Aggregate productivity and the allocation of resources over the business cycle*

Sophie Osotimehin†
Paris School of Economics and CREST

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Abstract

This paper analyzes the consequences of changes in the allocation of resources between incumbent, entering and exiting firms for the dynamics of aggregate productivity. I propose a novel decomposition of aggregate productivity growth which accounts for changes in allocative efficiency. By deriving aggregate productivity from the aggregation of firm-level production functions, this approach extends Solow (1957)'s growth accounting exercise to a framework with firm heterogeneity and frictions in the allocation of resources across firms. Using firm-level data from the French manufacturing industry, I find that the allocation of resources between incumbent firms improves during recessions, thereby reducing the volatility of aggregate productivity. In contrast with the theoretical literature on the cleansing effect of recessions, my results indicate that entry and exit flows play a negligible role for the cyclical dynamics of aggregate productivity.

Keywords: aggregate productivity, resource allocation, entry and exit, cleansing.
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†Address for correspondence: CREST INSEE, Timbre J360, 15 Bd Gabriel Péri, 92245 Malakoff Cedex, France. sophie.osotimehin@ensae.fr

1 Introduction

Recessions are often viewed as time where the economy is "cleansed": the least productive firms are forced to exit the market, allowing resources to be reallocated towards more productive uses. This Schumpeterian view of recessions, which has been emphasized by Caballero and Hammour (1994), suggests that the efficiency in the allocation of resources improves during recessions. While the theoretical literature has mainly focused on the contribution of entry and exit, empirical analyses indicate that resource reallocation mainly involves incumbent firms (Davis and Haltiwanger, 1998). Does the efficiency of resource allocation across incumbent firms vary over the business cycle? Is allocative efficiency an important determinant of aggregate productivity changes over the business cycle? To answer these questions, I propose a novel decomposition of aggregate total factor productivity (TFP) growth which separates out the variations that are due to changes in allocative efficiency from those due to within-firm productivity changes. This decomposition requires deriving the link between micro and aggregate productivity in a framework where resources are potentially inefficiently allocated across firms. Exploring the micro determinants of aggregate productivity raises a methodological problem: how should we aggregate firm-level TFP? There is no consensus on that question. In this paper, I advocate the use of a measure of aggregate productivity consistent with the firm level and therefore computed from the aggregation of firm-level production functions. This paper thus extends Solow (1957)'s growth accounting exercise to a framework with firm heterogeneity and allocative inefficiency. Deriving the contribution of allocative efficiency using a consistent measure of aggregate productivity is not only of theoretical interest, it has also important implications for our understanding of the dynamics of aggregate productivity. I estimate the decomposition on French firm-level data and find that the allocation of resources between incumbent firms improves during recessions, thereby reducing the volatility of aggregate productivity. By contrast, entry and exit flows play a negligible role for the cyclical dynamics of aggregate productivity. I then show how crucially these results depend on the aggregation and decomposition methods.

The decomposition of aggregate productivity growth is derived in a framework where firms are heterogeneous and where frictions in output and input markets generate cross-sectional inefficiencies. Following Restuccia and Rogerson (2008) and Chari et al. (2007), I use a reduced-form approach and do not specify the frictions that induce this resource misallocation. Rather, the frictions are modelled as wedges between the firms' marginal products. The model therefore encompasses various sources of distortions such as adjustment costs, search frictions, financial constraints or distortionary regulation. Resources are efficiency allocated when the value of marginal productivities are equalized across firms. Measured with respect to this first-best benchmark, the level of allocative efficiency then depends on the dispersion in labor and capital marginal productivities. Within this framework, I show how to aggregate the heterogenous production functions into an aggregate production function and hence derive a measure of aggregate productivity consistent with the firm-level measure. In the aggregation literature, the traditional approach consists in defining the aggregate production function as the efficient frontier of the production possibilities set (e.g. Fisher, 1969; Houthakker, 1955). Aggregate productivity is then computed from this aggregate production function for an optimal allocation of resources. As my objective is to measure the consequences of allocation distortions on aggregate productivity, this is not the approach considered here. Instead, I follow Malinvaud (1993) and define the aggregate production function as the relation between aggregate output and input for a given allocation of resources. Derived from this aggregate production function, aggregate productivity captures the variations in output that are due to changes in firm-level distortions, as well as those due to within-firm productivity changes.[1] It must be emphasized that distortions that modify identically the marginal productivity of inputs of all firms do not affect aggregate productivity; only cross-sectional inefficiencies affect the amount of aggregate output produced holding fixed aggregate inputs. Using statistical indexes similar to those used to separate price and volume changes, I decompose aggregate productivity growth between productivity changes at the firm-level, changes in allocative efficiency, and changes induced by entry and exit flows. Note that entry and exit cannot be broken down into a within-firm productivity and an allocative efficiency component as they modify the composition of the economy both in terms of firm-level TFP and distortions.

Then, I estimate the decomposition of aggregate productivity growth on French firm-level data from the manufacturing sector over the period 1991-2006. I use a dataset collected annually by the tax administration and combined with survey data in the INSEE unified system of business statistics (SUSE). The empirical analysis leads to the following findings: 1) within-firm productivity changes and allocative efficient are both key determinants of the cyclical dynamics of aggregate productivity, whereas the role of entry and exit is negligible. 2) movements in allocative efficiency are somewhat countercyclical, with a correlation to real value added growth of -0.25 while within-firm productivity changes are procyclical, with a correlation coefficient equal to 0.64. The finding that entry and exit flows have a negligible role for aggregate productivity growth contrasts sharply with the literature on the cleansing effect of recession (Caballero and Hammour, 1994; Barlevy, 2003; Ouyang, 2009). While the cleansing effect would imply a countercyclical extensive margin component, I find that, not only is the contribution of entry and exit small, it is also positively correlated to real value added growth. Actually, it is the reallocation of resources between incumbents, and not that between entering and exiting firms that tends to raise aggregate productivity during recessions. These movements in allocative efficiency also reduce the volatility of aggregate productivity. These results, which hold at the aggregate level as well as for most sectors, suggest new directions for future theoretical work as very little is

[1] I do not investigate the source of within-firm productivity changes. Just as aggregate productivity also depends on allocative efficiency, within-firm productivity could also depend on the allocation of resources within the firm. This dimension is left aside in the paper.

known on the mechanisms behind the cyclical patterns of allocative efficiency.

There exists a vast literature that documents the importance of resource reallocation for aggregate productivity growth (e.g. Baily et al., 1992; Foster et al., 2001; Griliches and Regev, 1995). The aggregation and decomposition methods proposed in these papers are completely different from my approach. Aggregate productivity is defined as a weighted average of firm-level TFP and then decomposed into changes in firm-level TFP and changes in the weights. To underline the importance of using a consistent measure of aggregate productivity and explicitly accounting for allocative efficiency, I compare my results with those obtained when implementing such a decomposition. Using Foster et al. (2001)'s version of the decomposition, the reallocation component, measured by changes in the weights, is positively correlated to real value added growth (correlation of 0.19) which is completely at odds with my findings. The approach used in the existing decompositions thus gives a biased measure of the role of allocative efficiency for aggregate productivity growth. The first reason is that they focus on *average* rather than on *aggregate* productivity. While the two concepts are equivalent when firms produce homogeneous goods using a linear technology with only one input, in the general case the consequences of input reallocation on average productivity are very different from those on aggregate productivity. Shifting resources towards high TFP firms mechanically raises average productivity but may reduce allocative efficiency and aggregate production if high TFP firms have a low marginal productivity. Therefore, though widely used in the literature, the correlation between changes in input shares and firm-level TFP does not capture the contribution of resource reallocation to aggregate productivity growth. Contrary to the existing literature, I analyze the contribution of resource reallocation on *aggregate* productivity which I derive from the aggregation of firm-level production functions. My approach also differs from this literature in that I explicitly model the frictions that distort the allocation of resources and measure the consequences of those frictions on aggregate productivity growth. While the existing literature studies the consequences of changes input shares, I measure the contribution of changes in allocative efficiency.

This paper is not the first to advocate the use of a well-defined measure of allocative efficiency. Several recent papers (Petrin and Levinsohn, 2005; Basu et al., 2009; Petrin et al., 2011) have emphasized that the reallocation component should capture changes in the allocation of inputs between firms with different marginal values. However, the methods used, as well as the results obtained are substantially different from my paper. Their decompositions are based on the Solow residual measure of productivity at the firm-level. They all build on Basu and Fernald (2002)'s insight that, under some conditions, the aggregate Solow residual approximates the welfare change of a representative consumer even when the allocation of resources is distorted by imperfect competition. Their measure of aggregate productivity growth therefore includes the effects of changes in aggregate input reflecting the fact that, under imperfect competition, welfare increases with aggregate input use. Moreover, their measure of allocative efficiency only captures the consequences of reallocation across firms with different markups and therefore does not account for all changes in the dispersion of marginal products. Basu et al. (2009) compute this decomposition for several European countries over the period 1998-2005 and find that allocative efficiency is not an important component of aggregate productivity. In particular, for France, they find that within-firm productivity changes explain all the changes in the aggregate Solow residual. This contrasts with my results in which allocative efficiency reduces average productivity growth by 1.2 percentage points. Contrary to Basu and Fernald (2002), I explicitly address the aggregation issue to investigate the link between the Solow residual and firm-level productivity change. By taking explicit account of firm heterogeneity and microeconomic frictions, I provide a complementary analysis to Hall (1991) who highlights the consequence of market imperfections for the measure of aggregate productivity growth in a representative firm framework.

This paper is also related to the growing literature that highlights the role of allocation distortions as a determinant of aggregate productivity (e.g. Restuccia and Rogerson, 2008; Buera et al., 2011; Hsieh and Klenow, 2009; Guner et al., 2008). The closest paper is Hsieh and Klenow (2009) who study the role of resource misallocation in explaining the TFP differential between China, India and the United States. As in their paper, resource misallocation is captured by the dispersion in the marginal products of capital and labor. However, both the objective and the decomposition differ from their paper. They analyze TFP differentials across countries, and quantify misallocation by measuring the distance between observed and first-best TFP levels. By contrast, I focus on TFP variation across time, and propose a decomposition of observed TFP which, besides, accounts for entry and exit flows. Furthermore, contrary to Hsieh and Klenow (2009), I use a unified approach at both the sectoral and aggregate levels. This allows me to provide an estimation of allocative efficiency both within and between sectors.

