Stagnation of productivity in France: A legacy of the crisis or a structural slowdown?

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Abstract - The productivity slowdown has been analysed either as an effect of the crisis, resulting from the financial and demand shocks, or as a more structural decline. In France, using macroeconomic and microeconomic data, we identify downward breaks in the trends of labour productivity and total factor productivity in the 2000s, several years before the crisis. These breaks result in historically weak rhythms of the trends. Using data on firms located in France, we highlight that, at the technological frontier, productivity has accelerated, especially over the recent period, which contradicts the hypothesis of a decline in innovation. The most productive firms in a given year do not, however, improve their relative advantage. The convergence of firms' productivity does not seem to have slowed down in the 2000s, which does not confirm the hypothesis of a decrease in the dissemination of innovation. On the other hand, the dispersion of productivity between firms has increased, which suggests increasing difficulties in the reallocation of production factors, labour and capital, between firms.

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Productivity is the main source of gains in GDP per capita and therefore of the increase of the average living standard of a population. However, at the beginning of the 2000s, that is, before the financial crisis which began in 2007-2008, productivity slowed down in all the main developed countries, including France (on this topic see Bergeaud et al., 2016). Such a slowdown brings productivity growth to historically low levels compared to those we have been used to since the second industrial revolution which completely disrupted lifestyles and production processes in the 20th century. The third industrial revolution, associated with the production and dissemination of information and communication technologies (ICT), galvanised productivity in some countries and over short periods (for example the United States from the mid-1990s to the mid-2000s). It has not yet fulfilled the biggest expectations that many had in the "new economy".

This apparent decline of productivity growth has been largely discussed in the literature[1]. It leads certain economists (for example Summers, 2014 and 2015; or Gordon, 2016) to consider the risk of secular stagnation, in other words a long period of weak growth[2]. In fact, as Mokyr et al. (2015) have thoroughly analysed in a recent – and already much referred to – article, such a fear has been recurrent since the beginning of the first industrial revolutions. Other authors envisage considerable shake-ups in the decades to come – for example Brynjolfsson and McAfee (2014) or Pratt (2015) about robotics – which will lead to a new wave of productivity growth (see Cette, 2014 and 2015, for a literature review). The third industrial revolution, associated with ICT, might therefore lead to two successive waves of acceleration of productivity, the first having been clearly identified in the US and in a few other countries over the 1995-2005 decade, and the second still to come. Such a phenomenon of a double wave of productivity acceleration had already been observed during the first industrial revolution associated with, among other transformations, the invention and dissemination of the steam engine, with a first wave from the end of the 18th century to the first half of the 19th century with, for example, the use of this energy source in the textiles industry, and from the second half of the 19th century to the beginning of the 20th century with the development of railway transportation. In other words, and as Van Ark (2016) writes, the current pause in the productivity gains of the third industrial revolution would characterise the transition from the phase of creation and installation of new technologies to the phase of their widespread use. Since this had been the case for the preceding technological revolutions, especially electricity, this deployment phase would require time because it involves drastic changes to our institutions and our production and management processes, but now it would be close. But for certain economists, for example Branstetter and Sichel (2017), the gains in productivity brought on by the transformations associated with the digital economy could be both durable and greatly significant.

The aim of this article is not to answer all the questions opened by the universal productivity slowdown in the developed world since the start of the decade of 2000. It is first of all, within the well-outlined framework of the French economy, to make sure of the existence of such a slowdown and to research some explanatory elements. To do so, two types of data have been mobilised: macroeconomic data and firm-level data. If both are useful in characterising the potential changes in productivity, only the wealth of information at firm-level will allow us to confront some economic interpretations of this slowdown with empirical observations. Two productivity indicators will be considered over the two types of data: labour productivity (LP) and total factor productivity (TFP). We will see that the diagnostics of productivity slowdown are consistent for the indicators and the two datasets. Company-level data, furthermore, reveal that the dispersion of productivity between firms has intensified, suggesting an increase of the difficulties in reallocating the production factors, labour and capital (cf. Boxes 1 and 2).

Breaks in productivity trends

On the basis of macroeconomic data: Breaks in downward trends at the start of the 1990s and 2000s

Over the period 1976-2015, prior to the first oil crisis, the evolution of total factor productivity per hour (TFPH) saw two significant downward

1. For a literature review, see for example Crafts & O'Rourke (2013), or Bergeaud et al. (2016). For the US, see for example Byrne et al. (2013).

2. This visible decline in productivity gains has led certain observers to suggest that the measurement of GDP might be ignoring a growing section of business activity linked to the digital economy and the collaborative economy. Recent works on the matter (for example Byrne et al., 2016; or Syverson, 2016), however, show that, for the US, even with extreme hypotheses, the valuation of new activity associated with the digital economy would not call into question the drop in productivity observed at the start of the decade of 2000, and would even intensify this slowdown.

Box 1 – **Productivity indicators**

The aim of this study is to identify and estimate the potential dates of breaks in structural trends of two productivity indicators: labour productivity (LP) and total factor productivity (TFP). These two indicators are calculated over each of the two mobilised databases: macroeconomic data taken from national accounts (source being Insee [French National Institute of Statistics and Economic Studies]) and individual company data taken from databases built at Banque de France. These databases are presented in box 2.

The labour productivity (LP) indicator is output volume (Q) over amount of labour (L) $LP = Q/L$. The total factor productivity (TFP) indicator is output volume (Q) over a geometric average (in accordance with a Cobb-Douglas function) of the two factors considered, capital (K) and labour (L). $TFP = Q/(K^{\alpha}.L^{\beta})$. We expect constant returns from two factors of production, which correspond to the constraint: $\alpha + \beta = 1$. TFP is thus defined by the relation: $TFP = Q/(K^{\alpha}.L^{1-\alpha})$. Over the macroeconomic data, these two indicators are calculated at the overall level of the whole economy whereas they are calculated for each company on the basis of individual data.

Output volume (Q) corresponds to GDP volume over the macroeconomic data and to the volume of added value generated over the individual company data. Over these data, which do not have a price measurement of each company's added value, the volume of the added value is calculated, for each company, by deflating the added value of that company into a current value by a price index by branch (level 40 of the nomenclature of NAF rev 2 French economic activities) of the gross added value, with this index having been taken from national accounts.

Over the macroeconomic data, the evaluation of the volume of fixed revenue-earning capital (*K*) uses the one conducted by Bergeaud et al. (2016). It is based on the perpetual inventory method by using investment as an inflow and downgrading as an outflow, the latter being calculated with a constant depreciation rate over time. Two types of revenue-earning capital are distinguished: capital tied up in buildings and in materials, for which depreciation rates are different (respectively 2.5% with an average lifespan of 40 years, and 10% with an average lifespan of 10 years). Over the company data, the evaluation of the volume of fixed revenue-earning capital (*K*) is also conducted on the two construction products and the equipment. For each of these two products, the companies' accounts provide a value of the immobilised fixed revenue-earning capital at historical costs (that being at the purchase price of each investment making up this capital). To move on to a measurement in volume, these measurements at historical costs are deflated by a price index of the average age of the delayed investment of the capital component considered. The average age of each of these two components of capital is evaluated drawing on the proportion of depreciated capital, reconstituted from companies' accounts. Finally, over the two types of data, capital which is involved in the calculation of TFP of a year is that which is immobilised at the end of the preceding year.

Over the macroeconomic data, two alternative measurements of labour (*L*) are mobilised: the average number of employees (*N*) or the average number of hours worked (*H*) which is equal to the product of the number of employees (*N*) and of the average yearly number of hours worked per employee (Y). $H = N.Y$ We thus construct over these data two measurements of each of the two productivity indicators: labour productivity per hour (*LPH*) and per employee (*LPN*) and TFP per hour (*TFPH*) and per employee (*TFPN*). Over the company data, we do not have a measurement of the duration of employees' labour (*Y*). We therefore construct over these data one sole measurement of each of the two productivity indicators: LP per employee (*LPN*) and TFP per employee (*TFPN*). Over the four decades from 1974 to 2015, the average yearly number of hours worked per employee in France fell by 22% with sub-periods of declines faster than others (for example the first three decades compared to the last one). Because of this, per hour and per employee indicators can see contrasting evolutions. The empirical literature on macroeconomic data generally privileges hourly productivity indicators (cf. for example Bergeaud et al., 2016). But, in order to compare the evolutions characterised over macroeconomic data to those characterised over company data for which we do not have information on the duration of work, the two measurements are therefore considered over macroeconomic data.

The value of the weighting coefficient (α) which is involved in the calculation of TFP takes, over the macroeconomic data, a fixed value of 0.3 ($\alpha = 0.3$), as in Bergeaud et al. (2016) who show that the results (in terms of rhythms of TFP growth and of the dating of these breaks) are robust with the choice of foreseeable values ($\alpha = 0.25$ or $\alpha = 0.35$). Over the company data, the average value of the share of revenue from capital in the added value is 30%. We have retained for this parameter a specific value for each sector (as a nomenclature in 40 sectors) and equal to the average observed over the mobilised individual database. The values retained thus vary from 0.168 in the Medical and Social Accommodation sector (QB) to 0.622 in the Electricity, Gas, Vapour and Air Conditioning Production and Distribution sector (DZ); the average for all sectors is 0.303.

Finally, to characterise the breaks in productivity using an econometric approach, it is useful to neutralise the effects of short-term economic variations. To do this, we use over macroeconomic data an indicator of the capacity utilisation rate (CUR, source: Insee) and over individual company data variations of the turnover logarithm (TO, source: *Fiben*, *Fichier bancaire des entreprises*, which is managed by Banque de France).

breaks[3], the first at the start of the 1980s, with growth declining from 2.1% to 1.5%, then at the start of the 2000s, with the TFPH growth reaching zero (figure 1-A). The evolution of labour productivity per hour (LPH) saw three downward breaks at almost to the same time as that of TFPH, at the start of the 1980s, with yearly LPH growth going from 3.9% to 2.4%, then at the start of the 1990s, with LPH growth moving to 1.9% and finally at the start of the 2000s, with LPH growth then dropping to 0.5% (figure I-C)[4]. These dates of breaks differ slightly from those detected in previous studies, for example Bergeaud et al. (2016), for two reasons. First of all, the data are updated here with regards to that preceding study. Then, because the estimation that underpins the detection of breaks here takes into account the economic climate and its possible impact on the

3. Box 3 outlines the methodology for detecting breaks in trends.

4. Annex 1 presents the robustness tests in relation to these tests for breaks.

Box 2 – **Data**

Two databases are used: macroeconomic data and individual company data taken from databases built at Banque de France.

The macroeconomic data are taken directly from 2010 base national accounts, 2015 provisional accounts (source being Insee) with the exception of the series of fixed revenue-earning capital (*K*) which are essential to calculating TFP. The series of capital (*K*) are taken from Bergeaud et al. (2016) who built them using the perpetual inventory method drawing on macroeconomic investment data (source: Insee), see also Box 1. These series are available on www.longtermproductivity.com.

