is the operating surplus (net of depreciation), K is the capital stock, S is the stocks of inventories, V is total sales and α is the average cost of capital calculated from the whole sample (7.2% on average over the whole period). An unweighted mean for each of the NES 114 sectors (3-digit level) is calculated, since the regressions are themselves unweighted.

In other words, competitive pressure leads to an increase in capital intensity, either by more investment or by shedding labour, but does not lead to an improvement in technology or innovation.

This finding is in conflict with those of Nickell (1996) on British data. He tested the impact of monopoly profit on TFP. But the profitability measures used by Nickell were firm-level and averaged over the sample period, not averaged over the sector as here. The sector mean is used here to avoid the problem of endogeneity at the firm level. Sector-level data is also available at quite a detailed scale (NES 114 ie 3-digit level). When we employ firm-level measures of the Lerner index, we reproduce Nickell's finding. This shows that the dispersion of the Lerner index is high within each sector. This means either on the one hand that there are differences between the markets in which firms within the same sector are operating, or differences in product quality, or even geographical differences, or on the other hand that there are differences in profitability between firms operating in the same market due to their inherent capacities. In the first case, the Nickell approach is the most relevant, in the second the sectoral approach remains valid.

The coefficient on the interaction term is negative: an increase in competition (a fall in the Lerner index) reduces the speed of convergence. This effect is significant but small: for the most competitive sectors (the first decile of the Lerner index), the speed of convergence is reduced by 40% (after correcting for the interaction term β is -0.10 rather than -0.18). When all the determinants are included (see Annex 6), the interaction term remains significant and of the same sign. Setting the Lerner index at its mean value, the impact of competition on convergence is weaker than that of ICT but comparable to that of exporting.

This finding receives support when the equation is estimated without the interaction term and decile by decile (see Table 8), which throws an interesting light on how competition works at the aggregate level. The intensity of competition has a positive impact on the most productive firms and a negative one on the laggards, for both labour productivity and TFP. This finding is robust to both the estimation method and to the choice of sample (see Annex 5). It can be understood by extending the model of Aghion *et al.* (2005) which relates to investment in R&D: competition reduces returns and this tends to make the laggards reduce investment since the average profitability of the sector is lower, while the leaders are motivated to invest and innovate in order to escape competition.

According to these estimates, competition reduces convergence as well. Scharfstein's (1997) model suggests a theoretical explanation for this relationship: competition reduces the incentives for the laggards and stimulates the productivity of the leaders. In addition, the intensity of competition also affects the entry-exit process and the reallocation of market shares which are the other components of productivity growth at the macro level. Of course, the results presented here relate to growth within firms and not to these two other components which may also influence the link between competition and productivity growth at the macro level.

4. Conclusion

This study has tried to set out some stylised facts about and some possible explanations for the convergence of productivity in France in the 1990s. There are limits to the conclusions that can be reached on the basis of this study. These relate to the difficulty in distinguishing between convergence and the statistical phenomenon of regression to the mean, the impact of firm demographics, and the possible endogeneity of the explanatory variables employed.

Several stylised facts have been set out in this study. Convergence of productivity exists, which confirms earlier work on this topic, and it is stronger for labour productivity than for TFP. In addition, convergence in labour productivity works through catch-up by the least productive firms and in TFP by a return to the mean by the most productive.

Focusing on changes in the 1990s, we observe a fall in convergence due to an increase in the relative growth rate of the most productive firms. Several possible explanations have been suggested for this latter stylised fact. ICT may have been of greater benefit to leading firms, for example because of the higher qualifications of their employees. The growth of exports as a result of globalisation may also have benefited leading firms who are responsible for the bulk of exports as a result of the fixed costs which have to be incurred in order to enter a foreign market. Finally, if we accept the theoretical explanation of our findings due to Scharfstein (1988), the intensity of competition, which increased in most sectors during the 1990s, especially in those exposed to international competition, tends to stimulate the productivity of leading firms and to reduce the incentives for convergence of the laggards.

Other possible explanations could no doubt be advanced. The development of the financial markets may have benefited the most productive firms. Employment policy, and particularly the reduction of social security contributions for employees paid at or near the level of the SMIC (the minimum wage), may have led to a certain amount of substitution of labour for capital and of non-qualified for qualified labour (Crépon and Desplatz, 2001). This may have had a larger effect on the convergence of the least productive firms given their greater dependence on less well qualified labour.