The paper is organized as follows. Section 2 lays out the framework and shows how to aggregate heterogeneous production units to derive the aggregate productivity index. Section 3 presents the decomposition of aggregate productivity both within and between sectors and provides a comparison with the usual decomposition. Section 4 presents the estimation method and the results obtained on French firm-level data. Section 5 concludes.

2 Aggregation in an inefficient economy

Total factor productivity is a concept which is intrinsically related to the production function as it is defined as the change in real output not accounted for by the change in real input. To analyze changes in aggregate total factor productivity, it is therefore necessary to derive the link between aggregate inputs and aggregate output. This section lays out the setup and shows how to derive the aggregate production function in a framework where producers are heterogeneous and face allocation frictions.

2.1 Framework

Consider an economy with S sectors. In each sector $s = 1...S$, there are N_s potential firms indexed by $i = 1, ..., N_s$. Firms produce a differentiated good Y_{it} using a Cobb-Douglas technology[2]:

$$Y_{it} = z_{it} K_{it}^{\alpha_s} L_{it}^{\beta_s},$$

where K_{it} denotes capital, L_{it} labor and z_{it} the firm-level total factor productivity. Depending on the value of $\gamma_s \equiv \alpha_s + \beta_s$, firms face either decreasing or constant returns to scale $\gamma_s \leq 1$, for all $s = 1, ..., S$. The factor elasticities are assumed to be identical within sectors, but may vary from one sector to another. Firms face a downward sloping demand curve. For simplicity let us assume that the demand functions are iso-elastic. The inverse demand for good i reads:

$$p_{it} = b_{it} Y_{it}^{\theta_s - 1},$$

where $0 < \theta_s < 1$ if $\gamma_s = 1$ and $0 < \theta_s \leq 1$ if $\gamma_s < 1$.[3] The parameter θ_s governs the price elasticity of demand in sector s and b_{it} is a firm-specific demand shock.

In this economy, the allocation of input across firms is distorted by market frictions. Following Restuccia and Rogerson (2008) and Chari et al. (2007), let us remain agnostic about the nature of the frictions. Consider a generic model in which distortions are captured by the presence of wedges $\tau_{it} = (\tau_{it}^K, \tau_{it}^L)$ that disrupt the firms' input decisions with respect to the frictionless first-order conditions:

$$\alpha_s \frac{p_{it} Y_{it}}{K_{it}} = r_t (1 + \tau_{it}^K) \quad (1)$$

$$\beta_s \frac{p_{it} Y_{it}}{L_{it}} = w_t (1 + \tau_{it}^L), \quad (2)$$

The distortions τ_{it} reduce the efficiency of aggregate production as they prevent the value of marginal products to be equalized across firms. The cross-sectional inefficiency may differ across inputs: τ_{it}^K denotes distortions that affect specifically the marginal product of capital, and τ_{it}^L, the marginal product of labor. As already mentioned, this model encompasses different types of

[2]To simplify notations, sector subscripts s are omitted for the firms' output and inputs.

[3]In the case where goods are homogeneous ($\theta_s = 1$ and $b_i = b$) and firms use a constant returns to scale technology ($\gamma_s = 1$), the framework described in this section does not allow us to characterize the observed allocation. Combining the first order conditions of the firms with the inverse demand equation does not pin down the size of the firms. I therefore restrict the analysis to the case where $\theta_s \leq 1$ and $\gamma_s \leq 1$, with at least one strict inequality.

frictions. Adjustment costs, search frictions, financial constraints and distortionary regulation all generate gaps between the firms' marginal products. Note that the wedges τ_{it} are distortive only if they are heterogenous across firms. Frictions that generate a wedge between the marginal product and the marginal cost of an input are not a source of allocative inefficiency if they affect all the firms in the same way. Hence, imperfect competition does not distort the cross-sectional allocation of resources as long as all firms charge the same markup.

The firm does not always find it profitable to produce; depending on its level of productivity and distortions, the firm could decide to exit. The function I_{it} characterizes the participation decision of the firm and may vary across firms and across time as this decision depends on factor prices, firm-specific fixed costs, and whether the firm considers to enter or exit. The firm exits if $I_{it}(z_{it}, b_{it}, \tau_{it}) < 0$ and produces if $I_{it}(z_{it}, b_{it}, \tau_{it}) \geq 0$. Combining the participation decision with equations (1) and (2), together with the demand curve, we can write the input levels as a function of the firm's distortions, productivity and demand shock:

$$K_{it} = \begin{cases} z_{it}^{\frac{\theta_s}{1-\gamma\theta_s}} b_{it}^{\frac{1}{1-\gamma\theta_s}} \left(\frac{r}{\alpha_s}(1+\tau_{it}^K)\right)^{-\frac{1-\beta_s\theta_s}{1-\gamma\theta_s}} \left(\frac{w}{\beta_s}(1+\tau_{it}^L)\right)^{-\frac{\beta_s\theta_s}{1-\gamma\theta_s}} & \text{if } I_{it}(z_{it}, b_{it}, \tau_{it}) \geq 0 \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

$$L_{it} = \begin{cases} z_{it}^{\frac{\theta_s}{1-\gamma\theta_s}} b_{it}^{\frac{1}{1-\gamma\theta_s}} \left(\frac{r}{\alpha_s}(1+\tau_{it}^K)\right)^{\frac{-\alpha_s\theta_s}{1-\gamma\theta_s}} \left(\frac{w}{\beta_s}(1+\tau_{it}^L)\right)^{-\frac{1-\alpha_s\theta_s}{1-\gamma\theta_s}} & \text{if } I_{it}(z_{it}, b_{it}, \tau_{it}) \geq 0 \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

2.2 Aggregation

The aggregation of heterogeneous firm-level production functions is a classical problem in macroeconomics. The link between aggregate input and output is not straightforward to derive. In fact, changes in aggregate input may affect aggregate output differently, depending on the way the additional input is allocated across firms. It is well known that the aggregation of firm-level technological constraints is impossible if individual firm inputs are allowed to take any values, unless very restrictive conditions are imposed on the production functions.[4] In the aggregation literature, the traditional solution consists in deriving the aggregate production function for an optimal allocation of resources. As the focus is on resource misallocation and production inefficiencies, this is not the approach considered here. Instead, I follow Malinvaud (1993)'s insight and derive the aggregate production function for a given allocation rule. With this definition, the conditions for aggregation become less restrictive. Consider an economy where individual production functions are given by $f_i(K_i, L_i)$. To derive the aggregate production function, we need to find the relation between aggregate output ($Y = \sum_i f_i(K_i, L_i)$) and aggregate inputs ($K = \sum_i K_i$ and $L = \sum_i L_i$). The idea is to find the allocation rules, i.e how aggregate inputs are

[4] The individual production functions must be linear and have the same slopes (Nataf, 1948).

allocated between firms, and then aggregate output over firms using the allocation rules. More formally, once the allocation rules $K_i = k_i(K, L)$ and $L_i = l_i(K, L)$ are known, the aggregate production function is simply: $Y = \sum_i f_i(k_i(K, L), l_i(K, L))$. Note that in general the aggregate production function does not share the same functional form as the individual production functions. Besides, the functional form of the aggregate production function does not always permit to assess the contribution of entry and exit to aggregate productivity. Because of the discontinuity introduced by entry and exit decisions, the contribution of entry and exit can be computed only if the aggregate productivity can be summarized by a scalar. Without this separability property, the impact of entry and exit on aggregate productivity cannot be disentangle from its impact on aggregate inputs. I show in Appendix A that, in the present framework, separability is obtained when the factor and demand elasticities are identical across firms. In order to assess the contribution of entry and exit to aggregate productivity, I therefore aggregate the production functions in two steps. First, I aggregate the production functions at the sectoral level. Since factor and demand elasticities are identical within sectors, this will enable us to compute the contribution of entry and exit to sectoral productivity. Then, I aggregate the sectoral production functions and take into account the heterogeneity between sectors. This two-step aggregation procedure will also allow us to account for the changes in allocative efficiency between sectors, as well as within sectors. Before applying this aggregation procedure, we must take into account the heterogeneity in the goods produced. In particular, reallocating resources between two different goods should have a different impact on aggregate productivity depending on the relative value of the goods produced.[5] In the following, I show how to deal with goods heterogeneity and then derive the sectoral and the aggregate production functions.

2.2.1 Accounting for goods heterogeneity

Since goods are heterogeneous, we need to use relative prices to compute sectoral output. Sectoral output can be written: $Y_s = \sum_{i=1}^{N_s} \frac{p_{it}}{P_{st}} Y_{it} = \sum_{i=1}^{N_s} f_i(K_{it}, L_{it})$ and

$$f_i(K_{it}, L_{it}) = A_{it} K_{it}^{\alpha_s \theta_s} L_{it}^{\beta_s \theta_s}, \tag{5}$$

with $A_{it} \equiv z_{it}^{\theta_s} b_{it} / P_{st}$ and P_{st} is the sectoral price index. The output function f_i takes into account the impact of changes in output on the relative value of the goods produced.[6] When accounting

[5]Note that accounting for goods heterogeneity will not modify the conditions required for the separability of the aggregate production function.