The individual company data are taken from Fiben [Company Banking File] data which is managed by Banque de France. Fiben is a very large database which gathers accounting data (corresponding to the tax returns) of all companies (Metropolitan France and Overseas Departments [*Départements d'outre mer - DOM*]) whose turnover exceeds €750,000 per year or which hold more than €380,000 in credit. This database is therefore not as exhaustive as Insee's Ficus-Fare databases but it focuses on the companies which make up most of the added value and the private sector workforce (market sectors with the exception of the financial sector) and whose accounting data are of a higher quality. The Fiben database has seen its coverage increase over the period considered, being affected by different factors, due mainly to the fixing of thresholds in nominal and non-real terms. The companies present in this database correspond to the legal unit, and to a legal definition of the company. The Fiben base covers 84% of employment of the companies present in BIC-BRN in 2004, with the companies having fewer than 20 employees being less well-covered than the others (54% of employment).

A clean-up of this database was conducted in order to avoid the presence of abnormal data. For the calculations of the indicators of total factor productivity and labour productivity, we apply a method based on the outliers principle developed by John Tukey (Kremp, 1995), which deletes values located beyond quartile 1 (and 3) which are less (and more) than three times the interquartile spread. We conduct the processing of abnormal observations first for the logarithm variable then for the growth rate variable.

Using the cleaned Fiben database, we have an unbalanced sample made up of between 59,767 and 130,750 companies per year over the study period in order to study the evolution of labour productivity (*LPN*) (11,428 companies over the balanced sample and the period 1992-2014) and between 42,241 and 109,579 companies to study the evolution of *TFPN* (7,857 companies over the balanced sample and the period 1993-2014, knowing that to obtain a sizeable sample over the balanced panel, the study period starts a year later for *TFPN*). The difference in the number of companies available is explained by the fact that the construction of the *TFP* indicator requires more accounting information than the *LP* indicator. The two indicators are calculated per company and per year (cf. box 1).

The problem of the convergence of smaller companies' productivity is not treated and the different indicators used are adapted to this limitation (for example the use of median indicators rather than average ones). The mobilised indicators in this study are always the median indicators over the field considered: sector, size, sector x size, the 5% most productive companies to characterise the technological frontier or the 95% remaining companies to characterise the others... This choice means that the indicators are not influenced by possibly extreme or even abnormal values which are often observed over individual data.

In order to characterise the possible heterogeneity of the dates of break, we have distinguished six business sectors (agriculture and silviculture, manufacturing industries, construction, retail, transport and other services, with the classifications having been conducted on the basis of NAF rev 2) and three size classes of companies, on average over the period of their presence in the database (size 1: less than 50 employees, size 2: 50 to 249 employees, size 3: 250 or more employees). Size 1 represents 87% of the companies in the two samples, with size 2 near 11% and size 3 a bit more than 2%.

The productivity frontier is defined as the median value of the 5% most productive companies. To characterise this frontier's catch-up effects, the median value of the 95% least productive companies is compared to the median value of the 5% most productive companies.

evolution of productivity, via the indicator of the capacity utilisation rate (CUR). But the overall diagnostic is very much the same and can be summarised by two main points: (i) a gradual slowdown in productivity was observed over the period and (ii) a slowdown occurred at the start of the 2000s, before the crisis of 2008.

The first drop (at the start of the 1980s) of the two productivity per hour indicators is also observed in many developed countries (cf. Bergeaud et al., 2016, for an overview) and can be explained by different factors, for example the second oil crisis but also the start of the implementation of policies aimed to strengthen the employment content of growth, e.g. a drop in the labour cost of the least qualified workers. The second drop, in the first half of the 1990s, is also observed (except for TFPH) in many countries, with the notable exception of the United States. It can also be associated in these countries with the toughening of policies of wage costs moderation, often by reductions in tax contributions targeted at low-paid work and therefore for the least qualified workers. In the US, a break in productivity growth is also observed at the start of the 1990s, but upwards, making this country a particular case. This acceleration, which has been the subject of many analyses (cf. for example Jorgenson, 2001), is generally associated with the rapid production and dissemination of information and communication technologies (ICT). As this has been shown in many subsequent analyses (for example Van Ark et al., 2008; or Timmer et al., 2011), the gap in ICT dissemination might be one of the main factors explaining the contrast between the United States and other countries with regards to productivity dynamics, this dissemination being much greater and faster in the US than anywhere else. Finally, the last fall in the two indicators, at the start of the 2000s, is observed in almost all developed countries, including the US. This slowdown has not yet had a consensual explanation.

The analysis of the evolutions of productivity in the following section rests on per employee – and not per hour indicators – due to the absence of information on the average duration of work in the individual data at firm level. For this reason, it is also useful at this stage to characterise the evolutions of productivity at the macroeconomic level over per employee indicators, and not only per hour since this has already been done. The differences in the evolutions of per hour and per employee indicators are obviously going to be linked to changes in the average yearly duration of work over the period, with this yearly duration having seen a sharp decline, even though not uniform between sub-periods. So, over the period studied here, employees' average yearly duration of work has declined to a rhythm of

Box 3 – **Detection of breaks in productivity**

The detection of breaks in productivity is conducted with the same methodology over macroeconomic data and over individual data. Over the latter, the detection of breaks is made over the medians per year of the indicators considered.

For each productivity indicator considered (*I*), the productivity trends are defined over the logarithm of the indicator (*i* = *Log(I)*):

$$i_t = \alpha + \sum_{k=0}^{m} \beta_k . (t - T_k) . \mathbb{I}(t \geq T_k) + \gamma . CUR_t + u_t .$$

With *i*, the productivity logarithm; *m* the number of breaks; $\{T_1, T_2, \ldots, T_m\}$ the dates of the breaks; $\mathbb{I}$ an indicative function such as $\mathbb{I} = 1$ if $t \geq T_k$ and $\mathbb{I} = 0$ otherwise; $\beta = \{\beta_1, \ldots, \beta_m\}$ the difference of the productivity growth trend between two consecutive periods; *CUR* capacity utilisation rate, and u_t the error term.

We first test the stationarity hypothesis, (i.e. $m = 0$), which would mean that productivity has a constant trend over the whole period. If the stationarity is rejected, we can exclude the presence of a unique trend. We can nevertheless not conclude with the presence of a stochastic trend since the unit root test is biased when there is structural change in the trend (Perron, 2006). The Bai and Perron test (1998) determines whether the series follows the model above, with linear trends per part, a linear regressor and errors I(0). The values of *m* and the dates of break $\{T_1, T_2, \ldots, T_m\}$ must be determined. Three tests (ADF, Phillips-Perron and KPSS) lead us to reject the stationarity of the series of labour productivity and TFP (in log) compared to a temporal trend.

Bai and Perron (1998) have developed a methodology to calculate simultaneously the number of breaks, their dates and trends (on the methodologies of breaks in trend, see Eksi, 2009, and Aue & Horvath, 2013). The main idea is to estimate $\{\beta_0, \ldots, \beta_m\}$ for each division $\tau = \{T_1, T_2, \ldots, T_m\}$ by minimising the sum of the residual squares. Then, a suitable value of τ is chosen with the help of the statistic *sup*F (τ +1|τ), with F the Fisher statistic.

around -1.6% from 1976 to 1982, -0.5% from 1982 to 1993, -1.0% from 1993 to 2003 and has remained stable thereafter[5]. It appears that taking the duration of work into account or not alters the positioning and intensity of some drops in productivity, without calling into question the diagnosis of a slowdown in particular at the beginning of the 2000s.

The two productivity per employee indicators have, like labour productivity per hour, seen three breaks over the period studied, and approximately at the same dates (Figures I-B and I-D). But, with regards to TFP, the TFPN indicator saw a first break in its rise at the start of the 1980s, with its average yearly growth moving from 0.8% to 1.3%. The break of the beginning of the 1990s was downward and brought the average yearly TFPN growth rate to 0.9%. Finally, the break of the start of the 2000s was also downward and almost led to a stability in TFPN over the following years, with this indicator's average yearly growth rate then reaching 0.1%, very close to that of TFPH, which is quite logical, with employees' average yearly duration of work remaining stable. With regards to labour productivity, the LPN indicator saw a slight acceleration, which was not significant, at the start of the 1980s, with its average yearly growth rate moving from 2.0% to 2.1%, then a large and significant drop at the start of the 1990s, with its growth rate moving to 1.2%, and finally a second one at the start of the 2000s, with its growth rate moving to 0.5%, like that of the per hour indicator (LPH) due to the stabilisation of employees' average yearly duration of work over this final sub-period.

For the comparison with the evolutions of productivity observed on individual data at firm level from the start of the 1990s, the two important results drawn from the macroeconomic data are as follows:

- Most of the productivity indicators (per hour and per employee, labour productivity and TFP) see a considerable downward double-drop, the first at the start of the 1990s and the second at the start of the 2000s, before the crisis of 2008. The first break is not as strong as the second and results at least partially from policies aimed at enriching employment growth (notably the reduction of employers' tax contributions) mitigated by the positive effect of the technological shock linked to ICT.

- Over the final sub-period, that is, since the start of the 2000s, the progression of productivity is historically weak. The average yearly growth of the two TFP indicators appears close to zero (0.1%) whereas that of the two labour productivity indicators seems only around 0.5% per year.

Using company level data: Downward breaks in the 2000s for most sectors and company sizes

The evolutions of productivity are characterised over individual firm-level data using the median of the TFP per employee (TFPN) and labour productivity per employee (LPN) indicators calculated within different scopes: the whole market economy, three company sizes (size 1: fewer than 50 employees; size 2: from 50 to fewer than 250 employees; size 3: 250 or more employees[6]), and six business sectors (agriculture, industry, construction, retail, transportation, other services) and the junction of the three sizes and these six sectors. As with the macroeconomic data, the breaks in productivity are characterised by the Bai and Perron method (1998) for each indicator and over each of the different company sector/sizes. The effects of cyclical economic variations are neutralised by introducing the variation of the turnover logarithm (TO) into the regression as an explanatory variable.

Company data relate only to the market sector whereas macroeconomic data also integrate the non-market sector. For this reason among others, the changes in productivity indicators may differ between these two types of data. Finally, it must be highlighted that as size 1 (fewer than 50 employees) represents around 90% of the companies in our database, the evolutions of the medians of our productivity indicators are, over the whole economy or over each sector, fairly close whether measured over the whole market economy or only over size 1.