Finally, in addition to casting light on convergence in productivity in the 1990s, another contribution of this study is to show that the macroeconomic impact of some of the determinants of productivity can be complex since it varies with a firm's relative productivity level.

Table 1
Model of simple convergence (equation (1))

Dependent variable	Δ log TFP	Δ log LP	Δ log TFP	Δ log LP
Sample	All	All	Balanced	Balanced
Estimation method	GMM	GMM	GMM	GMM
Constant	0.0684***	0.0246***	0.0847***	0.0298***
Lagged level of TFP/LP	-0.184***	-0.203***	-0.182***	-0.226***
Number of observations	892,287	968,583	356,674	429,357
Sargan-Hansen test (*p*-value)	0 .502	0.730	0.0819	0.154

* $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Note Estimation period: 1992-2004. TFP: total factor productivity; LP: labour productivity (deviations from sector-year means). Equation (1) estimated with dummy variables for year, sector (NES 36), and region. Instruments for the level of lagged productivity: first difference of productivity (lagged twice) and age of firm. The F tests for significance of the instruments in the first-stage regressions are strongly significant; the estimates are robust to the use of different instruments (eg change in lags or in export share, at firm level) and of a different estimation method (GLS, with an upward bias in the estimate of β); the Sargan-Hansen tests for over-identification of the instruments do not reject the null hypothesis that the model is correctly specified.

Source FiBEn, Banque de France.

Table 2
Model of convergence by decile (equation (3))

Dependent variable	Δ log LP	Δ log LP
Estimation method	GLS	GMM
Decile 1 (lowest productivity)	-0.177***	-0.199***
Decile 2	-0.137***	-0.226***
Decile 3	-0.126***	-0.152*
Decile 4	-0.130***	-0.333***
Decile 5	-0.150***	-0.185
Decile 6	-0.140***	0.0849
Decile 7	-0.0562***	0.0567
Decile 8	-0.0678***	-0.239***
Decile 9	-0.0706***	-0.135***
Decile 10 (highest productivity)	-0.0697***	-0.202***
Number of observations	1,185,554	790,633
R^2	0.0491	
Sargan-Hansen test (*p*-value)		0.121

* p<0.05, ** p<0.01, *** p<0.001

Note Estimation period: 1992-2004. TFP: total factor productivity; LP: labour productivity (deviations from sector-year means). Equation (3) estimated with dummy variables for year, sector (NES36), and region. Instruments for the interaction terms (decile dummies x lagged productivity): second lag of these variables in first differences and age of firm. Instrumenting these variables is difficult: as the results using GLS have a known bias (they are higher than the true value), they may be considered more reliable for assessing the relative value of the coefficients. The Sargan-Hansen tests for over-identification of the instruments do not suggest rejection of the null hypothesis that the model is correctly specified. The Wald test tends to reject the null hypothesis that the coefficients for the 10 deciles are equal in equation (3).

Source FiBEn, Banque de France.

Table 3
Model of convergence incorporating ICT (equation (4))

Dependent variable	Δ log TFP	Δ log LP
Constant	0.231***	0.118**
Lagged productivity level	-0.708***	-0.876***
Lagged share of ICT	0.0426***	0.0820***
ICT share x lagged productivity	2.752***	3.430***
Number of observations	583,786	519,107
Sargan-Hansen test (*p*-value)	0.983	0.432

* $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Note Estimation period: 1992-2004. TFP: total factor productivity; LP: labour productivity (deviations from sector-year means). Equation (4) estimated with dummy variables for year, sector (NES36), and region. Estimation is by GMM, using the method developed by Arellano and Bover (1995). Instruments for the lagged level of productivity and the interaction term: second lag and third lag of the first differences of these variables. The *F* tests for significance of the instruments in the first-stage regressions are highly significant; the estimates are robust to the use of different instruments (eg age of firms) and different estimation methods (GLS, with an upward bias in the estimate of β) ; the Sargan-Hansen tests for over-identification of the instruments do not reject the null hypothesis that the model is correctly specified.