[6]Accounting for this change in relative prices is crucial when studying the impact of reallocations on aggregate productivity. Suppose that all the firms use a constant returns to scale technology and consider a situation where all inputs are reallocated towards the firm with the highest TFP level. If the impact of reallocation on the relative value of the goods is not accounted for, we would wrongly conclude that this reallocation maximizes aggregate production. Actually, when goods are heterogeneous, the optimal allocation is the one that equalizes the value of marginal productivities across firms. Reallocating all resources toward the production of one good would decrease the value of this good, and raise that of non-produced goods. Even when the good is produced by the firm with

for changes in the relative value of goods, the actual productivity of the firm combines both technical efficiency and demand factors. Note that A_{it} is also the usual measure of productivity at the firm level. Because firm-level prices are rarely available, the firm's output is usually measured by its nominal output divided by a sectoral deflator. Though it hinders the measure of technical efficiency at the firm-level, the absence of firm-level prices is not problematic here.[7] What matters for aggregate productivity is the measured firm-level productivity A_{it}. In fact, the whole model can be rewritten as a function of measurable variables only. In particular, the input decision described in equations (3) and (4) can be rewritten as $K_i(P_{st}A_{it}, \tau_{it}, r_t, w_t)$ and $L_i(P_{st}A_{it}, \tau_{it}, r_t, w_t)$:

$$K_{it} = \begin{cases} (P_{st}A_{it})^{\frac{1}{1-\gamma\theta_s}} \left(\frac{r}{\alpha_s}(1+\tau_{it}^K)\right)^{-\frac{1-\beta_s\theta_s}{1-\gamma\theta_s}} \left(\frac{w}{\beta_s}(1+\tau_{it}^L)\right)^{-\frac{\beta_s\theta_s}{1-\gamma\theta_s}} & \text{if } I_{it}(z_{it}, b_{it}, \tau_{it}) \geq 0 \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

$$L_{it} = \begin{cases} (P_{st}A_{it})^{\frac{1}{1-\gamma\theta_s}} \left(\frac{r}{\alpha_s}(1+\tau_{it}^K)\right)^{\frac{-\alpha_s\theta_s}{1-\gamma\theta_s}} \left(\frac{w}{\beta_s}(1+\tau_{it}^L)\right)^{-\frac{1-\alpha_s\theta_s}{1-\gamma\theta_s}} & \text{if } I_{it}(z_{it}, b_{it}, \tau_{it}) \geq 0 \\ 0 & \text{otherwise} \end{cases} \quad (7)$$

2.2.2 The sectoral production functions

Let us now aggregate the output functions described above. The allocation rules can be derived from the equilibrium condition on the inputs markets. Specifically, they are obtained after inverting the aggregate input equations. At the sectoral level, total inputs are given by:

$$\begin{aligned} K_{st} &= \sum_{i=1}^{N_s} K_i(P_{st}A_{it}, \tau_{it}, r_t, w_t) \\ L_{st} &= \sum_{i=1}^{N_s} L_i(P_{st}A_{it}, \tau_{it}, r_t, w_t). \end{aligned}$$

Inverting this system of equations allows us to write the factor prices as a function of aggregate capital, labor input and the vector of firm-level productivity $\widetilde{A}_{st} = \{A_{1t}, ..., A_{N_st}\}$ and distortions $\widetilde{\tau}_t = \{\tau_{1t}, ..., \tau_{N_st}\}$.[8] The input levels can then be written as a function of aggregate inputs, firm-level productivities and distortions. The sectoral production function follows:

$$F_s(K_{st}, L_{st}, \widetilde{A}_{st}, \widetilde{\tau}_{st}) = \sum_{i=1}^{N_s} f_i(k_i(P_{st}\widetilde{A}_{st}, \widetilde{\tau}_{st}, K_{st}, L_{st}), l_i(P_{st}\widetilde{A}_{st}, \widetilde{\tau}_{st}, K_{st}, L_{st})).$$

In general, the aggregate production function does not share the same functional form as the individual production functions. However, when the factor and demand elasticities are identical

the highest TFP level, the reallocation of all resources towards this good does not maximizes aggregate output.

[7] The consequences of the absence of firm-level prices for the measure of firm-level TFP have been recently emphasized by Foster et al. (2008).

[8] This system is locally invertible if the Jacobian of the application $\{K_s(r,w), L_s(r,w)\}$ is non-zero.

across firms (as assumed within sectors), I show in Appendix A that the aggregate production function is also Cobb-Douglas, and is then separable in aggregate productivity. As already mentioned, this result is crucial to assess the contribution of entry and exit. The sectoral production function is (see Appendix B for more details on the derivation):

$$F_s(K_{st}, L_{st}, \widetilde{A}_{st}, \widetilde{\tau}_{st}) = \mathrm{TFP}_{st} K_{st}^{\alpha_s \theta_s} L_{st}^{\beta_s \theta_s},$$

where TFP_{st} is a function of both firm-level productivity $\widetilde{A}_{st}$ and distortions $\widetilde{\tau}_{st}$.

2.2.3 From the sectoral to the aggregate production function

In order to aggregate the sectoral production functions, let us characterize each sector's representative firm. The sectoral input demand function are identical to the firm-level functions (equations (6) and (7) with the participation equation always satisfied). The sectoral input levels $K_s(P_{st}\mathrm{TFP}_{st}, \omega_{st}, r_t, w_t)$ and $L_s(P_{st}\mathrm{TFP}_{st}, \omega_{st}, r_t, w_t)$ are functions of sectoral level of distortions $\omega_{st} = (\omega_{st}^K, \omega_{st}^L)$ which are given by:

$$1 + \omega_{st}^K = \sum_i \frac{K_{it}}{K_{st}}(1 + \tau_{it}^K) \quad (8)$$

$$1 + \omega_{st}^L = \sum_i \frac{L_{it}}{L_{st}}(1 + \tau_{it}^L). \quad (9)$$

Like at the sectoral level, the aggregate production function is obtained after inverting the aggregate input equations.[9] Since the factor and demand elasticities are allowed to be heterogenous across sectors, the aggregate production function is not Cobb-Douglas. Real aggregate output Y is given by $\sum_s Y_s = F(K_t, L_t, \widetilde{\mathrm{TFP}}_t, \widetilde{\omega}_t, P_{st})$, where:

$$F(K_t, L_t, \widetilde{\mathrm{TFP}}_t, \widetilde{\omega}_t, \widetilde{P}_t) = \sum_{s=1}^{S} \mathrm{TFP}_{st} K_{st}^{\alpha_s \theta_s} L_{st}^{\beta_s \theta_s}$$

$$\begin{aligned} \text{with } K_{st} &= k_s(\widetilde{\mathrm{TFP}}_t, \widetilde{\omega}_t, \widetilde{P}_t, K_t, L_t) \\ L_{st} &= l_s(\widetilde{\mathrm{TFP}}_t, \widetilde{\omega}_t, \widetilde{P}_t, K_t, L_t). \end{aligned}$$

$\widetilde{\mathrm{TFP}}_t = \{\mathrm{TFP}_{1t}, ..., \mathrm{TFP}_{St}\}$ is the vector of sectoral level productivity, $\widetilde{\omega}_t = \{\omega_{1t}, ..., \omega_{St}\}$ the vector of sectoral level distortions and $\widetilde{P}_t = \{P_{1t}, ..., P_{St}\}$ is the vector of sectoral price indexes.

[9] The aggregate input equations are:
$K = \sum_{s=1}^{S} K_s(P_{st}\mathrm{TFP}_{st}, \omega_{st}, r_t, w_t)$
$L = \sum_{s=1}^{S} L_s(P_{st}\mathrm{TFP}_{st}, \omega_{st}, r_t, w_t)$

3 Accounting for changes in aggregate productivity

This section presents the decomposition of aggregate productivity growth into changes in firm-level productivity, changes in the efficiency of resource allocation within and between sectors, and changes due to entry and exit flows. I first decompose sectoral productivity growth. Then, I aggregate the within-sector components and derive the contribution of allocative efficiency between sectors using the aggregate production function. Because of the non-separability caused by the heterogeneity between sectors, I cannot apply the same decomposition method at the sectoral and aggregate levels. Whereas the separability of the sectoral production function allows me to to derive an exact decomposition of sectoral productivity changes, the decomposition of aggregate productivity relies on an approximation. This section also compares my decomposition to the standard decomposition of Foster et al. (2001).

3.1 Decomposition of sectoral productivity

As shown in section 2.2.2 and Appendix B, the sectoral production function is given by: $Y_{st} = \text{TFP}_{st} K_{st}^{\alpha_s \theta_s} L_t^{\beta_s \theta_s}$, where sectoral productivity is a function of firm-level productivity A_{it} and distortions $\tau_{it} = (\tau_{it}^K, \tau_{it}^L)$:

$$\text{TFP}_{st} = \sum_{i=1}^{N_s} A_{it} \left(\frac{K_{it}}{K_{st}} \right)^{\alpha_s \theta_s} \left(\frac{L_{it}}{L_{st}} \right)^{\beta_s \theta_s}, \tag{10}$$

with:[10]

$$\frac{K_{it}}{K_{st}} = \frac{g_s^K(A_{it}, \tau_{it})}{\sum_{i=1}^{N_s} g_s^K(A_{it}, \tau_{it})} \quad \text{and} \quad \frac{L_{it}}{L_{st}} = \frac{g_s^L(A_{it}, \tau_{it})}{\sum_{i=1}^{N_s} g_s^L(A_{it}, \tau_{it})}.$$

The decomposition consists in isolating the changes in aggregate productivity which are due to changes in the composition of firms caused by entry and exit from those due to changes in the firm-level distortions τ_{it} and changes in firm-level productivity A_{it} of incumbent firms. Firm-level productivity shocks affect aggregate productivity not only by modifying each firm's productivity but also through their consequences on the firms' input shares.