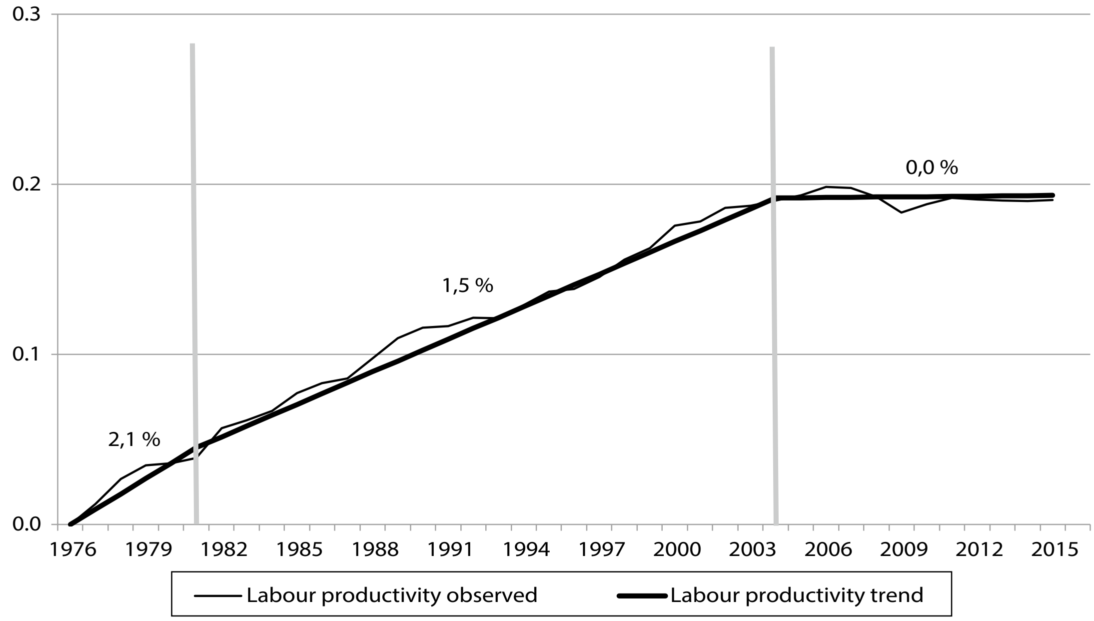
Over the whole data, the two indicators of TFP per employee (TFPN) and labour productivity per employee (LPN) see three significant breaks: at the start of the 1990s, at the start of the 2000s

5. Over the period studied, these evolutions of the duration of work have been influenced by the drop in the legal weekly work hours, from 40 hours to 39 hours in 1982 and from 39 to 35 hours in 1998-2000, as well as by the standardisation of the 5th week of paid holiday in 1982.

6. These thresholds have been chosen due to the existence of major legal thresholds for these workforces and/or due to the existence of this sizeable criterion in the definition of the categories of companies according to the definition of the Modernisation of the Economy Law (MEL).

Figure I
Trends of different productivity indicators on macroeconomic data

A – Total hourly factor productivity (TFPH)
in log, 0 base in 1976, trend average yearly growth rate in % (Bai and Perron method with CUR)



B – Total factor productivity per employee (TFPN)
in log, 0 base in 1976, trend average yearly growth rate in % (Bai and Perron method with CUR)

C – Labour productivity per hour (LPH)
in log, 0 base in 1976, trend average yearly growth rate in % (Bai and Perron method with CUR)

D – Labour productivity per employee (LPN)
in log, 0 base in 1976, trend average yearly growth rate in % (Bai and Perron method with CUR)

Reading note: the vertical bars indicate the breaks in productivity growth, determined on the basis of the Bai and Perron method (1998) with the capacity utilisation rate as the cycle control (cf. Box 3). The figures which appear next to the curve over each sub-period correspond to the indicator's estimated average yearly growth rates over the corresponding sub-period; they are greyed out if these trends are not significantly different from the preceding one (which is the case only for the break in 1982 in graph-D).
Coverage: whole economy.
Source: National accounts, 2015 provisional, 2010 base, Insee; authors' estimations.

and at the time of the crisis, in 2008 (Table 1). The first break in the mid-1990s reflects a strong acceleration in productivity, which corresponds to the economic recovery after the recession of 1993. This cyclical recovery is thus only partially captured by the indicator of the turnover variation. The second break of the beginning of the 2000s corresponds to a severe slowdown in productivity, as observed using the macroeconomic data. Finally, the third break, concurrent with the start of the crisis in 2008, also corresponds to a slowdown in productivity which average yearly growth becomes lower than over the other preceding sub-periods. This last break is often not statistically significant.

The changes in productivity are similar, for each of the two indicators considered, between only the size 1 companies and those which have just been commented on over all three sizes. For the TFP per employee (TFPN) indicator, they are also similar over the two larger sub-sets of size, sizes 2 and 3. For the labour productivity per employee (LPN) indicator, the number of breaks is smaller: two for size 2, at the end of the 1990s and in 2008, and just one in 2008 for size 3. But these breaks mean a drop in productivity which average yearly growth from 2008 also becomes inferior or equal to that observed over the preceding sub-periods.

Over four of the six sectors considered – agriculture, industry, construction and transport – the two productivity indicators also see downward breaks in all sectors, after sometimes an acceleration, but this is either at the start of the 2000s (or at the very end of the 1990s), or in 2008, or at these two dates. In the other services, a downward change is also observed for the TFP indicator (TFPN) in 2008. Changes of the same type are generally observed in these sectors for each of the three company sizes. Only two sectors among the six considered are an exception to this: retail and, only for the productivity per employee indicator (LPN), the other services. In these two activities, productivity accelerates at one of these two dates at least and the growth rate observed at the end of the period is equal to or greater than that observed on average over the preceding sub-periods. This more atypical behaviour is only seen in small retail companies and is observed over the three company sizes with regards to labour productivity in the other services.

The significant result drawn from company level data is that, except for a few rare exceptions like the retail sector and, for the labour productivity indicator only, in the other services, the two productivity indicators see a slowdown, both on all activity and in each sector, at the start of the 2000s or in 2008 or at these two dates. This slowdown brings productivity growth at the end of the period to levels equivalent or inferior to those observed on average over the preceding sub-periods. Such evolutions are generally observed on each of the three company sizes considered. The use of company-level data therefore confirms almost across the board the assessment made with aggregate data of a slowdown in productivity after the start of the decade of 2000. The notable difference is that the time of this slowdown doesn't appear to be necessarily only at the start the 2000s, but also, or sometimes only, from 2008 onwards.

Searching for causes of the slowdown in productivity in France using company data

A few interpretations of the slowdown in productivity

As documented above, productivity saw a downward trend before the financial crisis, which was widespread over the sectors and company sizes, and its growth remains particularly weak in the current period. Numerous explanations have been put forward for this slowdown, which is hitting the most advanced countries (Bergeaud et al., 2016), and company data will shed light on several of them.

- A decline in the contribution of technological progress to productivity growth (Gordon, 2012, 2013, 2014 et 2016): the current wave of technological progress might not be as booming as the one the world saw following the second industrial revolution which boosted growth, directly or through convergence to the United States, up to the 1970s (see Cette, 2014 and 2015, for an overview of this debate). In this hypothesis, productivity should then slow down for companies at the frontier.

- A decline in the dissemination of technologies between companies at the frontier and those not, due to the growing importance of “tacit knowledge”, linked to the increase in complexity of technology with time (Andrews et al., 2015): the convergence of the productivity levels of the least and the most productive companies should then decelerate.

Tablea 1
Trends of various productivity indicators on unbalanced company data – average yearly growth rate in %

A – Total factor productivity per employee (TFPN)

<table>
<tr><th></th><th></th><th>1991</th><th>1992</th><th>1993</th><th>1994</th><th>1995</th><th>1996</th><th>1997</th><th>1998</th><th>1999</th><th>2000</th><th>2001</th><th>2002</th><th>2003</th><th>2004</th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th></tr>
<tr><td rowspan="4">Agriculture</td><td>size 1</td><td colspan="18">2.3</td><td colspan="6">- 0.2</td></tr>
<tr><td>size 2</td><td colspan="5">1.9</td><td colspan="9">0.7</td><td colspan="5">5.6</td><td colspan="5">- 2.7</td></tr>
<tr><td>size 3</td><td colspan="13">2.4</td><td colspan="11">2.5</td></tr>
<tr><td>all sizes</td><td colspan="18">2.3</td><td colspan="6">- 0.1</td></tr>
<tr><td rowspan="4">Industry</td><td>size 1</td><td colspan="5">0.9</td><td colspan="6">4.0</td><td colspan="7">2.9</td><td colspan="6">0.5</td></tr>
<tr><td>size 2</td><td colspan="5">0.9</td><td colspan="13">3.0</td><td colspan="6">0.5</td></tr>
<tr><td>size 3</td><td colspan="5">1.7</td><td colspan="13">2.8</td><td colspan="6">0.6</td></tr>
<tr><td>all sizes</td><td colspan="5">1.3</td><td colspan="13">3.4</td><td colspan="6">0.4</td></tr>
<tr><td rowspan="4">Construction</td><td>size 1</td><td colspan="7">0.1</td><td colspan="5">3.1</td><td colspan="7">- 3.5</td><td colspan="5">- 2.8</td></tr>
<tr><td>size 2</td><td colspan="5">- 0.8</td><td colspan="5">3.5</td><td colspan="9">- 2.0</td><td colspan="5">- 3.7</td></tr>
<tr><td>size 3</td><td colspan="13">1.0</td><td colspan="5">- 3.0</td><td colspan="6">- 2.4</td></tr>
<tr><td>all sizes</td><td colspan="7">0.1</td><td colspan="5">3.1</td><td colspan="7">- 3.4</td><td colspan="5">- 2.8</td></tr>
<tr><td rowspan="4">Retail</td><td>size 1</td><td colspan="6">0.6</td><td colspan="6">3.0</td><td colspan="7">0.0</td><td colspan="5">1.5</td></tr>
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<tr><td>all sizes</td><td colspan="6">0.6</td><td colspan="6">2.8</td><td colspan="6">0.0</td><td colspan="6">1.1</td></tr>
<tr><td rowspan="4">Transport</td><td>size 1</td><td colspan="8">5.5</td><td colspan="16">0.9</td></tr>
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<tr><td>all sizes</td><td colspan="8">5.6</td><td colspan="16">1.0</td></tr>
<tr><td rowspan="4">Other Services</td><td>size 1</td><td colspan="8">- 0.5</td><td colspan="5">- 0.6</td><td colspan="5">0.2</td><td colspan="6">- 0.4</td></tr>
<tr><td>size 2</td><td colspan="5">- 1.3</td><td colspan="5">- 0.6</td><td colspan="8">0.0</td><td colspan="6">- 0.8</td></tr>
<tr><td>size 3</td><td colspan="14">- 0.5</td><td colspan="5">- 2.5</td><td colspan="5">- 2.3</td></tr>
<tr><td>all sizes</td><td colspan="8">- 0.5</td><td colspan="5">- 0.5</td><td colspan="5">0.2</td><td colspan="6">- 0.5</td></tr>
<tr><td rowspan="4">All sectors</td><td>size 1</td><td colspan="5">- 0.1</td><td colspan="5">3.8</td><td colspan="9">0.7</td><td colspan="5">- 0.1</td></tr>
<tr><td>size 2</td><td colspan="5">0.2</td><td colspan="7">2.6</td><td colspan="7">0.7</td><td colspan="5">- 0.4</td></tr>
<tr><td>size 3</td><td colspan="5">0.6</td><td colspan="8">2.7</td><td colspan="6">0.6</td><td colspan="5">- 0.5</td></tr>
<tr><td>all sizes</td><td colspan="5">0.0</td><td colspan="5">3.7</td><td colspan="9">0.8</td><td colspan="5">- 0.2</td></tr>
<tr><td colspan="2">Macroeconomic data</td><td colspan="5">0.4</td><td colspan="9">0.9</td><td colspan="5">0.1</td><td colspan="5">- 0.1</td></tr>
</table>

B – Labour productivity per employee (LPN)