Source FiBEn, Banque de France.

Table 4
Coefficients on ICT, by decile (equation (5))

Dependent variable	Δ log LP	Δ log LP	Δ log TFP	Δ log TFP
Estimation method	GLS	GMM	GLS	GMM
Decile 1 (lowest productivity)	0.0134	0.0153	0.0486**	0.0862
Decile 2	-0.00442	-0.00175	0.00225	0.0590
Decile3	-0.00401	-0.00659*	0.00383	0.0114
Decile4	0.00133	0.00351	0.00131	0.0411
Decile5	0.00104	0.000279	0.00112	0.0625*
Decile6	0.00139	0.00117	0.00354	0.0385
Decile7	0.00409	0.00617*	0.00260	0.108***
Decile8	0.00527	0.00418	0.00472	0.107***
Decile9	0.0109*	0.00709	-0.000318	0.120***
Decile10 (highest productivity)	0.0420**	0.0734**	0.0548***	0.162***

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Note Estimation period: 1992-2004. TFP: total factor productivity; LP: labour productivity (deviations from sector-year means). Estimation is by GMM and GLS on each decile separately, with dummy variables for year, sector (NES36), and region. Instruments for the lagged level of productivity: first difference of productivity, lagged twice, and age of firm. The *F* tests for significance of the instruments in the first-stage regressions are highly significant; the Sargan-Hansen tests for over-identification of the instruments do not reject the null hypothesis that the model is correctly specified.

Source FiBEn, Banque de France.

Table 5
Model of convergence incorporating export share (equation (4))

Dependent variable	Δ log LP	Δ log LP	Δ log TFP	Δ log TFP
Estimation method	GLS	GMM	GLS	GMM
Constant	-0.037***	-0.033***	0.002	0.0531***
Lagged productivity level	-0.102***	-0.188***	-0.0577***	-0.187***
Lagged export share (NES36)	0.163***	0.157***	0.0688***	0.0604***
Interaction export share x productivity	0.00566***	0.0493***	0.00376***	0.0350**
Number of observations	1,170,870	633,077	1,062,235	713,678
R^2	0.04		0.03	
Sargan-Hansen test (*p*-value)		0.00		0.111

* p<0.1,** p<0.05, *** p<0.01

Note Estimation period: 1992-2004. TFP: total factor productivity; LP: labour productivity (deviations from sector-year means). Equation (4) estimated with dummy variables for year, sector (NES36), and region. Estimation is by GLS and GMM, using the method developed by Arellano and Bover (1995). Instruments for the lagged level of productivity and the interaction terms: second lag (third for labour productivity) of productivity and of the first difference of the interaction term and age of firm. The *F* tests for significance of the instruments in the first-stage regressions are highly significant; the estimates are robust to the use of different instruments (eg change in the number of lags); the Sargan-Hansen tests for over-identification of the instruments reject the null hypothesis that the model is correctly specified in the case of labour productivity.

Source FiBEn, Banque de France.

Table 6
Coefficients on export variables, by decile

Dependent variable	Δ log LP	Δ log LP	Δ log TFP	Δ log TFP
Export variables	Export share	Dummy variable for exporter	Export share	Dummy variable for exporter
Decile 1 (lowest productivity)	-0.0716***	-0.0289***	-0.0593***	-0.0277***
Decile 2	-0.00516**	-0.00189**	-0.00803***	-0.00251**
Decile 3	0.00192	0.000494	-0.00472***	-0.00155*
Decile 4	0.00175*	0.000486	-0.000708	-0.000586
Decile 5	0.00252***	0.000846*	-0.00198*	-0.000564
Decile 6	0.00166*	0.000969**	0.00055	0.0000212
Decile 7	0.00224**	0.000394	-0.000511	-0.000374
Decile 8	0.00440***	0.00178***	0.000546	0.0000935
Decile 9	0.0108***	0.00452***	0.00516**	0.00176
Decile10 (highest productivity)	0.0510***	0.0225***	0.0719***	0.0281***

* p<0.05, ** p<0.01, *** p<0.001

Note Estimation period: 1992-2004. TFP: total factor productivity; LP: labour productivity (deviations from sector-year means). Dummy variable for exporter: = 1 if exports more than 25% of sales. Estimation is by GMM on each decile separately, with dummy variables for year, sector (NES36), and region. Instruments for the lagged level of productivity: first difference of productivity, lagged twice, and age of firm. The *F* tests for significance of the instruments in the first-stage regressions are highly significant; the Sargan-Hansen tests for over-identification of the instruments do not reject the null hypothesis that the model is correctly specified.