Before deriving the decomposition of sectoral productivity, let us examine in more details how aggregate productivity depends on the cross-sectional distribution of firm-level productivity and distortion. For simplicity, let us assume that firm-level productivity is independently and identically distributed across firms with mean $\bar{A}_{st}$ and standard deviation σ_A and the distortions

[10] The g functions are given by:
$g_s^K(A_{it}, \tau_{it}) = A_i^{\frac{1}{1-\gamma\theta_s}} (1 + \tau_i^K)^{-\frac{1-\beta_s\theta_s}{1-\gamma\theta_s}} (1 + \tau_i^L)^{-\frac{\beta_s\theta_s}{1-\gamma\theta_s}}$
$g_s^L(A_{it}, \tau_{it}) = A_i^{\frac{1}{1-\gamma\theta_s}} (1 + \tau_i^K)^{-\frac{\alpha_s\theta_s}{1-\gamma\theta_s}} (1 + \tau_i^L)^{-\frac{1-\alpha_s\theta_s}{1-\gamma\theta_s}}$

$(\tau_{it}^K, \tau_{it}^L)$ are also independently and identically distributed with mean $(\bar{\tau}_t^K, \bar{\tau}_t^L)$ and standard deviation $(\sigma_\tau^K, \sigma_\tau^L)$ and covariance $Cov(\tau^K, \tau^L)$. For uniformly small deviations, using a second order Taylor expansion of equation (10) and the law of large numbers, sectoral TFP can be approximated by:

$$\text{TFP}_{st} \simeq N_{st}^{1-\gamma} \bar{A}_{st} \left[1 + \eta^A \left(\frac{\sigma_A}{\bar{A}_{st}} \right)^2 - \eta^K \left(\frac{\sigma_\tau^K}{1+\bar{\tau}_t^K} \right)^2 - \eta^L \left(\frac{\sigma_\tau^L}{1+\bar{\tau}_t^L} \right)^2 - \eta^{KL} \frac{Cov(\tau^K, \tau^L)}{(1+\bar{\tau}_t^K)(1+\bar{\tau}_t^L)} \right] \tag{11}$$

with $\eta^A > 0, \eta^K > 0, \eta^L > 0$ and $\eta^{KL} > 0$.[11]

Sectoral TFP does not depend only on average firm-level productivity. The dispersion of firm-level productivity and distortions are also key determinants of aggregate productivity. This equation also indicates that the average level of distortion $(\bar{\tau}_t^K, \bar{\tau}_t^L)$ has no impact on aggregate productivity. This result is not surprising as the distortions affect the efficiency of resource allocation only as long as they differ across firms. Therefore, an increase in the average level of distortions does not modify the level of allocative efficiency in the economy; only the changes in the relative marginal productivity of inputs matter. The insensitivity of aggregate productivity to the average level of distortions is a property that will be very useful to estimate firm-level distortions (cf. section 4.2.2). The equation also shows that a high covariance between capital and labor specific distortions reduces aggregate productivity whereas the covariance between firm-level productivity and distortions plays no role. It also appears that aggregate productivity increases with the number of firms in the economy. The role of the number firms on aggregate productivity arises from the presence of decreasing returns to scale and/or the love for variety implied by the demand function.

Let us now decompose sectoral TFP growth (ΔTFP_{st}) into changes in within-firm productivity (ΔTE_s), changes in allocative efficiency (ΔAE_s) and changes at the extensive margin (ΔEX_s) (the details of the derivation are given in Appendix C):[12]

$$\Delta\text{TFP}_{st} \approx \Delta\text{TE}_s + \Delta\text{AE}_s + \Delta\text{EX}_s,$$

An approximation for each component is given below. The decomposition between changes in within-firm productivity and changes in allocative efficiency is similar to the decompositions we can find in the index number literature to separate price and volume changes. To avoid any asymmetry induced by the functional form of the indexes, I measure in the data each component with a Fisher-like index, i.e. the geometric mean of the Laspeyres-like and Paasche-like indexes. The exact decomposition with the Fisher-like index is described in Appendix C. For simplicity, I present here an approximation in which the effects of within-firm productivity changes are

[11] $\eta^A = \frac{1}{2}\frac{\gamma_s\theta_s}{1-\gamma_s\theta_s}$; $\eta^K = \frac{1}{2}\frac{\alpha_s\theta_s(1-\beta_s\theta_s)}{1-\gamma_s\theta_s}$; $\eta^L = \frac{1}{2}\frac{\beta_s\theta_s(1-\alpha_s\theta_s)}{1-\gamma_s\theta_s}$; $\eta^{KL} = \frac{\alpha_s\beta_s\theta_s^2}{1-\gamma_s\theta_s}$.

[12] For convenience, we denote the aggregate productivity growth by $\Delta\text{TFP}_{st} \equiv \text{TFP}_{st}/\text{TFP}_{st-1} - 1$

measured with a Laspeyres-like index, while those of allocative efficiency are measured with a Paasche-like index.

The change in firm-level productivity can be approximated as a combination of weighted averages of the firm-level productivity changes:

$$\Delta TE_s \simeq \frac{1}{1-\gamma_s\theta_s}\sum_{i\in C_s}\frac{\Delta A_{it}}{A_{it-1}}\left[\frac{p_{it-1}Y_{it-1}}{\sum\limits_{i\in C_s} p_{it-1}Y_{it-1}} - \alpha_s\theta_s\frac{K_{it-1}}{\sum\limits_{i\in C_s} K_{it-1}} - \beta_s\theta_s\frac{L_{it-1}}{\sum\limits_{i\in C_s} L_{it-1}}\right], \tag{12}$$

with C_s is the set of continuing firms ($I_{it-1} \geq 0$ and $I_{it} \geq 0$). It must be emphasized that this within-firm productivity component includes the effect of demand shocks as well as that of technology shocks. Indeed, the productivity of each firm is measured in terms of the relative value of production and a positive demand shock, by increasing its relative value, raises the the productivity of the firm. The within-firm productivity component captures changes in within-firm productivity for a given level of allocative efficiency. Therefore, this measure includes the effect of within-firm productivity changes for a given distribution of inputs, as well as the consequences of within-firm productivity changes on input shares for a given level of distortions. The level of distortions is measured here by the relative marginal productivities of input across firms.Therefore, the firm-level efficiency component captures the impact of within-firm productivity changes, had relative marginal productivities remained constant.

The change in allocative efficiency is a combination of weighted averages of firm-level changes in distortion:

$$\begin{aligned}\Delta AE_s \;\simeq\;& \frac{\alpha_s\theta_s}{1-\gamma_s\theta_s}\sum_{i\in C_s}\frac{\Delta(1+\tau^K_{it})}{1+\tau^K_{it-1}}\left[(1-\beta_s\theta_s)\frac{K_{it}}{\sum\limits_{i\in C_s} K_{it}} + \beta_s\theta_s\frac{L_{it}}{\sum\limits_{i\in C_s} L_{it}} - \frac{p_{it}Y_{it}}{\sum\limits_{i\in C_s} p_{it}Y_{it}}\right]\\ &+\frac{\beta_s\theta_s}{1-\gamma_s\theta_s}\sum_{i\in C_s}\frac{\Delta(1+\tau^L_{it})}{1+\tau^L_{it-1}}\left[\alpha_s\theta_s\frac{K_{it}}{\sum\limits_{i\in C_s} K_{it}} + (1-\alpha_s\theta_s)\frac{L_{it}}{\sum\limits_{i\in C_s} L_{it}} - \frac{p_{it}Y_{it}}{\sum\limits_{i\in C_s} p_{it}Y_{it}}\right]\end{aligned} \tag{13}$$

Consistently with equation (11), a change in the level of distortions modifies aggregate productivity only if this change is heterogeneous across firms.

The contribution of the extensive margin to aggregate productivity growth depends of the relative weights of entering and exiting firms:

$$\Delta EX_s \simeq \frac{\sum\limits_{i\in E_s} \frac{p_{it}Y_{it}}{P_{st}Y_t} - \sum\limits_{i\in X_s} \frac{P_{it-1}Y_{it-1}}{P_{st-1}Y_{t-1}}}{1 - \sum\limits_{i\in E_s} \frac{p_{it}Y_{it}}{P_{st}Y_t}} - \alpha_s\theta_s \frac{\sum\limits_{i\in E_s} \frac{K_{it}}{K_t} - \sum\limits_{i\in X_s} \frac{K_{it-1}}{K_{t-1}}}{1 - \sum\limits_{i\in E_s} \frac{K_{it}}{K_t}} - \beta_s\theta_s \frac{\sum\limits_{i\in E_s} \frac{L_{it}}{L_t} - \sum\limits_{i\in X_s} \frac{L_{it-1}}{L_{t-1}}}{1 - \sum\limits_{i\in E_s} \frac{L_{it}}{L_t}} \quad (14)$$

with E_s the set of new entrants ($I_{it-1} < 0$ and $I_{it} \geq 0$) and X_s the set of exiting firms ($I_{it-1} \geq 0$ and $I_{it} < 0$) in sector s. The extensive margin contributes positively to aggregate productivity growth if entering firms are more productive and face less distortions than exiting firms. As long as there are decreasing returns to scale $\gamma_s\theta_s$<1 (in production or in demand), the positive effect of higher output shares is not offset by larger input shares. All else equal, a higher returns to scale parameter reduces the role of entry and exit for aggregate productivity growth. The relative weight of entering firms also increases with the number of entering firms. The extensive margin component also captures the impact of the number of firms on aggregate productivity. As emphasized in equation (11), the efficiency of production increases with the number of firms.

When resources are perfectly allocated across firms ($1 + \tau_i = 1 + \tau$, for all $i = 1, ..., N_s$), the allocation of labor, capital and output depends only on the firms' relative productivity. Moreover, in this case, input and output shares are equal ($\frac{K_i}{K} = \frac{L_i}{L} = \frac{p_{it}Y_{it}}{P_{st}Y_t}$), and the components of aggregate productivity simplify to:

$$\Delta TE_s^{FL} \simeq \sum_{i\in C_s} \frac{\Delta A_{it}}{A_{it-1}} \frac{p_{it-1}Y_{it-1}}{\sum\limits_{i\in C_s} p_{it-1}Y_{it-1}} \quad (12')$$

$$\Delta AE_s^{FL} = 0 \quad (13')$$

$$\Delta EX_s^{FL} \simeq (1 - \gamma_s\theta_s) \frac{\sum\limits_{i\in E_s} \frac{p_{it}Y_{it}}{P_{st}Y_t} - \sum\limits_{i\in X_s} \frac{p_{it-1}Y_{it-1}}{P_{st-1}Y_{t-1}}}{1 - \sum\limits_{i\in E_s} \frac{p_{it}Y_{it}}{P_{st}Y_t}} \quad (14')$$

In the absence of allocation distortions, the impact of within-firm productivity changes can be measured by a simple weighted average. The allocative efficiency component is null as resources are always efficiently allocated, and the extensive margin component simplifies to the difference between the output shares of entering and exiting firms.