<table>
<tr><th></th><th></th><th>1991</th><th>1992</th><th>1993</th><th>1994</th><th>1995</th><th>1996</th><th>1997</th><th>1998</th><th>1999</th><th>2000</th><th>2001</th><th>2002</th><th>2003</th><th>2004</th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2014</th></tr>
<tr><td rowspan="4">Agriculture</td><td>size 1</td><td colspan="19">4.3</td><td colspan="6">1.4</td></tr>
<tr><td>size 2</td><td colspan="6">4.4</td><td colspan="9">1.2</td><td colspan="5">7.0</td><td colspan="5">- 1.4</td></tr>
<tr><td>size 3</td><td colspan="10">1.1</td><td colspan="10">4.1</td><td colspan="5">- 0.7</td></tr>
<tr><td>all sizes</td><td colspan="19">4.2</td><td colspan="6">1.6</td></tr>
<tr><td rowspan="4">Industry</td><td>size 1</td><td colspan="9">2.2</td><td colspan="10">3.8</td><td colspan="6">1.6</td></tr>
<tr><td>size 2</td><td colspan="11">2.8</td><td colspan="8">3.8</td><td colspan="6">1.9</td></tr>
<tr><td>size 3</td><td colspan="13">3.4</td><td colspan="7">3.9</td><td colspan="5">1.3</td></tr>
<tr><td>all sizes</td><td colspan="9">2.3</td><td colspan="10">3.8</td><td colspan="6">1.7</td></tr>
<tr><td rowspan="4">Construction</td><td>size 1</td><td colspan="7">- 0.4</td><td colspan="5">3.0</td><td colspan="8">- 2.4</td><td colspan="5">- 2.2</td></tr>
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<tr><td>all sizes</td><td colspan="7">- 0.3</td><td colspan="5">2.9</td><td colspan="8">- 2.4</td><td colspan="5">- 2.3</td></tr>
<tr><td rowspan="4">Retail</td><td>size 1</td><td colspan="7">0.1</td><td colspan="6">2.8</td><td colspan="6">0.9</td><td colspan="6">1.8</td></tr>
<tr><td>size 2</td><td colspan="9">1.1</td><td colspan="5">0.9</td><td colspan="5">0.9</td><td colspan="6">0.6</td></tr>
<tr><td>size 3</td><td colspan="6">1.3</td><td colspan="7">1.1</td><td colspan="6">0.8</td><td colspan="6">0.8</td></tr>
<tr><td>all sizes</td><td colspan="7">0.2</td><td colspan="6">2.6</td><td colspan="6">0.9</td><td colspan="6">1.8</td></tr>
<tr><td rowspan="4">Transport</td><td>size 1</td><td colspan="13">2.2</td><td colspan="12">0.7</td></tr>
<tr><td>size 2</td><td colspan="7">3.1</td><td colspan="7">0.5</td><td colspan="5">0.6</td><td colspan="6">1.3</td></tr>
<tr><td>size 3</td><td colspan="8">3.9</td><td colspan="6">- 0.6</td><td colspan="11">1.5</td></tr>
<tr><td>all sizes</td><td colspan="11">2.5</td><td colspan="14">0.7</td></tr>
<tr><td rowspan="4">Other services</td><td>size 1</td><td colspan="8">- 1.1</td><td colspan="5">- 0.4</td><td colspan="6">0.3</td><td colspan="6">0.5</td></tr>
<tr><td>size 2</td><td colspan="10">- 0.9</td><td colspan="7">- 1.5</td><td colspan="8">- 0.4</td></tr>
<tr><td>size 3</td><td colspan="12">- 0.1</td><td colspan="13">0.3</td></tr>
<tr><td>all sizes</td><td colspan="8">- 0.8</td><td colspan="5">- 0.5</td><td colspan="6">0.2</td><td colspan="6">0.4</td></tr>
<tr><td rowspan="4">All sectors</td><td>size 1</td><td colspan="8">0.9</td><td colspan="5">3.0</td><td colspan="6">1.0</td><td colspan="6">0.9</td></tr>
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<tr><td>size 3</td><td colspan="19">2.1</td><td colspan="6">0.0</td></tr>
<tr><td>all sizes</td><td colspan="8">1.1</td><td colspan="5">2.8</td><td colspan="6">1.0</td><td colspan="6">0.9</td></tr>
<tr><td colspan="2">Macroeconomic data</td><td colspan="5">1.4</td><td colspan="9">1.1</td><td colspan="6">0.7</td><td colspan="5">0.2</td></tr>
</table>

Reading note: for size 1, in agriculture, the trend of labour productivity per employee was at 4.3% per year from 1990 to 2008, then at 1.4% from 2009 to 2014. The breaks in productivity growth are determined on the basis of the Bai and Perron method (1998) with turnover as the cycle control (cf. box 3). The numbers correspond to the indicator's estimated average yearly growth rates over the corresponding sub-period; they are in grey if these trends are not significantly different from the preceding one (or a trend negligibly different to 0 for the trend immediately after 1990). The tests on macroeconomic data differ from those presented in figure I since the estimation period was made shorter for the sake of consistency with the company data.
Coverage: whole market economy except for the financial sector. Metropolitan France and Overseas Departments [*Départements d'outre mer* - DOM].
Source: authors' database from Fiben, Banque de France; unbalanced sample; authors' calculations.

- "Winner takes all" phenomena linked to the characteristics of ICT (large economies of scale, linked especially to network effects; non-rival goods whose marginal production costs are nil): in this case, the most productive companies' productivity should rapidly accelerate relative to the least productive companies. These evolutions have an ambiguous impact on aggregate productivity, to the extent that they explain a growing divergence rather than an overall slowdown. It can be noted that they nevertheless lead to monopolies which stifle competition and, in turn, have a detrimental effect on productivity growth.

- An insufficiently efficient reallocation when faced with crises that require significant sectoral and geographical reallocation of the production factors. It can be a matter of technological shocks, like that of ICT, shocks to industrial specialisation in the context of globalisation, or shocks linked to the financial crisis or the bursting of the real estate bubble, which had a significant impact on construction in France. Berthou (2016) showed that the efficiency of the allocation of the labour force in France would have been particularly weak after the crisis. Fontagné and Santoni (2015) explain the differences in the efficiency of allocation by agglomeration economies, with the efficiency of allocation being better in the densest zones. In this case, the dispersion of productivity increases and that of the surviving companies decelerates.

Others arguments, more specific to the French case, have been put forward. Askenazy and Erhel (2015) have highlighted the role of the labour market: the legal relaxation of the use of fixed-term contracts (FTCs) and self-employed have thus contributed to developing low-productivity jobs, while the reduction of labour costs has incited companies to keep their unskilled workforce, even in times of crisis.

In France, using company data also drawn from the *Fiben* base, Chevalier et al. (2008) have examined specifically the convergence of productivity up to the beginning of the 2000s. They highlight a deceleration of the convergence of company productivity from the mid-1990s to the start of the 2000s which might be linked to an acceleration of the most productive companies' productivity. This relative acceleration was explained by three factors:

- Information and communication technology (ICT) has particularly benefited the already most productive companies, which have a well-trained workforce capable of taking full advantage of this technology shock.

- Globalisation and the development of foreign trade have benefited the most productive companies since they are the only ones able to finance the fixed costs necessary to break into a foreign market (Bernard & Jensen, 1999).

- By lowering the level of profitability, the strengthening of competition linked to the deregulation of the 1990s led the most productive companies to try to escape neck and neck competition, whereas it discouraged the least productive companies from catching up to the sector average productivity level (Aghion et al., 2005).

The evolution of productivity at the frontier: increase of dispersion between the most productive firms and the others

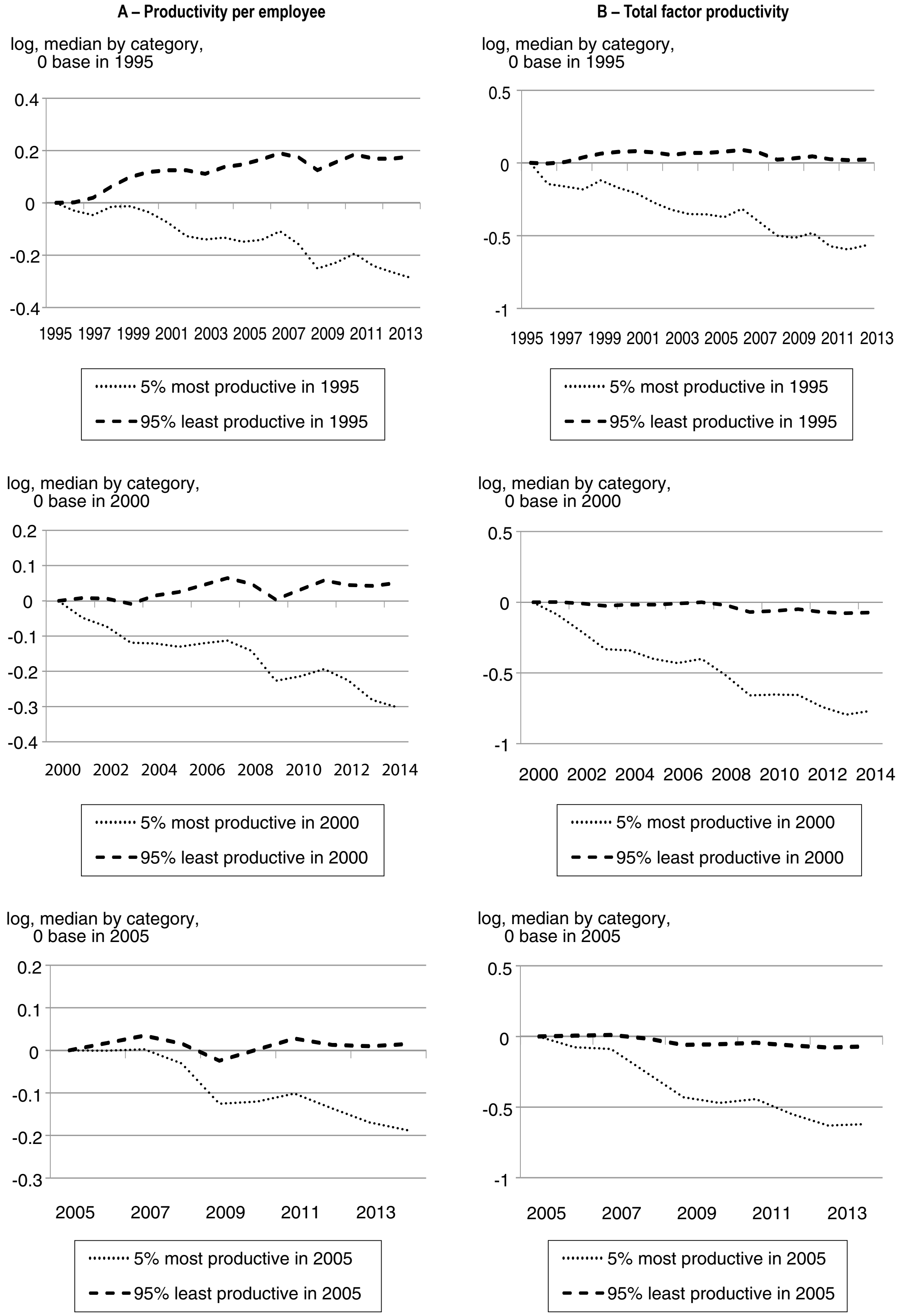
A decline in technical progress would suppose a productivity slowdown at the production frontier, while a winner-takes-all mechanism would on the contrary lead to its acceleration. Nevertheless, in this latter case, companies at the frontier in a given year should increase their lead.