Source FiBEn, Banque de France.

Table 7
Convergence model with competition (equation (4))

Dependent variable	Δ log LP	Δ log LP	Δ log TFP	Δ log TFP
Constant	0.00838**	0.0177***	0.0965***	0.0323***
Lagged productivity level	-0.217***	-0.214***	-0.191***	-0.180***
Lerner index	-0.278***	-0.139***	0.668***	0.0915***
Interaction: Lerner index x productivity	-1,996***	-1,959***	-2,092***	-1,951***
Sector dummies	YES	NO	YES	NO
Number of observations	780,444	780,444	714,616	714,616
Sargan-Hansen test (*p*-value)	0.379	0.273	0.75	0.841

* p<0.05, ** p<0.01, *** p<0.001

Note Estimation period: 1992-2004. TFP: total factor productivity; LP: labour productivity (deviations from sector-year means). Equation (4) estimated with dummy variables for year, sector (NES36), and region. Estimation is by GMM, using the method developed by Arellano and Bover (1995). Instruments: for the lagged level of productivity, second lag of first difference of productivity; for the interaction term, age of firm. The *F* tests for significance of the instruments in the first-stage regressions are highly significant; the estimates are robust to the use of different instruments (lagged change in export share, at firm level) and of a different estimation method (GLS, with an upward bias in the estimate of β); the Sargan-Hansen tests for over-identification of the instruments do not reject the null hypothesis that the model is correctly specified.

Source FiBEn, Banque de France.

Table 8
Coefficient on Lerner index, by decile

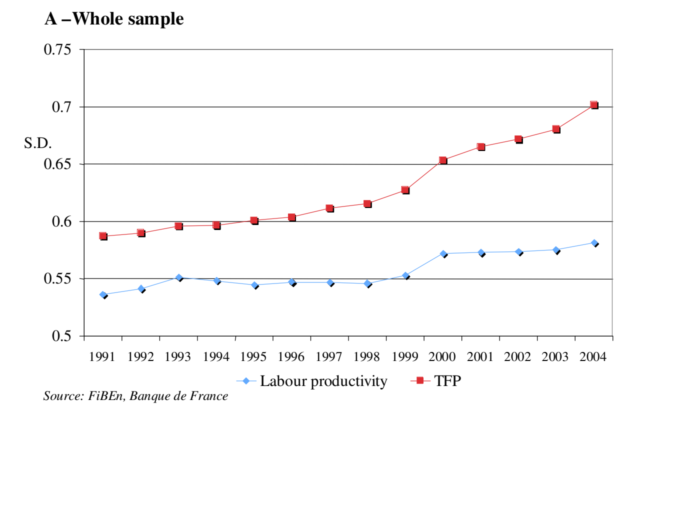
Dependent variable	Δ log LP	Δ log LP	Δ log TFP	Δ log TFP
Estimation method	GLS	GMM	GLS	GMM
Decile 1 (lowest productivity)	0.442***	0.413***	0.265***	0.831***
Decile 2	-0.00664	-0.0184	0.151***	0.187***
Decile 3	-0.0108	-0.00919	0.0513**	0.0871***
Decile 4	-0.00206	-0.00776	0.0280*	0.0186
Decile 5	-0.00204	0.00662	0.0177	0.0181
Decile 6	0.0115	0.00893	0.0170	0.0266*
Decile 7	0.00948	-0.000324	0.0140	0.0120
Decile 8	-0.0155	-0.0195	0.00877	-0.0151
Decile 9	-0.00731	-0.0135	0.0154	0.0197
Decile 10 (highest productivity)	-0.112*	-0.305***	-0.111	-0.201***