3.2 Decomposition across sectors

The aggregate production function, derived in section 2.3.3, is a function of the vector of sectoral productivity $\widetilde{\text{TFP}}_t = \{\text{TFP}_{1t}, ..., \text{TFP}_{St}\}$, and sectoral distortions $\widetilde{\omega}_t = \{\omega_{1t}, ..., \omega_{St}\}$:

$$\sum_s Y_s = F(K_t, L_t, \widetilde{\text{TFP}}_t, \widetilde{\omega}_t, P_{st}), \tag{15}$$

Aggregate productivity growth is the change in output that is not due to the change in aggregate inputs. Taking the total differential of equation (15), aggregate productivity can then be written as the change in aggregate output explained by changes in sectoral productivity and distortions. This leads to the following decomposition:[13]

$$\frac{d\text{TFP}_t}{\text{TFP}_t} = \underbrace{\sum_{s=1}^{S} \frac{\partial F}{\partial \text{TFP}_s} \frac{\text{TFP}_s}{Y} \frac{d\text{TFP}_s}{\text{TFP}_s}}_{\text{Within sectors}} + \underbrace{\sum_{s=1}^{S} \frac{\partial F}{\partial \omega_s^K} \frac{1+\omega_s^K}{Y} \frac{d\omega_s^K}{1+\omega_s^K} + \frac{\partial F}{\partial \omega_s^L} \frac{1+\omega_s^L}{Y} \frac{d\omega_s^L}{1+\omega_s^L}}_{\text{Between sectors}}.$$

The first term measures changes in within-sector productivity, including changes in between-sector allocative efficiency, and the second term measures changes in the efficiency of resource allocation across sectors. Using the implicit function theorem to compute the derivative of F with respect to TFP_s and replacing the within-sector productivity change by the decomposition derived at the sectoral level yields the decomposition of aggregate productivity growth (ΔTFP_t) into changes in firm-level productivity $\Delta\overline{\text{TE}}$, changes in the allocation of resources between $\Delta\overline{\text{AE}}_{\text{between}}$ and within sectors $\Delta\overline{\text{AE}}_{\text{within}}$, as well as changes in entry and exit patterns $\Delta\overline{\text{EX}}$:

$$\Delta\text{TFP}_t = \Delta\overline{\text{TE}} + \Delta\overline{\text{AE}}_{\text{within}} + \Delta\overline{\text{EX}} + \Delta\overline{\text{AE}}_{\text{between}}. \tag{16}$$

The details of the derivation are given in Appendix C.[14] The within-sector productivity decomposition is aggregated at the macro level using input and output sectoral shares and the elasticities of the aggregate production function with respect to aggregate inputs, ε_K and ε_L:[15]

$$\Delta\overline{\text{TE}} = \sum_{s=1}^{S} \frac{1}{1-\gamma_s\theta_s} \left(\frac{Y_s}{Y} - \varepsilon_K \frac{K_s}{K} - \varepsilon_L \frac{L_s}{L} \right) \Delta\text{TE}_s \tag{17}$$

Similarly, the change in within-sector allocative efficiency and the aggregate impact of the ex-

[13] Note that the impact of changes in sectoral prices are neglected. In the empirical results I verify that the last term of the decomposition $\sum_{s=1}^{S} \frac{\partial F}{\partial P_s} \frac{P_s}{Y} \frac{dP_s}{P_s}$ is indeed negligible.

[14] Note that, contrary to the within-sector decomposition, the decomposition across sectors requires no specific assumptions about the individual production functions ; it requires though the existence of a unique allocation rule, necessary for the existence of the aggregate production function.

[15] The aggregate factor elasticities are function of both labor and capital sectorial elasticities. The expressions for ε_K and ε_L are given in Appendix C.

tensive margin can be computed as:

$$\Delta\overline{\mathrm{AE}}_{\mathrm{within}} = \sum_{s=1}^{S} \frac{1}{1-\gamma_s\theta_s} \left(\frac{Y_s}{Y} - \varepsilon_K \frac{K_s}{K} - \varepsilon_L \frac{L_s}{L} \right) \Delta \mathrm{AE}_s \tag{18}$$

$$\Delta\overline{\mathrm{EX}} = \sum_{s=1}^{S} \frac{1}{1-\gamma_s\theta_s} \left(\frac{Y_s}{Y} - \varepsilon_K \frac{K_s}{K} - \varepsilon_L \frac{L_s}{L} \right) \Delta \mathrm{EX}_s \tag{19}$$

Finally, the change in between-sector allocative efficiency is computed as follows:

$$\begin{aligned} \Delta\overline{\mathrm{AE}}_{\mathrm{between}} \quad = \quad & \sum_{s=1}^{S} \frac{1}{1-\gamma_s\theta_s} \left(\varepsilon_K (1-\beta_s\theta_s) \frac{K_s}{K} + \varepsilon_L \alpha_s\theta_s \frac{L_s}{L} - \alpha_s\theta_s \frac{Y_s}{Y} \right) \frac{d\omega_s^K}{1+\omega_s^K} \\ & + \sum_{s=1}^{S} \frac{1}{1-\gamma_s\theta_s} \left(\varepsilon_K \beta_s\theta_s \frac{K_s}{K} + \varepsilon_L (1-\alpha_s\theta_s) \frac{L_s}{L} - \beta_s\theta_s \frac{Y_s}{Y} \right) \frac{d\omega_s^L}{1+\omega_s^L} \end{aligned} \tag{20}$$

And overall allocative efficiency is given by:

$$\Delta\overline{\mathrm{AE}} = \Delta\overline{\mathrm{AE}}_{\mathrm{within}} + \Delta\overline{\mathrm{AE}}_{\mathrm{between}} \tag{21}$$

If factor elasticities were equal across sectors, all these expressions would be exactly equal to the approximate decomposition derived at the sectoral level.

3.3 Comparison with the existing decompositions

There exists a vast literature that analyzes the importance of resource reallocation for aggregate productivity growth (Baily et al., 1992; Foster et al., 2001; Griliches and Regev, 1995). These papers do not derive aggregate productivity from the aggregation of firm-level production functions. Instead, they define aggregate productivity as the weighted average of firm-level TFP.

$$\ln \mathrm{TFP}_t = \sum_i s_{it} \ln A_{it},$$

where $s_{it} = Y_{it}/Y_t$ is the output share of firm i.

The decompositions found in the literature slightly differ from one another in the weights used (previous or/and current period, labor or market shares) and whether or not firm-level productivity is normalized (relative to the aggregate productivity index). Let us consider the decomposition proposed by Foster, Haltiwanger and Krizan (hereafter FHK, 2001):

$$
\begin{aligned}
\Delta \ln \mathrm{TFP}_t \quad = \quad & \underbrace{\sum_{\text{stay}} s_{it-1}\Delta \ln A_{it}}_{\text{within}} + \underbrace{\sum_{\text{stay}} \Delta s_{it}(\ln A_{it-1} - \ln \mathrm{TFP}_{t-1})}_{\text{reallocation}} \\
& + \underbrace{\sum_{\text{entry}} s_{it}(\ln A_{it} - \ln \mathrm{TFP}_{t-1}) - \sum_{\text{exit}} s_{it-1}(\ln A_{it-1} - \ln \mathrm{TFP}_{t-1})}_{\text{extensive margin}} \\
& + \underbrace{\sum_{\text{stay}} \Delta \ln A_{it}\Delta s_{it}}_{\text{cross term}}
\end{aligned}
\tag{22}
$$

The first component captures changes in within-firm productivity holding fixed the market shares. The second component measures the impact of changes in market shares on average productivity. The third component measures the contribution of entering and exiting firms, and the last component is a cross term that measures the correlation between changes in within-firm productivity and changes in market shares. This decomposition is completely different from the one derived from the aggregation of firm-level production functions (equations (12) to (14), and (17) to (20)). The main difference comes from the definition of aggregate productivity itself. While FHK focus on *average* productivity, I analyze the changes in *aggregate* productivity. This yields a very different decomposition, and in particular a very different reallocation component. In the FHK decomposition, changes in cross-sectional allocation are measured by the correlation between changes in market shares and firm-level TFP. This component captures changes in allocative efficiency when goods are homogeneous and produced using a technology with constant returns to scale and only one input. However, in the more general case where goods are heterogeneous or the marginal productivity of one input is decreasing, reallocating resources towards high TFP firms could decrease aggregate output. In this case, aggregate productivity depends on the relative marginal productivity of the firms between which resources are reallocated and not on their relative TFP. The contribution of the extensive margin is also very different when the focus in on average rather than on aggregate productivity. In the FHK decomposition, the contribution of entry and exit depends on the relative TFP of entering an exiting firms. Compared to equation (14), the FHK component does not take into account the impact of the distortions face by entering and exiting firms on aggregate productivity growth. Furthermore, this measure does not capture the impact of entry and exit on the total number of firms in the industry. When firms use a decreasing returns to scale technology or when consumers have a love for variety, entry and exit flows affect aggregate productivity not only through a composition effect, but also trough their impact on the number of firms. My decomposition also differs from the existing literature as I model the distortions that generate production inefficiencies and measure the effect of changes in those distortions on aggregate productivity. By contrast, the FHK decomposition examines the impact of changes in input shares. This difference affects both the reallocation component and the within-firm productivity component. While the latter is computed holding fixed the input shares in FHK, I compute the contribution of firm-level productivity changes holding fixed the level of allocative efficiency. Note that when resources are efficiently allocated, the difference between the within-firm components vanishes (cf. equation (12')).

4 Estimation

Aggregate and sectoral productivity growth can be computed directly from aggregate data. However, estimating the decomposition given by equation (16) requires the use of firm-level data. First, the firm-level efficiency, allocative efficiency and extensive margin components are computed at the sectoral level using equations (12) to (14). Then the within-sector components are aggregated at the macro level as described by equation (17) to (19). The change in between-sector allocative efficiency is computed with equation (20). In this section, I present the data used, the estimation strategy and the results of this decomposition estimated on French firm-level data.