To decide between these two explanations, we will examine the evolution of the productivity of companies at the frontier from two angles. Firstly, we will monitor the productivity of the companies which were the most productive at a given date, and keep this sample after that date, even if it does not necessarily constitute the productivity frontier in the following years. Secondly, we will monitor the productivity of the most productive companies each year, with these companies possibly being different from one year to the next. In the two cases, we retain the companies in the 5% most productive but the results are not qualitatively different for the 2% or 10% most productive.

With Figure II, we notice, firstly, that the median productivity of the most productive companies at a given date – 1995, 2000 and 2005 (the thin line) – follows a downward trend, whereas it increases for the least productive companies at this same date (dashed thin line).

This indicates a convergence of the companies' productivity over the whole period: whatever the date of reference, the most productive companies' productivity at a given date decreases

Figure II
Development of the productivity of the most productive company at a given date compared with that of other companies – balanced panel



Reading note: on the first graph on the top left, the dotted line represents the median productivity of the companies which were the 5% most productive in their sector in 1995, and the dashed line represents the median productivity of the companies making up 95% of the least productive in their sector in 1995.
Coverage: whole market economy except for the financial sector. Metropolitan France and Overseas Departments [*Départements d'outre mer* - DOM].
Source: authors' database from Fiben, Banque de France; balanced sample; authors' calculations.

compared to that of the other companies. It should nevertheless be noted that the median productivity of the most productive companies stays very much above that of the least productive companies at the date of reference, or that of all the companies in the sample whatever the period of reference. Thus, in 2014, the most productive companies in 1995 remain 1.9 times more productive (against 3.4 times in 1995) than the companies that were less productive than them in 1995.

The productivity of companies at the frontier in a given year declines, except over some very rare and short sub-periods. This decline intensified slightly at the end of the period. These evolutions do not seem in line with a 'winner-takes-all' dynamic: the productivity of the most productive companies does not accelerate, contrary to what would be expected if these companies gained more and more market share at zero marginal cost. It does indeed seem difficult to envisage that a dynamic of this type could apply to all sectors of the economy, whether their characteristics correspond or not to the ICT sectors (economy of scale linked to network effects, non-rival goods).

We are looking now at the evolution of the productivity frontier, with a different sample each year. Contrary to Figure II, Figure III represents the median productivity of the 5% most productive companies of the year[7]. The black line therefore defines the productivity frontier, with a renewal each year of the companies that define it. The dotted line corresponds to the median productivity of the other companies. The spread between the two lines therefore constitutes an indicator of the dispersion of productivity between the companies at the frontier and the others. Since the mid-1990s, the productivity of the companies at the frontier has accelerated in relation to that of the other companies, with a pause at the turn of the 2000s. The financial crisis did not slow down these evolutions which intensified, on the contrary, in 2014.

The productivity frontier has gained considerable speed over the recent period, very closely in line with the results of Andrews et al. (2015) over international data. This does not run parallel with a decline in technological progress, a hypothesis defended by Gordon. Nevertheless, in the case of France, the dissemination of ICT has been less considerable than in other countries (Cette et al., 2015). The progression of productivity at the productivity frontier in France therefore does not necessarily correspond to technological progress on a global scale, since existing technologies might also still be in ongoing dissemination throughout the most productive companies. The efficiency frontier is of course international, but it is striking to notice the similitude of the results obtained over French data in this article and over international data in Andrew et al. (2015). It should be noted that, considering the under-representation of Germany and especially of the USA in the company data used by Andrew et al. (2015), relative to the main countries of the OECD[8], the frontier which has been empirically characterised there is not necessarily the global efficiency frontier.

The concept of the productivity frontier is nevertheless difficult to apprehend here: in fact, we notice that the companies in our database stay on average for 3 years among the most productive in a given year, for both TFP and labour productivity. Furthermore, this duration is close to that of the results of Andrews et al. (2015) over international data. Considering their very high initial relative level, the productivity of the companies at the frontier returns naturally to the average, as is illustrated in figure II[9]. Then the frontier represented in figure III therefore corresponds to a temporary performance, possibly unsustainable in the long term for a large proportion of firms.

The other companies' productivity has decelerated, even stagnated for TFP, since the financial crisis. This relative acceleration of the most productive companies therefore demonstrates an increase of the dispersion of productivity between very productive companies and other companies. This is confirmed in Figure IV, representing the interquartile or interdecile dispersion[10]: the dispersion has greatly increased since the crisis and reaches its highest levels at the end of the period. This may correspond to the hypothesis of reallocation difficulties following

7. These figures correspond to graphs 1 of Andrews, Criscuolo and Gal (2015). Nevertheless, the frontier is defined here at the national level and not global like in this study.

8. Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, the UK, Greece, Hungary, Italy, Japan, South Korea, the Netherlands, Norway, Poland, Portugal, Spain, Sweden, Slovenia, Slovakia, the US.

9. Without, however, reaching this average, since these companies remain more productive than the media, even after 19 years of decline of their relative level of productivity.

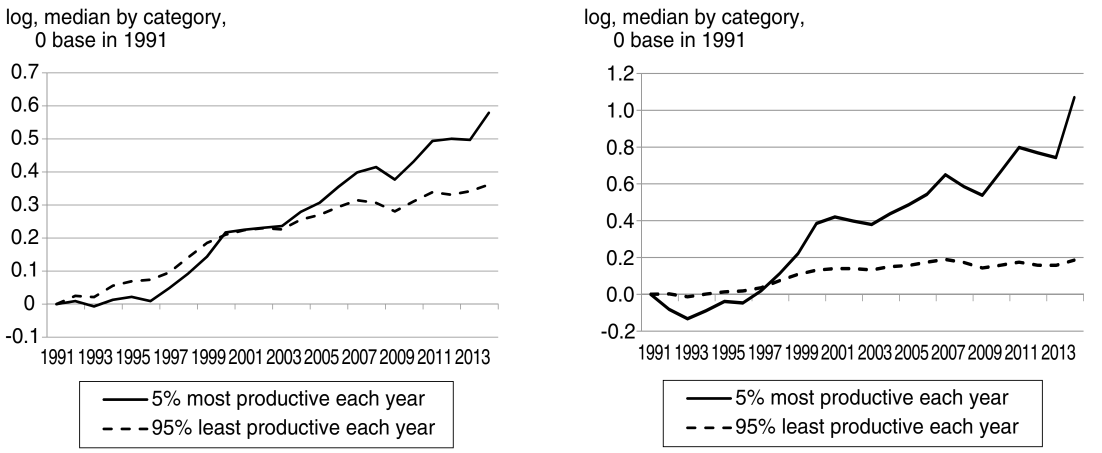
10. Taking into account the fact that the database is not comprehensive, these dispersion indicators were chosen because they are less sensitive to the sample's variations than the indicators based on the standard deviation or the Gini coefficient.

shocks. In fact, sectoral shocks can emphasise the need to reallocate, but if market rigidities or a lack of skilled labour stifle these reallocations, low-productive companies will continue to operate and their productivity will slow down, whereas that of successful companies with adequate factors of production accelerates. The impact of these shocks can be seen, for example, in the construction sector: following the financial crisis, the residential property sector adjusted through a reduction of construction work rather than a drop in property prices; this resulted in a drop in the median productivity of the sector's companies (cf. Table 1) and difficulties in reallocating this sector's labour force.

Such difficulties in reallocation have been confirmed by economic literature, for example Bartelsman et al. (2016) over several European countries. For the US and the UK, Foster et al. (2014) and Barnett et al. (2014) have shown that reallocations had a less positive impact

Figure III
Productivity of the most productive companies each year

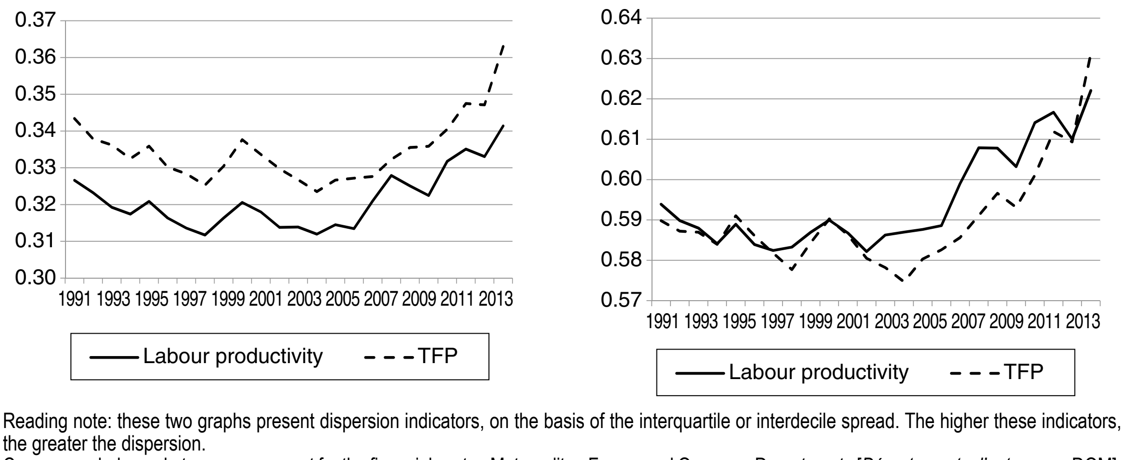
A – Productivity per employee – unbalanced sample **B – Total factor productivity – unbalanced sample**



Reading note: contrary to figure II, median productivity is measured over the whole database each year, not over the most or least productive companies in the base year. The straight line measures the median productivity of the 5% most productive companies in the year and sector. The dashed line represents the median productivity of all the other companies.
Coverage: whole market economy except for the financial sector. Metropolitan France and Overseas Departments [*Départements d'outre mer* - DOM].
Source: authors' database from Fiben, Banque de France; unbalanced sample; authors' calculations.

Figure IV
Companies' productivity dispersion indicator – unbalanced sample

A – Interquartile dispersion (Q3-Q1)/(Q1+Q3) **B – Interdecile dispersion (D9-D1)/(D1+D9)**



Reading note: these two graphs present dispersion indicators, on the basis of the interquartile or interdecile spread. The higher these indicators, the greater the dispersion.
Coverage: whole market economy except for the financial sector. Metropolitan France and Overseas Departments [*Départements d'outre mer* - DOM].
Source: authors' database from Fiben, Banque de France; unbalanced sample; authors' calculations.

on productivity after the Great Recession. Furthermore, Berthou (2016) shows that the efficiency of labour allocation in France would have been particularly weak since the crisis compared to other European countries. The studies on companies confirm these results, especially the *Wage Dynamics Network* study of the Eurosystem. 70% of companies (weighted by their workforce) declare in it that the lack of an available skilled labour force is an obstacle to recruitment in France, compared to just over 40% in Spain and just over 30% in Italy (Jadeau et al., 2015).

Among the explanations for these reallocation difficulties, the impact of the financial crisis on the functioning of the banking system has been highlighted for several countries. Nevertheless, for France, it does not appear that erroneous allocations of credit to insolvent companies ("zombie lending") have developed significantly with the crisis (Avouyi-Dovi et al., 2016). Hence, the explanations are rather to be found in rigidities on the labour market, in particular obstacles to labour or enterprise mobility (Fontagné & Santoni, 2015; Bergeaud & Ray, 2017), in terms of initial and continued training, or in market regulations which might reduce competition by entry barriers. Finally, the collapse of international trade, which was particularly notable during the Great Recession, hit highly productive companies – which are also more export-oriented companies – the most. Except in 2008-2009, this explanation does not appear to be confirmed with the French data that we have used.