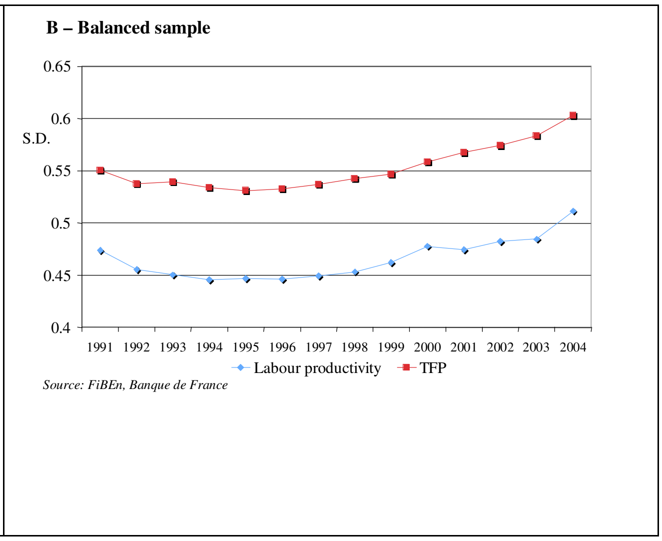
* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Note Estimation period: 1992-2004. TFP: total factor productivity; LP: labour productivity (deviations from sector-year means). Estimation is by GMM on each decile separately, with dummy variables for year, sector (NES36), and region. Instruments for the lagged level of productivity: first difference of productivity, lagged twice, and age of firm. The *F* tests for significance of the instruments in the first-stage regressions are highly significant; the Sargan-Hansen tests for over-identification of the instruments do not reject the null hypothesis that the model is correctly specified.

Source FiBEn, Banque de France.

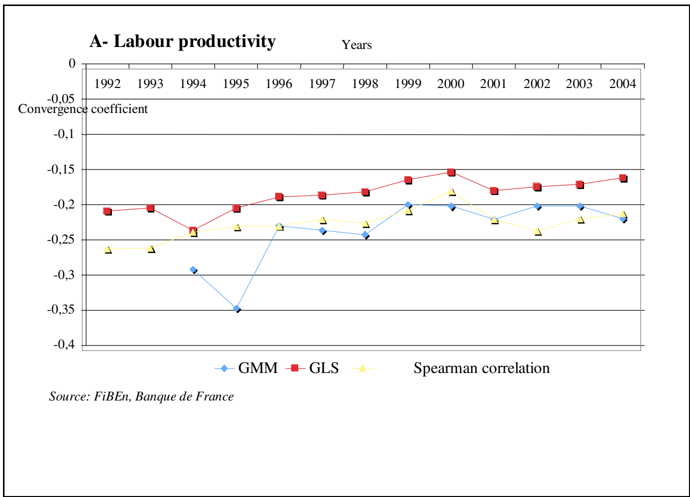
Chart 1
Changes in productivity dispersion, 1991-2004

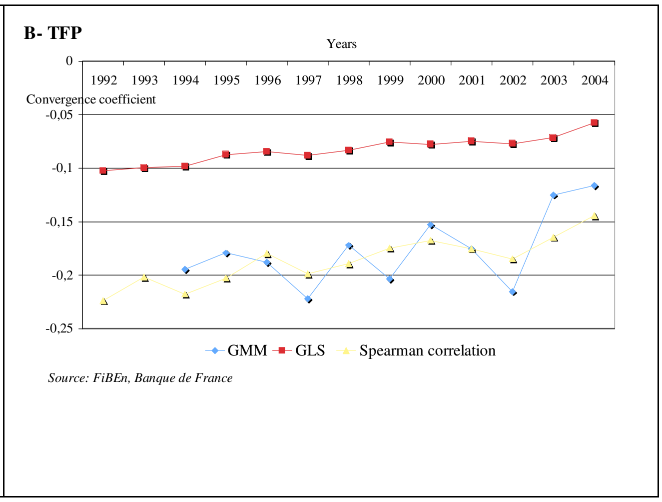




Note The standard deviation of the log of labour productivity (deviation from sector-year means) changed from 0.54 in 1991 to 0.58 in 2004.