4.1 Data description

Following the bulk of the literature, I investigate the dynamics of aggregate productivity in the manufacturing industry. The data used in this analysis are collected every year by the French tax administration, and combined with survey data in the INSEE unified system for business statistics (SUSE). I use the database of private businesses that declare their profits under the "normal" regime (*Bénéfice réel normal*) from 1989 to 2007. In 2003, the "normal" regime accounted for 24.4 % of firms and 94.3% of total sales. Firms are required to provide balance sheet data, which includes measures of the firms' value added, expenditures on capital and number of employees. I use sectoral value added price indexes to deflate firm-level value added and reconstruct the real capital stock using the perpetual inventory method.

Potential entries and exits are detected by following firms with at least one employee that appear in and disappear from the database.[16] Since firms are followed through their identification number (SIREN), they appear and disappear from the database not only when they actually open or shut down their businesses, but also in case of restructuring or takeover as this induces a change in their identification number. Entry and exit rates are therefore likely to be overestimated. I try to limit this bias by excluding firms that disappear or appear with a number of employees higher

[16]Note that entering flows are likely to be overestimated as firms appear in the database when they cross the sales threshold of 763 000 euros above which the *Bénéfice réel normal* regime is mandatory. However, these spurious entry flows are likely to be limited as the "normal" tax regime is widely chosen by firms which are below the threshold: in 2003, 46% of the sample was below the sales threshold. Furthermore the dataset covers a lot of small firms, in 2003 71% of the sample (restricted to firms with at least one employee) had less than 20 employees

than the 99.8 percentile among exiting and entering firms[17]. Furthermore, to avoid spurious entry or exit flows induced by missing values, firms that temporarily move below the threshold of one employee, or temporarily disappear from the database are excluded. The procedure used for excluding temporary exits is likely to overestimate the entry rate in the first years of the sample, and overestimate the exit rate in the last years of the sample. Since about 75% of the firms that temporarily disappear from the database are absent only one year, dropping the first and the last year of the sample considerably reduces the amount of spurious entry and exit flows. I therefore remove the first two years (entry cannot be identified in the first year) and the last year of the sample, and undertake the analysis over the period 1991-2006. I also remove outliers as the decomposition is quite sensitive to extreme values[18]. After this trimming procedure, the dataset is constituted by about 126 000 observations each year. Figure A.1 in appendix D, shows that the aggregate value added is not affected much by this trimming procedure and that it compares quite well with the national accounts data. Appendix D also provides a more detailed description of the data and the sources.

4.2 Estimation method

To implement the decomposition, I need estimates of firm-level and aggregate factor elasticities, firm-level and sectoral distortions, and firm-level productivity. In the following, I present the issues that arise and the assumptions required to estimate these parameters.

4.2.1 Estimation of production functions

The firm-level productivity estimates are likely to suffer from the traditional bias linked to unobserved factor utilization[19]. I leave aside this well-known measurement issue and focus here on the specific issues that arise in the presence of heterogeneity in factor elasticities and unobserved allocation frictions. First, I show that the standard growth accounting approach gives a biased measure of aggregate factor elasticities when the underlying factor elasticities are heterogeneous. Second, I investigate the biases induced by unobserved micro frictions.

[17] This correspond to firms appearing in or disappearing from the database with about 1000 employees. Despite this correction, the entry and exit rates are likely to be overestimated since the threshold is quite high in light of the median size of target firms. Using French data over the period 2000-2004, Bunel et al. (2009) find a median size between 30 and 87 employees, depending on the exact nature of the restructuring operation. Note however that the average entry and exit rates displayed in Table A.1 are in line with what has been found for the US manufacturing sector (Dunne et al., 1989).

[18] Firms whose TFP is multiplied or divided by 2.5 are excluded from the analysis.

[19] As emphasized in section 2.2.1, another bias comes from the absence of firm-level data which leads firm-level productivity estimates to combine both demand and technical efficiency components.

Heterogeneity bias

To isolate the effects of the heterogeneity bias from the biases generated by market imperfections, let us assume that resources are perfectly allocated across firms ($\tau_{it}^K = \tau_{it}^L = 0$ for all i), and that firms behave competitively ($\theta_s = 1$, for all $s = 1, ...S$). In that case, the aggregate capital and labor elasticity are both a combination of capital and labor elasticities. In particular, when the decreasing to scale and the demand parameters are identical across sectors ($\gamma_s = \gamma$ for all $s = 1, ...S$), the aggregate elasticities are given by:

$$\varepsilon_K(\widetilde{\alpha}, \widetilde{\beta}) = \frac{\alpha^Y(1-\alpha^L) - \beta^Y\alpha^L}{1-\alpha^L-\beta^K} \text{ and } \varepsilon_L(\widetilde{\alpha}, \widetilde{\beta}) = \frac{\beta^Y(1-\beta^K) - \alpha^Y\beta^K}{1-\alpha^L-\beta^K}, \tag{23}$$

with $\alpha^X = \sum_s \frac{X_s}{X}\alpha_s$ and $\beta^X = \sum_s \frac{X_s}{X}\beta_s$ for $X = PY, K, L$.

Standard growth accounting method yield $\widehat{\varepsilon_K} = rK/PY$ and $\widehat{\varepsilon_L} = wL/PY$. Using equation (1) and (2), we find:

$$\widehat{\varepsilon_K} = \alpha^Y \text{ and } \widehat{\varepsilon_L} = \beta^Y,$$

which is different from the actual elasticity. Though there are no market imperfections, the Solow residual does not properly measure aggregate productivity changes when factor elasticities are heterogeneous. Aggregate elasticities are therefore computed using equations (23).

Unobserved micro distortions

There is no heterogeneity bias when using the Solow residual at the firm-level. However, because of the presence of allocation distortions, the growth accounting approach cannot be used at the firm-level for it is not possible to identify separately the factor elasticities from the firm-level distortions (equations 1 and 2).[20] I use the assumption that factor elasticities are identical within sectors, and estimate the firms' production functions using growth accounting at the sectoral level. To derive an estimate for $\beta_s\theta_s$, I use equation (2) aggregated over firms and over time :

$$\beta_s\theta_s\frac{1}{T}\sum_t \frac{1}{(1+\omega_{st}^L)} = \frac{1}{T}\sum_t \frac{w_t L_{st}}{P_{st}Y_{st}}$$

In order to identify the factor elasticity, I assume that the average labor sectoral distortions are

[20] Note that the presence of unobserved allocation distortion also rules out the use of standard semi-parametric methods such as Olley Pakes or Levinshon Petrin. These methods, which consists in using a proxy for productivity, can accommodate only a unique unobservable state variable. In the present framework, firms decisions depend on productivity, but also on capital and labor distortions, which raise to three the number of unobservable state variables.

null over the period considered.[21] This assumption may bias the estimates of the factor elasticities but has no impact on the contribution of firm-level distortions to aggregate productivity. As shown in the next subsection, what matters for aggregate productivity growth is the change in the relative level of distortions and not in their absolute level. The elasticity of demand is pinned down using estimates of the elasticity of substitution between goods. For simplicity, I assume that the elasticity is identical across sectors. I set $\theta = 0.8$, which corresponds to an elasticity of substitution between goods of 5, in line with Broda and Weinstein (2006) estimates.[22] Finally, capital elasticities are derived by assuming constant return to scale in each sector $\alpha_s = 1 - \beta_s$. Once the factor elasticities are known, firm-level productivities can be estimated from output and input levels using equation (5).

4.2.2 Estimation of firm-level distortions

Firm-level distortions (τ_i^K, τ_i^L) are computed as the wedge between the marginal productivity of labor and capital and factor prices (equations (1) and (2)). Firm-level distortions are therefore sensitive to factor prices, which are known to be difficult to measure. Luckily, both changes in sectoral and aggregate TFP do not depend on the absolute level of distortions, but only on changes in relative distortions. Hence, the value chosen for factor prices has no impact on aggregate TFP growth and on its decomposition. To illustrate this point, suppose that we use biased measures of factor prices ($\hat{r}_t \neq r_t$ and $\hat{w}_t \neq w_t$) to measure firm-level distortions. This leads to the following biased measures:

$$\begin{aligned} 1 + \widehat{\tau_{it}^K} &= (1 + \tau_{it}^K)\frac{r_t}{\widehat{r_t}} \\ 1 + \widehat{\tau_{it}^L} &= (1 + \tau_{it}^L)\frac{w_t}{\widehat{w_t}} \end{aligned}$$

Using equation (10), it can be shown that the obtained measure of sectoral TFP is unbiased despite the measurement errors on firm-level distortions.

$$\begin{aligned} \widehat{\mathrm{TFP}_{st}} &= \frac{(r_t/\widehat{r_t})^{\frac{-\alpha_s\theta_s}{1-\gamma\theta_s}} (w_t/\widehat{w_t})^{\frac{-\beta_s\theta_s}{1-\gamma\theta_s}}}{\left((r_t/\widehat{r_t})^{\frac{-(1-\beta_s\theta_s)}{1-\gamma\theta_s}} (w_t/\widehat{w_t})^{\frac{-\beta_s\theta_s}{1-\gamma\theta_s}}\right)^{\alpha_s\theta_s} \left((r/\widehat{r_t})^{\frac{-\alpha_s\theta_s}{1-\gamma\theta_s}} (w_t/\widehat{w_t})^{\frac{-(1-\alpha_s\theta_s)}{1-\gamma\theta_s}}\right)^{\beta_s\theta_s}} \mathrm{TFP}_{st} \\ &= \mathrm{TFP}_{st} \end{aligned}$$

At the aggregate level, we can show that this measurement error in factor prices has no impact on changes in aggregate productivity if the returns to scale and demand parameters are homogenous

[21] More specifically, it is the average of the inverse of sector specific distortions that is assumed to be zero. Actually assuming an average of zero leads to estimate $\beta_s\theta_s$ as $1/(\frac{1}{T}\sum_t \frac{P_{st}Y_{st}}{w_t L_{st}})$. The results are not affected to this choice

[22] For the 3-digit aggregation level, they report a mean of 6.8 over the period 1972-1988 and of 4 over the period 1990-2001.

across sectors ($\gamma_s = \gamma$ and $\theta_s = \theta$).The measured sectoral distortions read:

$$\begin{aligned}
\frac{d\widehat{\omega_t^K}}{1+\widehat{\omega_t^K}} &= \frac{d\omega_t^K}{1+\omega_t^K} + \frac{d(r_t/\widehat{r_t})}{r_t/\widehat{r_t}} \\
\frac{d\widehat{\omega_t^L}}{1+\widehat{\omega_t^L}} &= \frac{d\omega_t^L}{1+\omega_t^L} + \frac{d(w_t/\widehat{w_t})}{w_t/\widehat{w_t}}
\end{aligned}$$

Using equation (18) and replacing with the value of ε_K and ε_L, it comes:

$$\begin{aligned}
\Delta\widehat{\mathrm{AE}}_{\mathrm{between}} &= \Delta\overline{\mathrm{AE}}_{\mathrm{between}} + \frac{1}{1-\gamma\theta}\left(\varepsilon_K(1-\beta^K) + \varepsilon_L\alpha^L - \alpha^Y\right)\frac{d(r_t/\widehat{r_t})}{r_t/\widehat{r_t}} \\
&\quad + \frac{1}{1-\gamma\theta}\left(\varepsilon_K\beta^K + \varepsilon_K(1-\alpha^L) - \beta^Y\right)\frac{d(w_t/\widehat{w_t})}{w_t/\widehat{w_t}} \\
&= \Delta\overline{\mathrm{AE}}_{\mathrm{between}}
\end{aligned}$$

Therefore, the values chosen for factor prices have no impact on the measure of changes in aggregate and sectoral productivity.