No slowdown in the convergence of productivity in the 2000s

Among the hypotheses to explain the slowdown in productivity at the aggregate scale, Andrews et al. (2015) have highlighted a slower convergence of the least productive companies' productivity with that of the most productive ones. This slower convergence could be explained by low dissemination of technological progress from the most productive companies to the least productive.

This slower convergence can be tested using an equation of β-convergence, which makes productivity growth depend on the gap with the frontier.

$$\Delta prod_{it} = \beta \cdot \left(prod\left(95^{th}\ percentile\right)_{t-1} - prod_{it-1}\right) + X_{ist} + \varepsilon_{ist} \quad (1)$$

For company *i*, of sector *s*, productivity growth per employee or TFP, *prod* (logged), is expressed according to the gap between the median of the productivity log of the 5% most productive companies in their sector and year considered, *prod(95th percentile)*, and its productivity, $prod_{it}$, and according to fixed effects (year, sector, size or company according to the specifications), $X_{ist,}$ with ε_{ist} error term[11].

If there is convergence, productivity growth will be much faster than the gap with the productivity frontier will be high: β will be positive and significant. Convergence is conducted towards a target that depends on fixed effects: the productivity of the company converges in the long-term with $prod(95^{th}\ percentile)_{t-1} + X_{ist}/\beta$. As is shown in Chevalier et al. (2008), lagged productivity is endogenous, being correlated to the firm's unobserved heterogeneity. Estimated using the ordinary least squares method (OLS), it can be shown that β will be underestimated, whereas it will be overestimated with company fixed effects. One solution would be to use an estimator such as Arellano-Bover's (1995). Nevertheless, this type of estimator leads to a considerable loss of precision in the estimation of β, whereas the bias of the OLS estimation runs parallel with the absence of convergence. If β is significant and positive, then a convergence of companies' productivity can effectively be concluded.

The results over the whole period are presented in Table 2. With the OLS estimation, whatever the fixed effects are, a significant convergence is found, with nearly 11% of the gap with the frontier made up each year for TFP and 14% for labour productivity per employee (LPN). Using company fixed effects (columns 7 and 8), the convergence is a lot faster, which stays in line with the definition of the objective of long-term convergence at company level but also with the estimation bias mentioned above.

The convergence is faster for productivity per employee (LPN) than for TFP. In fact, it seems easier to increase the capital intensity of a company in order to increase its productivity than to increase the efficiency of its production process with a constant capital stock. We have tested whether the speed of convergence was lower for sectors intensive in ICT. By using the share

11. An alternative specification consists in regressing over the level of the company's lagged productivity only, without the productivity of the 95th percentile. In the case of convergence, then β is negative. The results, presented in Annex 2, are very close, as well as on convergence per year.

of income on ICT capital in the total income on capital as a proxy of the intensity of ICT (source being EU-KLEMS), we find a convergence speed which decreases with the intensity in ICT but in a limited way.

To study the evolution of the speed of convergence over the period, we use a slightly different specification:

$$\Delta prod_{it} = \alpha \cdot (prod(95\%)_{t-1} - prod_{it-1}) + \sum_{j=1991}^{2014} \beta_j D_j (prod(95\%)_{j-1} - prod_{ij-1}) + D_t + D_s + D_a + \varepsilon_{ist} \quad (2)$$

still with the indices *i* for the company, s for the sector and t for the year, *prod* is the log of the productivity indicator, *prod(95%)* the log of the median productivity of the 5% most productive companies in their sector, D_j year dummies; D_t, D_s et D_a, are fixed effects for year, sector and size, and ε_{ist} the error term.

The speed of convergence in year *j* is then $\alpha+\beta_j$. There is convergence if the sum of the two coefficients is significant and positive. The results of these estimations are presented in Annex 3 and displayed in Figure V[12].

The speed of convergence slowed down throughout the 1990s, with a low point in 1999. It then stagnated until the financial crisis. The shock of the financial crisis led to an acceleration of the convergence largely due to the economic climate and adjusted accordingly after. In 2014 the convergence slows down considerably. Other years must nevertheless be observed in order to confirm this new stalling of the speed of convergence, observed over one sole year at this stage.

12. The results over the balanced panel are presented in Annex 4. The balanced panel isolates the input-output effect, although the probability of survival decreases with time for the companies in this sample. The results are qualitatively similar, with the slowdown appearing even less evident over the recent period.

Table 2
Convergence of estimated productivity over the whole period

A – Total factor productivity

	(1) ols	(2) ols	(3) ols	(4) ols	(5) ols	(6) ols	(7) fe	(8) fe
Distance to the frontier$_{t-1}$	0.101***	0.104***	0.112***	0.115***	0.100***	0.118***	0.434***	0.512***
	(0.000351)	(0.000351)	(0.000365)	(0.000370)	(0.000351)	(0.000370)	(0.000704)	(0.000729)
N	1781198	1781198	1781198	1781198	1781198	1781198	1781198	1781198
R^2	0.0441	0.0560	0.0526	0.0549	0.0442	0.0662	0.197	0.248
Fixed effects								
Year		X			X	X		X
Sector			X		X	X		
Size				X		X		

Reading note: estimation of $\Delta prod_{it} = \beta \cdot (prod(95^{th}\ percentile)_{t-1} - prod_{it-1}) + X_{ist} + \varepsilon_{ist}$ with $(prod(95^{th}\ percentile)_{t-1} - prod_{it-1})$, company's distance to the TFP frontier *i* in year *t*-1, Xist fixed effects for year, sector, size or companies; "ols" for ordinary least squares and "fe" for company fixed effects; standard deviation in brackets; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

B – Productivity per employee

	(1) ols	(2) ols	(3) ols	(4) ols	(5) ols	(6) ols	(7) fe	(8) fe
Distance to the frontier$_{t-1}$	0.113***	0.115***	0.139***	0.113***	0.140***	0.140***	0.506***	0.530***
	(0.000268)	(0.000269)	(0.000294)	(0.000269)	(0.000293)	(0.000294)	(0.000532)	(0.000533)
N	3348931	3348931	3348931	3348931	3348931	3348931	3348931	3348931
R^2	0.0502	0.0566	0.0642	0.0502	0.0701	0.0701	0.236	0.257
Fixed effects								
Year		X			X	X		X
Sector			X		X	X		
Size				X		X		

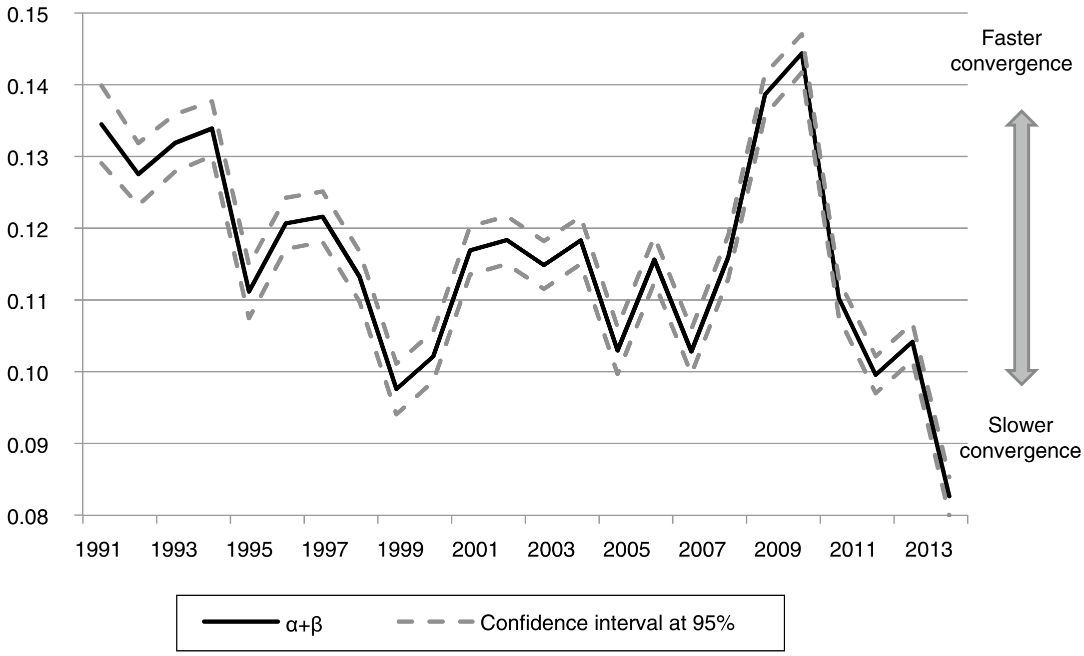
Reading note: estimation of $\Delta prod_{it} = \beta \cdot (prod(95^{th}\ percentile)_{t-1} - prod_{it-1}) + X_{ist} + \varepsilon_{ist}$ with $(prod(95^{th}\ percentile)_{t-1} - prod_{it-1})$, company's distance to the TFP frontier *i* in year *t*-1, Xist fixed effects for year, sector, size or companies; "ols" for ordinary least squares and "fe" for company fixed effects; standard deviation in brackets; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Coverage: whole market economy except for the financial sector. Metropolitan France and Overseas Departments [*Départements d'outre mer* - DOM].
Source: authors' database from Fiben, Banque de France; unbalanced sample; authors' calculations.

Figure V
Convergence of productivity per year

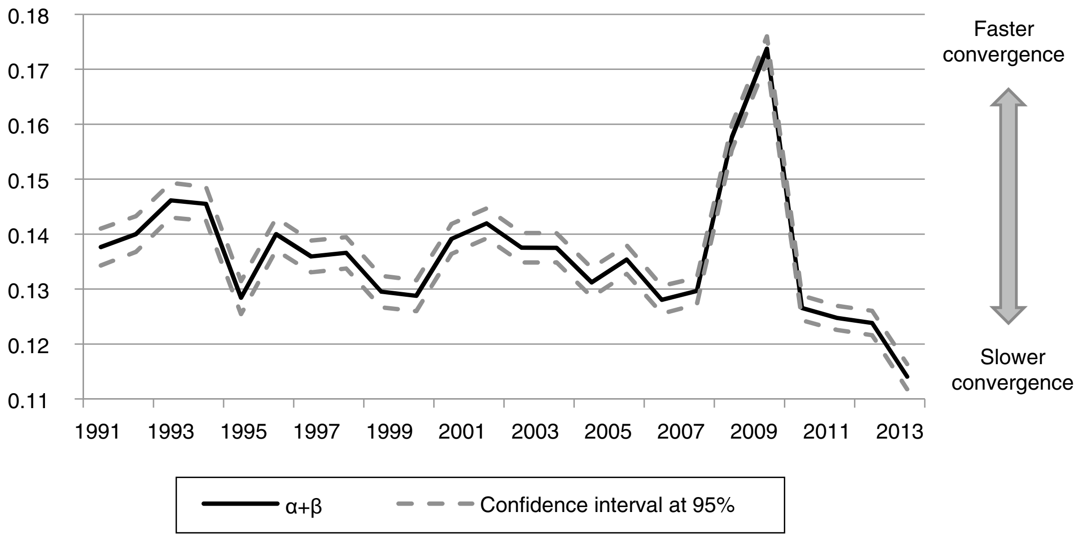
A – Total factor productivity
$\alpha+\beta_i$ - Convergence coefficients – TFP – unbalanced sample – OLS

$$\Delta tfp_{\alpha} = \alpha \cdot (tfp(95\%)_{\alpha-1} - tfp_{\alpha-1}) + \sum_{i=1991}^{2014} \beta_i D_i (tfp(95\%)_{i-1} - tfp_{i-1}) + D_s + D_t + D_{\alpha}$$



B – Productivity per employee
$\alpha+\beta_i$ - Convergence coefficients – Labour productivity – unbalanced sample – OLS

$$\Delta lp_{\alpha} = \alpha \cdot (lp(95\%)_{\alpha-1} - lp_{\alpha-1}) + \sum_{i=1991}^{2014} \beta_i D_i (lp(95\%)_{i-1} - lp_{i-1}) + D_s + D_t + D_{\alpha}$$



Reading note: these two graphs display the sum of the coefficients $\alpha+\beta_i$ of equation (2). The higher these indicators, the faster the convergence.
Field: whole market economy except for the financial sector. Metropolitan France and Overseas Departments [*Départements d'outre mer* - DOM].
Source: authors' database from Fiben, Banque de France; unbalanced sample; authors' calculations.