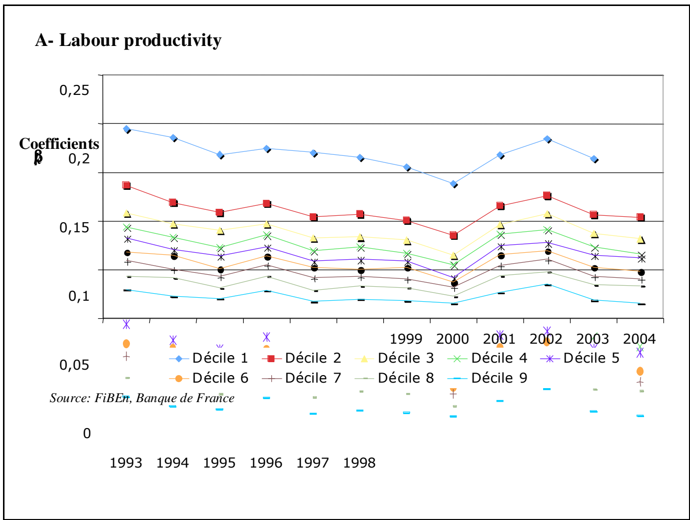
Chart II
Changes in speed of convergence, 1992-2004

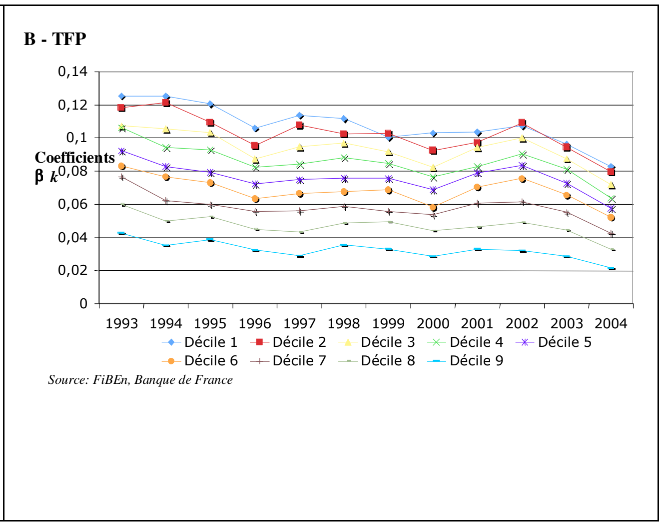




Note Estimation year by year of equation (1). The speed of convergence of labour productivity estimated by OLS changed from 0.20 in 1992 to 0.15 in 2004. Taking account of the standard error of the convergence coefficient does not change the conclusion that the speed of convergence has fallen.

Chart III
Changes in convergence over time and across deciles





Note: year-by-year estimation of equation (2). The estimated coefficients correspond to the difference between the mean growth rate of the firms in the *k*th decile and that of the firms in the 10th decile. The growth rate of TFP of the firms in the first decile is 12 % higher than that of firms in the 10th decile in 1992 and 8 % higher in 2004.

Annex 1
Model of simple convergence (equation (1))

Dependent variable	Δ^5 log TFP	Δ^5 log LP	Δ^5 log TFP	Δ^5 log LP
Sample	All	All	Balanced	Balanced
Estimation method	GMM	GMM	GMM	GMM
Constant	0.345***	0.0751***	0.345***	0
TFP/LP level lagged 5 years	-0.684***	-0.679***	-0.687***	-0.688***
Number of observations	130.800	139,768	108,270	115,075
Sargan-Hansen test (*p*-value)	0.156	0.581	0.170	0.187

* p<0.05, ** p<0.01, *** p<0.001

Note Estimation period: 1992-2004. TFP: total factor productivity; LP: labour productivity (deviations from sector-year means). Equation (1) estimated with dummy variables for year, sector (NES36), and region. Instruments for the lagged level of productivity: first difference of productivity, lagged twice, and age of firm. The *F* tests for significance of the instruments in the first-stage regressions are strongly significant; the estimates are robust to the use of different instruments (eg lagged change in export share, at firm level) and of a different estimation method (GLS, with an upward bias in the estimate of β); the Sargan-Hansen tests for over-identification of the instruments do not reject the null hypothesis that the model is correctly specified.

Source FiBEn, Banque de France.