4.3 Empirical results

In line with the rest of the literature, I implement the decomposition on the manufacturing industry.[23] First, I investigate the role of allocative efficiency, firm-level efficiency and the extensive margin in explaining the dynamics of productivity growth within sectors in the manufacturing industry. Then, I present the contribution of each component to the industry-wide productivity growth, and show the role of between-sector allocative efficiency. Finally, I compare these aggregate results to the standard decomposition used in the literature.

4.3.1 Decomposition at the sectoral and aggregate levels

Table 1 gives the average productivity growth for each sector as well as its decomposition in a firm-level efficiency, allocative efficiency and an extensive margin component. This decomposition is computed using the exact decomposition described in Appendix C. Over the period 1991-2006, average productivity grew by 2.3% in those sectors. Firm-level efficiency and allocative efficiency contribute both significantly to average TFP growth. While the contribution of firm-level efficiency is positive in virtually all sectors (+3.9 percentage points on average), changes in allocative efficiency tend to decrease sectoral productivity (-1.3 p.p.). By contrast, the contribution of the extensive margin appears to be negligible for most sectors. Entry and exit flows have increased sectoral productivity by an average of 0.1 percentage points. As shown in

[23] I dropped the electronic components sector as the estimation led to α<0.

Appendix E, net entry rates are positive and quite large (average of 2 p.p.) for most years, which tends to enhance aggregate productivity as the latter increases with the number of firms in the industry. This effect is however partially offset by the relatively small size of entrants, suggesting that entrants face either more distortion or have lower TFP than exiting firms. Figure A.2, A.3 and A.4 in Appendix E depict the TFP and distortion distributions of exiting and entering firms. These figures indicate that entrants are more productive than exiting firms, but that entering firms face higher distortions. This result is line with empirical studies that point to the existence of important financial constraints that hampers the development of new firms. These frictions limits the impact of entering firms on aggregate productivity. [24]

Table 1: Sectoral productivity decomposition, 1991-2006 average (in %)

Sector	ΔTFP_s	ΔTE_s	ΔAE_s	ΔEX_s
Food products*	0.54	0.09	1.01	-0.32
Wearing apparel and leather products	3.53	6.88	-3.97	1.10
Printing and reproduction	2.03	3.14	-0.84	0.15
Pharmaceutical and perfumes products	3.52	2.91	2.26	-0.11
Furniture	1.95	4.75	-2.74	0.14
Motor vehicle	0.29	2.59	-1.14	0.09
Other transportation equipment	2.97	8.33	-4.65	-0.06
Mechanical equipments*	2.94	4.08	-1.46	0.46
Mineral products	1.74	3.70	-1.75	0.10
Textiles	1.80	5.18	-3.64	0.58
Wood and paper products	1.79	2.77	-1.04	0.14
Rubber and plastics products*	4.95	5.60	-0.76	0.39
Fabricated metal products*	0.26	1.61	-1.35	0.15
Electronic products	6.26	8.54	-2.20	0.20
Weighted average	2.29	3.90	-1.33	0.13

Note: This table presents average sectoral productivity growth over the period 1991-2006, as well as the average level of its components. The first column gives the average sectoral productivity growth ΔTFP_s, the second column gives the average change in firm-level efficiency ΔTE_s, the third column gives the average change in allocative efficiency ΔAE_s, and the last column gives the average change in sectoral productivity due to the extensive margin ΔEX_s. Sectoral productivity has been computed using equation (10) and the components ΔTE_s , ΔAE_s and ΔEX_s have been computed using the formulas given in Appendix C. Because of approximation errors, the sum of the components is not exactly equal to sectoral productivity growth. Each sector denoted with * represents more than 10% of the total manufacturing industry value added.

Let us analyze the role of each of these components for the volatility of sectoral productivity growth. The variance of sectoral productivity growth can be computed as follows:

[24]Note also that we measure here only the impact of the extensive margin on the short run productivity. On the long run, the impact of entering firms could be higher if entering firms are characterized by a higher productivity growth rate.

$$V(\Delta\text{TFP}) = Cov(\Delta\text{TFP}, \Delta TE) + Cov(\Delta\text{TFP}, \Delta AE) + Cov(\Delta\text{TFP}, \Delta EX)$$

The contribution of firm-level efficiency is therefore measured as $Cov(\Delta\text{TFP}, \Delta TE)/V(\Delta\Delta\text{TFP})$[25]. It gives the variation in ΔTFP which is due to variations in within-firm productivity ΔTE, both directly and through its correlations with ΔEX and ΔAE. Correspondingly, the contribution of within-sector allocative efficiency and the extensive margin are measured as $Cov(\Delta\text{TFP}, \Delta AE)/V(\Delta\text{TFP})$ and $Cov(\Delta\text{TFP}, \Delta EX)/V(\Delta\text{TFP})$. Table 2 reports the contribution of each component to the volatility of sectoral TFP.

Table 2: Contribution to sectoral volatility, 1991-2006

Sector	Δ TFP stand. dev.	contribution to ΔTFP volatility		
		ΔTE_s	ΔAE_s	ΔEX_s
Food products*	2.36 %	1.26	-0.30	0.04
Wearing apparel and leather products	4.34 %	1.21	-0.33	0.12
Printing and reproduction	2.69 %	1.98	-1.05	0.07
Pharmaceutical and perfumes products	2.85 %	2.26	-1.20	-0.06
Furniture	2.66 %	0.91	0.01	0.08
Motor vehicle	9.35 %	1.54	-0.54	0.00
Other transportation equipment	5.98 %	1.47	-0.48	0.00
Mechanical equipments*	4.16 %	1.34	-0.39	0.05
Mineral products	3.74 %	1.36	-0.37	0.02
Textiles	3.96 %	1.00	-0.03	0.03
Wood and paper products	5.04 %	1.10	-0.09	-0.01
Rubber and plastics products*	3.72 %	1.38	-0.30	-0.07
Fabricated metal products*	6.39 %	1.15	-0.19	0.04
Electronic products	5.22 %	1.02	-0.09	0.07

Note: This table presents the contribution of each components to the volatility of sectoral productivity growth. The first column gives the standard deviation of sectoral productivity growth. The second column gives the contribution of firm-level efficiency (ΔTE_s) to the volatility of sectoral productivity growth. The third column gives the contribution of allocative efficiency (ΔAE_s), and the last column gives the contribution of the extensive margin (ΔEX_s). The contributions are computed as described in the text. The sum of the contribution of ΔTE_s, ΔAE_s and ΔEX_s equals 1. To avoid the discrepancies caused by approximation errors, the contributions to volatility have been computed with respect to the volatility of $(\Delta\text{TE}_s + \Delta\text{AE}_s + \Delta\text{EX}_s)$. Each sector denoted with * represents more than 10% of the total manufacturing industry value added.

Firm-level efficiency appears to be the main driver of sectoral productivity dynamics. In fact, changes in firm-level efficiency tend to exacerbate the volatility of sectoral productivity growth in many sectors. On the contrary, fluctuations in allocative efficiency dampen the movements in sectoral productivity growth. In absolute terms, the contribution of allocative efficiency is smaller

[25]Note that this is the parameter obtained when regressing ΔTE on ΔTFP. As noted by Fujita and Ramey (IER, 2009), this measure is conceptually equivalent to the beta used in finance.

than firm-level efficiency but still large. The extensive margin component plays a negligible role in the volatility of sectoral productivity growth in virtually all sectors.