While there was a visible slowdown in the speed of convergence in the 1990s (confirming the results of Chevalier et al., 2008), the slowdown since the 2000s or 2010 has not been proven. While it has not been rejected, the hypothesis of a slowdown in the convergence of the least productive companies is therefore not confirmed at this stage either.

This result contrasts with that of an increase of dispersion measured by indicators of the interdecile or interquartile range (see figure IV). These two approaches are not independent of each other but differ on different points: i) the β-convergence is estimated by taking into account an error term ε_{ist}, whereas the dispersion indicators integrate the temporary shocks; ii) the β-convergence is estimated over companies present for two consecutive years, whereas the dispersion is characterised over all the companies present each year; iii) the estimation of the β-convergence includes fixed effects, which make the objective of convergence vary per sector, year and company size, these variations not being taken into account in the dispersion indicators; iv) finally, the dispersion indicators built up on the interdecile or interquartile range leave out by definition the productivity of companies on the periphery of our sample's distribution, which are part of the estimation of the β-convergence. In terms of interpretation, the contrast between the two approaches calls for cautiousness: while the dispersion of productivity levels has increased over the last few years, as the dispersion indicators show, the possible estimations, with their numerous limitations, do not allow for this increase to be attributed to a weakening convergence of the productivity levels.

* *
*

The most important results of our analysis concerning the evolutions of labour productivity and TFP in France over the last few decades are as follows:

- Both macroeconomic data and company data indicate that labour productivity and TFP slowed down in the 1990s then again in the 2000s. Over the macroeconomic data, this last slowdown is observed at the start of the 2000s, before the financial crisis began in 2007-2008. But over company data, it is sometimes observed rather at the time of the crisis, or at two dates in this same decade. Except for some very rare exceptions, the slowdown of the 2000s is observed over the company data over the three company sizes and the six business sectors considered. It appears that productivity growth is, since the slowdown of the decade of 2000, weaker than it has even been over the whole period considered.

- The company data clearly indicate that the slowdown of the French companies' productivity during the decade of 2000 would not result from a faltering of the technological frontier. The most productive companies' productivity growth does not undergo a visible drop. This observation seems to belie, at least for France, the idea of a decline of the effects of technical progress on productivity.

- The company data also indicate that the convergence of follower companies with the technological frontier would not have decreased over the decade of 2000, which seems to deny the idea of a weakening dissemination of the most productive companies' innovations to the other companies. At the same time, the dispersion of productivity levels seems to have intensified, which could attest to a less efficient allocation of the production factors to the most successful companies.

At the end of these empirical investigations over two distinct types of data (macro- and microeconomic), it therefore appears that the reasons for the drop in productivity in France before the financial crisis which hit in 2007-2008 remain in part uncertain. The idea of an inefficient allocation of the production factors to the most promising business activities and the most successful companies seems to still be of real importance. This idea is reinforced by the fact that the slowdown observed in France also occurs in all the main developed economies, even though these economies differ on multiple features: distance to the frontier, institutions, the education level of the labour force, etc. This universality suggests that the reasons for the drop might be similar in the different advanced economies. One factor which comes to mind straight away is of course the drop in real interest rates, which has become widespread since the 1990s. Such a drop in the cost of borrowed capital has ensured the survival of many companies which would have been condemned by more onerous credit conditions. It also made barely-effective investment projects profitable. It results overall in an allocation of productive resources that is worse, on average, for the dynamism of productivity.

The previous industrial revolutions were always accompanied by vast institutional changes which were beneficial to production, and the dissemination and improvement of new technologies (cf. for example Ferguson and Washer, 2004). In such an approach, it is therefore important for each country or economic zone to prepare itself for the implementation of ambitious structural reforms which will promote the rebirth of the ongoing technological revolution and whose premises appear across many domains (cf. Cette, 2014 and 2015, for a review of the literature in this domain). Not adapting well enough will condemn the country or the economic zone concerned to worse performance, in other words impoverishment, relative to the countries that will have adapted and will benefit more from the effects of the current technological revolution.

The history of the preceding technological revolutions have shown us that there was not necessarily any trade-offs to be made between the full benefits of technological revolutions, protecting workers, and beyond that, people's standard of living. The gains in productivity associated with the second industrial revolution, which transformed production methods and lifestyles in the 20th century, thus facilitated the financing of an enhancement of protections (social ones in particular), average living standards (purchasing power) and leisure (through the reduction of the average time spent working). It is the prospect of such gains that must guide the desired institutional transformations in order to promote a more effective allocation of productive resources and a galvanisation of productivity brought about by the not-yet-complete technological revolution of ICT and the digital economy. ☐

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TESTS FOR BREAKS OVER MACROECONOMIC DATA

Table A1-A
Break in the labour productivity per hour trend
(dates of break, crossed out if not significant)

Model/Period	1974 - 2014	1990-2014
Without cycle control	~~1985~~ -1990-~~1997~~-2001-2006	1999-2003-2008
CUR	1981 - 1995 - 2004	~~1997~~-2003
GDP	1984 - 2003	2004
GDP + GDP acceleration	1985 - 2003	~~1994~~-2003-2009

Table A1-B
Break in the TFP per hour trend
(dates of break, crossed out if not significant)

Model/Period	1974 - 2014	1990-2014
Without cycle control	~~1977-1985~~-1995-2006	1997-2008
CUR	1981 - 2004	2003
GDP	1981 - 1988 - 1999 - 2007	1996-2001-2008
GDP + GDP acceleration	1990 - 1999 - 2007	1995-2004-~~2009~~

Note: breaks in productivity growth, determined on the basis of the Bai and Perron method (1998) with the capacity utilisation rate, GDP growth or its acceleration as the cycle control or without cycle control (cf. box 3). Dates crossed out if the break is not significant. For labour productivity per hour over the period 1974 to 2014, without cycle control, the Bai and Perron method (1998) identifies 5 breaks, in 1985, 1990, 1997, 2001 and 2006, but only 1990 and 2001 are statistically significant breaks.
Coverage: whole economy.
Sources: National accounts, 2015 provisional, 2010 base, Insee; authors' estimations.

ANNEX 2

RESULTS OF THE CONVERGENCE TESTS WITH NO PRODUCTION FRONTIER

A – Total factor productivity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ols	ols	ols	ols	ols	ols	fe	fe
tfp_{t-1}	- 0.0984***	- 0.0993***	- 0.113***	- 0.0986***	- 0.114***	- 0.114***	- 0.466***	- 0.475***
	(0.000324)	(0.000328)	(0.000359)	(0.000326)	(0.000363)	(0.000364)	(0.000701)	(0.000706)
N	1781198	1781198	1781198	1781198	1781198	1781198	1781198	1781198
R^2	0.0493	0.0582	0.0555	0.0493	0.0645	0.0645	0.221	0.234
Fixed effect								
Year		X			X	X		X
Sector			X		X	X		
Size				X		X		

Reading note: estimation of $\Delta tfp_{it} = \beta tfp_{it-1} + X_{ist} + \varepsilon_{ist}$ with tfp_{it-1}, *tfp* in the company's log *i* in year *t*-1, X_{ist} fixed effects for year, sector, size or companies; "ols" for ordinary least squares and "fe" for company fixed effects; standard deviation in brackets; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Coverage: whole market economy except for the financial sector. Metropolitan France and DOMs [*Départements d'outre mer* - Overseas Departments]
Sources: authors' database from Fiben, Banque de France; unbalanced sample; authors' calculations.

B – Productivity per employee

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ols	ols	ols	ols	ols	ols	fe	fe
pt_{t-1}	- 0.115***	- 0.119***	- 0.133***	- 0.116***	- 0.135***	- 0.136***	- 0.489***	- 0.498***
	(0.000261)	(0.000266)	(0.000285)	(0.000261)	(0.000288)	(0.000289)	(0.000513)	(0.000520)
N	3348931	3348931	3348931	3348931	3348931	3348931	3348931	3348931
R^2	0.0554	0.0606	0.0632	0.0555	0.0682	0.0683	0.237	0.244
Fixed effect								
Year		X			X	X		X
Sector			X		X	X		
Size				X		X		

Reading note: estimation of $\Delta lp_{it} = \beta lp_{it-1} + X_{ist} + \varepsilon_{ist}$ with lp_{it-1}, productivity per employee in the company's log *i* in year *t*-1, X_{ist} fixed effects for year, sector, size or companies; "ols" for ordinary least squares and "fe" for company fixed effects; standard deviation in brackets; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Coverage: whole market economy except for the financial sector. Metropolitan France and Overseas Departments [*Départements d'outre mer* - DOM]
Sources: authors' database from Fiben, Banque de France; unbalanced sample; authors' calculations.

CONVERGENCE PER YEAR

A – Total factor productivity per year

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
α+β	0,134	0,128	0,132	0,134	0,111	0,121	0,122	0,113	0,098	0,102	0,117	0,118
	(0,0027062)	(0,0021651)	(0,0019954)	(0,0019029)	(0,001851)	(0,0017831)	(0,0017558)	(0,001755)	(0,0017646)	(0,0017313)	(0,0016733)	(0,00167)
Confidence	0,139884	0,131876	0,1358906	0,1376896	0,1148541	0,1242331	0,1251061	0,1167816	0,1011093	0,1055762	0,1202483	0,1216808
interval at 95%	0,1290592	0,1232156	0,127909	0,130078	0,1074501	0,1171007	0,1180829	0,1097616	0,0940509	0,098651	0,1135551	0,1150008

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
α+β	0,115	0,118	0,103	0,116	0,103	0,116	0,139	0,144	0,110	0,100	0,104	0,083
	(0,0016664)	(0,0016517)	(0,0016406)	(0,0015961)	(0,0015625)	(0,0015175)	(0,0014372)	(0,0013355)	(0,0013125)	(0,0012804)	(0,0012942)	(0,0013339)
Confidence	0,1181963	0,1216044	0,1062357	0,1188139	0,1059255	0,1189874	0,1415068	0,1470523	0,1128604	0,102118	0,106756	0,0852946
interval at 95%	0,1115307	0,1149976	0,0996733	0,1124295	0,0996755	0,1129174	0,135758	0,1417103	0,1076104	0,0969964	0,1015792	0,079959

Reading note: estimation by ols of $\Delta prod_{it} = \alpha * \left(prod(95\%)_{t-1} - prod_{it-1} \right) + \sum_{j=1991}^{2014} \beta_j D_j \left(prod(95\%)_{t-1} - prod_{it-1} \right) + D_t + D_s + D_a + \varepsilon_{ist}$ with $prod_{it-1}$, TFP in the company's log *i* in year *t*-1, D_t, D_s and D_a fixed effects for year, sector, company size; standard deviation in brackets.
Coverage: whole market economy except for the financial sector. Metropolitan France and Overseas Departments [*Départements d'outre mer* - DOM]
Source: authors' database from Fiben, Banque de France; unbalanced sample; authors' calculations.