Annex 2
Transition matrix: proportion of firms which move from one decile to another in one year
A – Labour productivity

Productivity decile in year *t*-1

Productivity decile in year *t*

Decile (%)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	**62**	20	7	4	2	2	1	1	1	1
2	21	**40**	21	9	4	2	1	1	1	0
3	7	23	**31**	20	9	5	2	1	1	0
4	4	10	22	**28**	20	10	4	2	1	0
5	2	5	11	21	**27**	19	9	4	1	1
6	2	3	5	11	21	**28**	20	8	3	1
7	1	1	3	5	10	22	**31**	20	6	1
8	1	1	1	2	4	9	22	**37**	19	3
9	1	1	1	1	2	3	7	22	**48**	15
10	1	0	0	0	0	1	1	4	18	**74**

Note Each cell (*x*, *y*) shows the proportion of firms which are in decile *x* in year *t*-1 and in decile *y* in year *t*. For example, 21% of firms which were in the first decile in year *t*-1 are in the 2nd decile in the following year. If firms never moved from their original decile, all the diagonal entries would be 100. Deciles are ranked from the least productive (1) to the most productive (10). This transition matrix is estimated on annual data for the whole period 1991-2004. Rows and columns may not sum to 100 due to rounding.

Source FiBEn, Banque de France

Transition matrix: proportion of firms which move from one decile to another in one year (continued)
B – Total factor productivity

		Productivity decile in year *t*-1									
	Decile (%)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Productivity decile in year *t*	**1**	**82**	14	2	1	0	0	0	0	0	0
	2	14	**58**	20	4	2	1	0	0	0	0
	3	2	21	**45**	21	6	2	1	1	0	0
	4	1	5	22	**38**	21	7	3	1	1	0
	5	0	2	7	23	**34**	21	8	3	1	1
	6	0	1	3	9	23	**33**	21	8	3	1
	7	0	1	1	3	9	23	**34**	21	7	1
	8	0	0	1	2	4	9	23	**37**	20	4
	9	0	0	0	1	1	3	8	23	**47**	16
	10	0	0	0	0	1	1	2	5	20	**71**

Note Each cell (x, y) shows the proportion of firms which are in decile x in year t-1 and in decile y in year t. For example, 14% of firms which were in the first decile in year t-1 are in the 2nd decile in the following year. If firms never moved from their original decile, all the diagonal entries would be 100. Deciles are ranked from the least productive (1) to the most productive (10). This transition matrix is estimated on annual data for the whole period 1991-2004. Rows and columns may not sum to 100 due to rounding.

Source FiBEn, Banque de France.

Annex 3
Model of convergence with U.S. sectoral ICT share (equation (4))

Dependent variable	Δ log LP	Δ log TFP
Constant	-0.184*	0.264***
Lagged productivity level	-0.881***	-0.806***
ICT share	0.248***	0.120***
Interaction term	2.453***	2.127***
Number of observations	300,674	584,608
Sargan-Hansen test (*p*-value)	0.0742	0.65

* p<0.05, ** p<0.01, *** p<0.001

Note Estimation period: 1992-2004. TFP: total factor productivity; LP: labour productivity (deviations from sector-year means). Equation (4) estimated with dummy variables for year, sector (NES36), and region. Estimation is by GMM, using the method developed by Arellano and Bover (1995). Instruments for the lagged level of productivity and interaction term: first difference of productivity and interaction term, lagged twice and three times. The *F* tests for significance of the instruments in the first-stage regressions are highly significant; the estimates are robust to the use of different instruments (eg different lags) and of a different estimation method (GLS, with an upward bias in the estimate of β); the Sargan-Hansen tests for over-identification of the instruments do not reject the null hypothesis that the model is correctly specified.

Source FiBEn, Banque de France.