B – Productivity per employee per year

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
α+β	0,138	0,140	0,146	0,146	0,128	0,140	0,136	0,137	0,130	0,129	0,139	0,142
	(0,0017)	(0,0016)	(0,0016)	(0,0015)	(0,0015)	(0,0015)	(0,0014)	(0,0014)	(0,0014)	(0,0014)	(0,0014)	(0,0014)
Confidence	0,1410239	0,1432496	0,1493037	0,1485956	0,1314449	0,1429107	0,1388308	0,139472	0,1324079	0,131589	0,1418694	0,1446793
interval at 95%	0,1342795	0,1367484	0,1430101	0,1424256	0,1254393	0,1370743	0,1330484	0,13374	0,1266931	0,1259882	0,136399	0,1392417

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
α+β	0,138	0,138	0,131	0,135	0,128	0,130	0,158	0,174	0,127	0,125	0,124	0,114
	(0,0014)	(0,0013)	(0,0013)	(0,0013)	(0,0013)	(0,0012)	(0,0012)	(0,0011)	(0,0011)	(0,0011)	(0,0011)	(0,0011)
Confidence	0,1402297	0,1401619	0,1338355	0,1379293	0,1305815	0,1320791	0,1599767	0,1759997	0,1288072	0,1269227	0,1260372	0,1163485
interval at 95%	0,1348249	0,1348523	0,1285811	0,1327785	0,1255379	0,1272339	0,1553559	0,1714773	0,1243076	0,1225647	0,1216048	0,1117945

Reading note: estimation by ols of $\Delta prod_{it} = \alpha * \left(prod(95\%)_{t-1} - prod_{it-1} \right) + \sum_{j=1991}^{2014} \beta_j D_j \left(prod(95\%)_{t-1} - prod_{it-1} \right) + D_t + D_s + D_a + \varepsilon_{ist}$ with $prod_{it-1}$, productivity per employee in the company's log *i* in year *t*-1, D_t, D_s and D_a fixed effects for year, sector, company size; standard deviation in brackets.
Coverage: whole market economy except for the financial sector. Metropolitan France and Overseas Departments [*Départements d'outre mer* - DOM].
Source: authors' database from Fiben, Banque de France; unbalanced sample; authors' calculations.

ANNEX 4

CONVERGENCE OF PRODUCTIVITY - BALANCED SAMPLE

A – Total factor productivity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ols	ols	ols	ols	ols	ols	fe	fe
Distance to the frontière$_{t-1}$	0.0670***	0.0717***	0.0711***	0.0670***	0.0762***	0.0763***	0.280***	0.312***
	(0.000975)	(0.000966)	(0.00101)	(0.000975)	(0.001000)	(0.00100)	(0.00183)	(0.00184)
N	172854	172854	172854	172854	172854	172854	172854	172854
r^2	0.0266	0.0585	0.0362	0.0266	0.0683	0.0684	0.124	0.174
Fixed effect								
Year		X			X	X		X
Sector 38			X		X	X		
Size				X		X		

Reading note: estimation of $prod_{it} = \left(\left(95^{th}\ percentile\right)_{t-1} - prod_{it-1}\right) + X_{ist} + \varepsilon_{ist}$ with $\left(prod\left(95^{th}\ percentile\right)_{t-1} - prod_{it-1}\right)$, company's distance to the TFP frontier *i* in year *t*-1, X_{ist} fixed effects for year, sector, size or companies; ols for ordinary least squares and fe for company fixed effects; standard deviation in brackets; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Coverage: whole market economy except for the financial sector. Metropolitan France and Overseas Departments [*Départements d'outre mer* - DOM]
Source: authors' database from Fiben, Banque de France; balanced sample; authors' calculations.

B – Productivity per employee

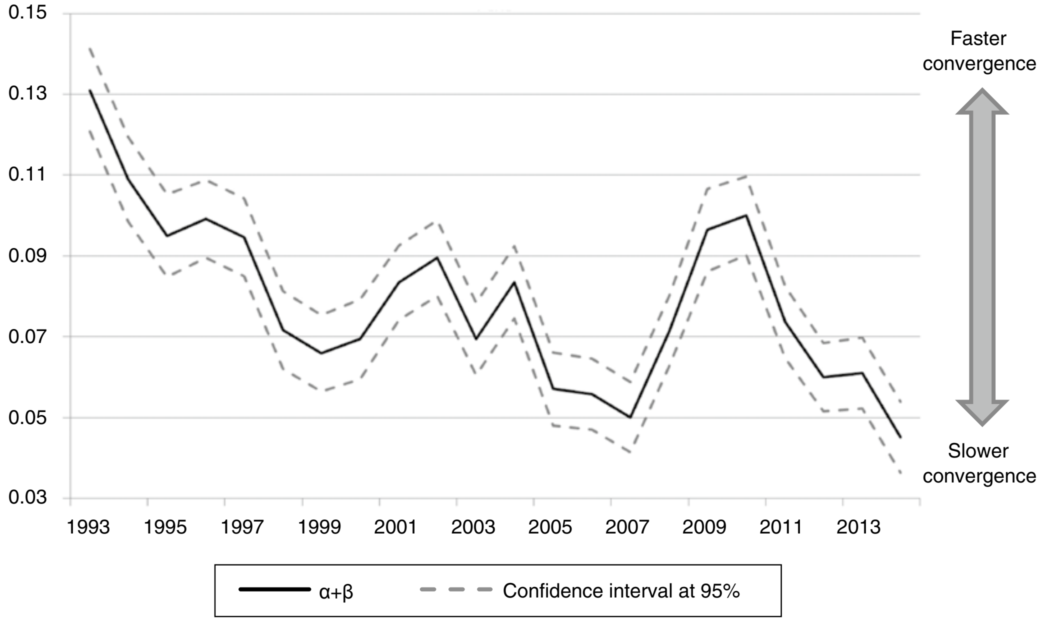
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ols	ols	ols	ols	ols	ols	fe	fe
Distance to the frontière$_{t-1}$	0.0761***	0.0784***	0.0856***	0.0763***	0.0882***	0.0884***	0.325***	0.340***
	(0.000806)	(0.000799)	(0.000847)	(0.000806)	(0.000840)	(0.000841)	(0.00155)	(0.00154)
N	262843	262843	262843	262843	262843	262843	262843	262843
r^2	0.0328	0.0553	0.0448	0.0330	0.0675	0.0676	0.149	0.181
Fixed effect								
Year		X			X	X		X
Sector 38			X		X	X		
Size				X		X		

Reading note: estimation of $prod_t = prod\left(95^{th}\ percentile\right)_{t-1} - prod_{it-1} + X_{ist} + \varepsilon_{ist}$ with $\left(prod\left(95^{th}\ percentile\right)_{t-1} - prod_{it-1}\right)$, company's distance to the productivity per employee frontier *i* in year *t*-1, X_{ist} fixed effects for year, sector, size or companies; ols for ordinary least squares and fe for company fixed effects; standard deviation in brackets; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Coverage: whole market economy except for the financial sector. Metropolitan France and Overseas Departments [*Départements d'outre mer* - DOM].
Source: authors' database from Fiben, Banque de France; balanced sample; authors' calculations.

C – Convergence of productivity per year over balanced sample

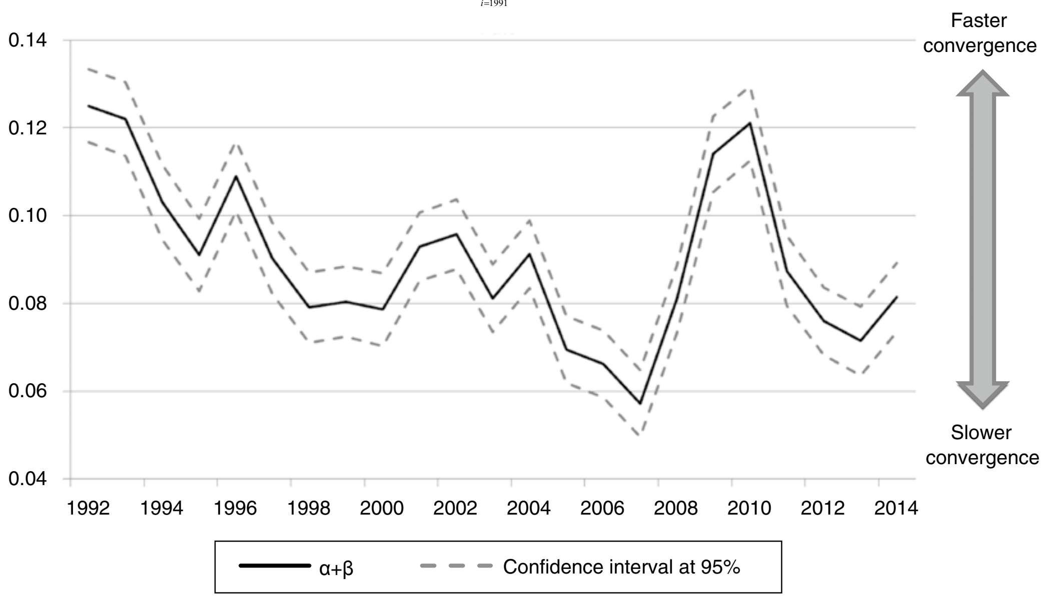
$\alpha+\beta_i$ – Convergence coefficients – TFP – balanced sample – OLS

$$\Delta tfp_\alpha = \alpha \cdot \left(tfp\left(95\%\right)_{\alpha-1} - tfp_{\alpha-1}\right) + \sum_{i=1991}^{2014} \beta_i D_i \left(tfp\left(95\%\right)_{i-1} - tfp_{i-1}\right) + D_s + D_t + D_\alpha$$



$\alpha+\beta_i$ – Convergence coefficients – Labour productivity balanced sample – OLS

$$\Delta lp_\alpha = \alpha \cdot \left(lp\left(95\%\right)_{\alpha-1} - lp_{\alpha-1}\right) + \sum_{i=1991}^{2014} \beta_i D_i \left(lp\left(95\%\right)_{i-1} - lp_{i-1}\right) + D_s + D_t + D_\alpha$$



Reading note: these two graphs present the sum of the coefficients $\alpha+\beta_i$ of equation (2). The higher these indicators, the greater the convergence; balanced sample from 1993 (TFP) and 1992 (labour productivity) to maintain a sufficient number of observations for the estimations.
Coverage: whole market economy except for the financial sector. Metropolitan France and Overseas Departments [*Départements d'outre mer* - DOM].
Source: authors' database from Fiben, Banque de France; balanced sample; authors' calculations.