Annex 4
Model of convergence with competition – balanced sample (equation (4))

Dependent variable	Δ log LP	Δ log LP	Δ log TFP	Δ log TFP
Constant	0.0243***	0.0278***	0.0986***	0.0434***
Lagged productivity level	-0.249***	-0.246***	-0.217***	-0.205***
Lerner index	-0.195***	-0.130***	0.480***	-0.0956**
Interaction Lerner-productivity	-3.118***	-3.041***	-3.025***	-2.906***
Sectoral dummies	YES	NO	YES	NO
Number of observations	380,267	380,267	356,674	356,674
Sargan-Hansen test (*p*-value)	0.367	0.245	0.578	0.305

* p<0.05, ** p<0.01, *** p<0.001

Note Estimation period: 1992-2004. TFP: total factor productivity; LP: labour productivity (deviations from sector-year means). Equation (4) estimated with dummy variables for year, sector (NES36), and region. Estimation is by GMM, using the method developed by Arellano and Bover (1995). Instruments for the lagged level of productivity and interaction term: first difference of productivity and interactions term, lagged twice, and change in firm export, lagged twice. The *F* tests for significance of the instruments in the first-stage regressions are highly significant; the estimates are robust to the use of different instruments (eg age of firms) and of a different estimation method (GLS, with an upward bias in the estimate of β); the Sargan-Hansen tests for over-identification of the instruments do not reject the null hypothesis that the model is correctly specified.

Source FiBEn, Banque de France.

Annex 5
Lerner index coefficient, by decile (balanced sample)

Dependent variable	Δ log LP	Δ log LP	Δ log TFP	Δ log TFP
Estimation method	GLS	GMM	GLS	GMM
Decile 1 (lowest productivity)	0.442***	0.413***	0.265***	0.831***
Decile 2	-0.00664	-0.0184	0.151***	0.187***
Decile 3	-0.0108	-0.00919	0.0513**	0.0871***
Decile 4	-0.00206	-0.00776	0.0280*	0.0186
Decile 5	-0.00204	0.00662	0.0177	0.0181
Decile 6	0.0115	0.00893	0.0170	0.0266*
Decile 7	0.00948	-0.000324	0.0140	0.0120
Decile 8	-0.0155	-0.0195	0.00877	-0.0151
Decile 9	-0.00731	-0.0135	0.0154	0.0197
Decile 10 (highest productivity)	-0.112*	-0.305***	-0.111	-0.201***

* p<0.05, ** p<0.01, *** p<0.001

Note Estimation period: 1992-2004. TFP: total factor productivity; LP: labour productivity (deviations from sector-year means). Estimation is by GMM and GLS on each decile separately, with dummy variables for year, sector (NES36), and region. Instruments for the lagged level of productivity: first difference of productivity, lagged twice, and age of firm. The *F* tests for significance of the instruments in the first-stage regressions are highly significant; the Sargan-Hansen tests for over-identification of the instruments do not reject the null hypothesis that the model is correctly specified.

Source FiBEn, Banque de France.

Annex 6
Model of convergence with all determinants included (equation (4))

Dependent variable	Δ log TFP	Δ log TFP	Δ log LP	Δ log LP
Estimation method	GLS	GMM	GLS	GMM
Constant	0.150***	0.208***	-0.0362	-0.0337
Lagged productivity level	-0.0758***	-0.333***	-0.118***	-0.367***
ICT share (lagged)	0.0499***	0.0405***	0.0282***	0.0294***
ICT x lagged productivity	0.0556***	0.833***	0.108***	0.950***
Export share NES36 lagged	0.101***	0.0809***	0.151***	0.142***
Export share x productivity	0.0107***	0.0613***	0.00322	0.0399**
Lerner index	0.388***	0.274***	-0.201***	0.00708
Lerner x lagged productivity	-0.448***	-3.263***	-0.419***	-3.469***
Number of observations	870,500	584,608	963,455	640,606
R^2	0.03		0.04	
Sargan-Hansen test (*p*-value)		0.892		0.340

* p<0.05, ** p<0.01, *** p<0.001

Note Estimation period: 1992-2004. TFP: total factor productivity; LP: labour productivity (deviations from sector-year means). Equation (4) estimated with dummy variables for year, sector (NES36), and region. Estimation is by GLS and GMM, using the method developed by Arellano and Bover (1995). Instruments for the lagged level of productivity and the interaction terms: lags of first differences and lagged change in the share of exports in turnover. The *F* tests for significance of the instruments in the first-stage regressions are highly significant; the estimates are robust to the use of different instruments (eg age of firm); the Sargan-Hansen tests for over-identification of the instruments do not reject the null hypothesis that the model is correctly specified.

Source FiBEn, Banque de France.

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