Table 3: Correlation with sectoral value added growth, 1991-2006

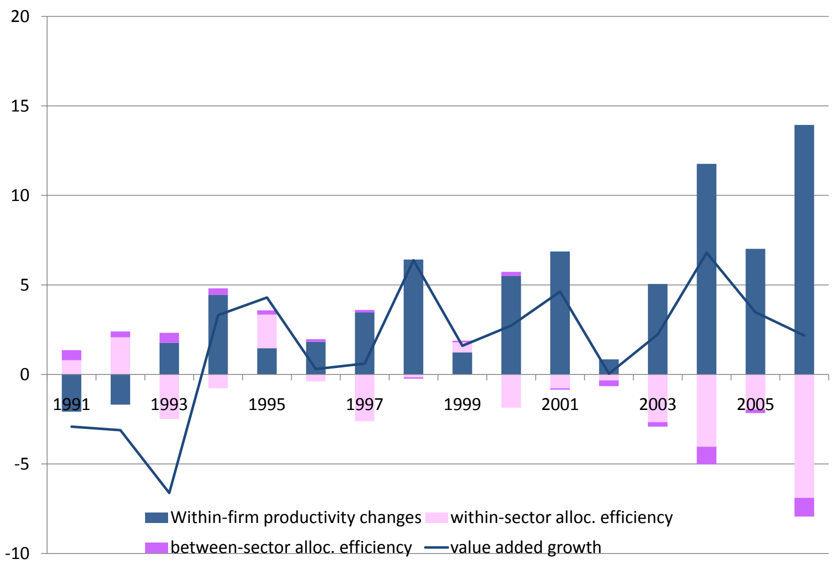
Sector	ΔTFP_s	ΔTE_s	ΔAE_s	ΔEX_s
Food products*	0.84	0.30	0.04	0.40
Wearing apparel and leather products	0.93	0.58	-0.10	0.81
Printing and reproduction	0.70	0.38	-0.18	0.46
Pharmaceutical and perfumes products	0.92	0.64	-0.46	-0.03
Furniture	0.84	0.47	0.11	0.31
Motor vehicle	0.84	0.54	-0.21	-0.17
Other transportation equipment	0.94	0.89	-0.66	0.09
Mechanical equipments*	0.91	0.80	-0.41	0.48
Mineral products	0.97	0.73	-0.31	0.28
Textiles	0.86	0.49	0.23	-0.21
Wood and paper products	0.96	0.86	-0.11	-0.01
Rubber and plastics products*	0.90	0.58	-0.08	-0.26
Fabricated metal products*	0.97	0.90	-0.34	0.35
Electronic products	0.89	0.82	-0.18	0.36

Note: This table presents the correlation of sectoral productivity growth and its components with real value added growth. The first column gives the correlation of sectoral productivity growth (ΔTFP_s) to real value added growth. The second column gives the correlation of firm-level efficiency (ΔTE_s). The third column gives the contribution of allocative efficiency (ΔAE_s), and the last column that of the extensive margin (ΔEX_s). Each sector denoted with * represents more than 10% of the total manufacturing industry value added.

Table 3 reports the correlation of aggregate productivity growth and each of its components with the sector's real value added growth. Sectoral TFP growth is highly correlated with changes in the sector's activity. The firm-level efficiency component also exhibits a positive, though smaller, correlation. In most sectors, the extensive margin component also is procyclical. This procyclicality contrasts with theories on the cleansing effect of recessions, according to which the higher exit rate of low productivity firms in recessions would enhance aggregate productivity. The results suggest that it is the reallocation of resources between continuing firms, and not between entering and exiting firms, that tends to raise aggregate productivity during recessions: for most sectors, allocative efficiency is countercyclical.

Figure 1 and 2 present the results at the aggregate level computed using equations (17) to (20) (the numbers are provided in Appendix D). These figures, which also display the value added growth of the entire manufacturing industry, complete the picture given by sectoral data. They give the aggregate values of within-sector firm-level efficiency, allocative efficiency and extensive margin, as well as the contribution of inter-sectoral allocative efficiency. Similarly to what we found at the sectoral level, changes in within-firm productivity growth and in allocative efficiency are the main determinants of aggregate productivity growth. Allocative efficiency lowers aggregate productivity growth by 1.2 percentage point and reduces its volatility by 51%. Figure 1 and 2 illustrate that the variation of aggregate productivity induced by the extensive margin is indeed negligible compared to the other components. While the firm-level efficiency component is procyclical, the overall allocative efficiency component is countercyclical. Their correlation with the manufacturing industry's value added is respectively 0.64 and -0.25. Note that the between-sector allocative efficiency is more procyclical (-0.55) than within-sector allocative efficiency (-0.17). Figure A.6 and A.7 in Appendix E show that the overall picture is not modified when a higher elasticity of substitution between goods is chosen (equal to 6).

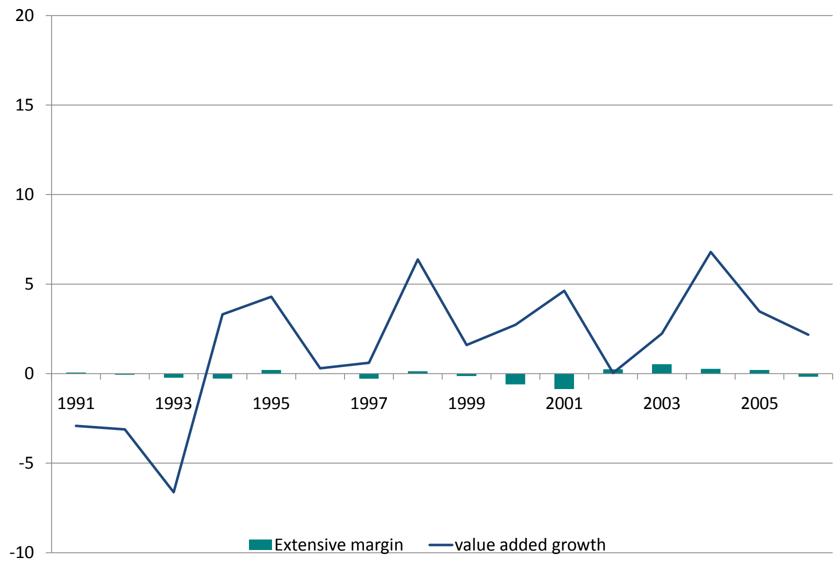
Figure 1: Firm-level productivity and allocative efficiency (manufacturing industry)



4.3.2 Comparison with the existing approach

I now show how these results differ from those obtained with the approach used in the existing literature. I find that using a consistent measure of aggregate productivity has important implications for our understanding of the behavior of allocative efficiency over the business cycle. I estimate the decomposition proposed by Foster, Haltiwanger and Krizan (hereafter FHK), described in section 3.3. Figure A.5 in Appendix D shows that the dynamics of *average* productivity given by the FHK measure is very close to that of *aggregate* productivity. The discrepancies are, however, substantial for the decompositions depicted in Figure 4.3.2 and 4.3.2 (numbers are provided in appendix E). The results are qualitatively similar to those obtained by FHK on the US

Figure 2: The extensive margin (manufacturing industry)



manufacturing sector. The cross term is the main determinant of the mean and the volatility of aggregate productivity growth. On average, the net entry component contributes positively and reallocation negatively to aggregate productivity growth. When compared with Figure 1 and 2, the year-to-year changes in the contribution of the extensive margin, within-firm productivity and reallocations are considerably different. In particular, entry and exit play a relatively larger role for aggregate productivity growth in the FHK decomposition. Computed in absolute values, the contribution of entry and exit is about 2 times lower than that of input reallocations in the FHK decomposition, and 7 times lower using my decomposition. Furthermore, the cyclical properties of the reallocation component are at odds with my findings. While my results indicate a countercyclical allocation efficiency, the reallocation component is here positively correlated with value added growth (correlation of 0.19). All in all, these results illustrate that average productivity is not a good proxy to study the consequences of resource reallocation on aggregate productivity.

5 Conclusion

This paper proposes a novel approach to analyze the micro determinants of aggregate productivity dynamics. After deriving aggregate productivity from the aggregation of firm-level production functions, I show how to decompose aggregate productivity into changes in firm-level efficiency,

Figure 3: The FHK decomposition

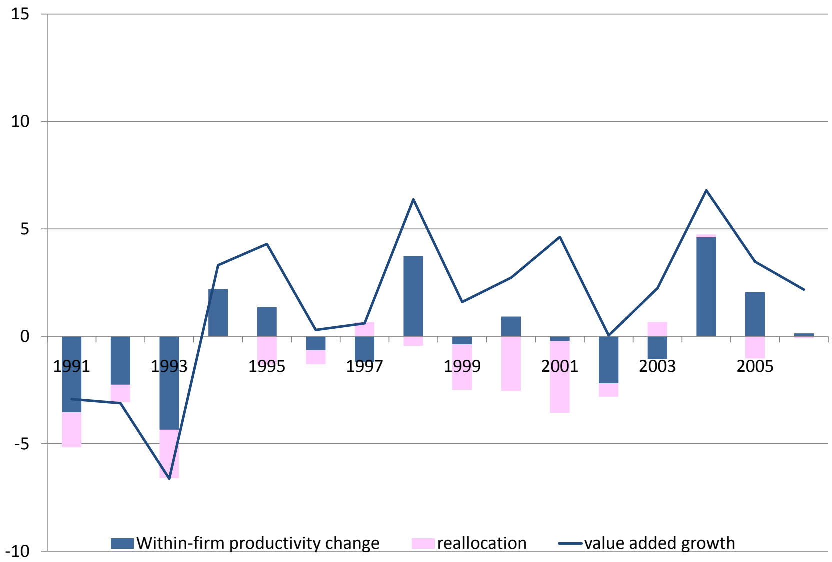
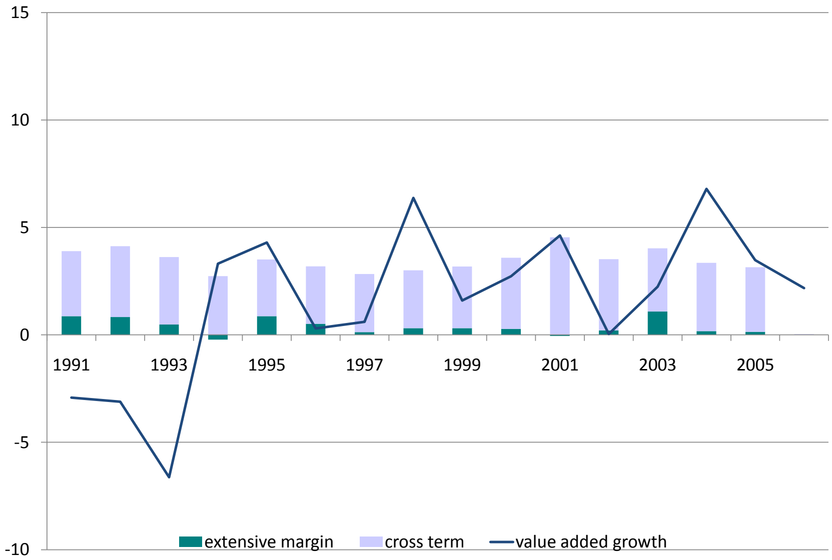


Figure 4: The FHK decomposition



changes in allocative efficiency and changes induced by entry and exit flows. Contrary to both existing empirical and theoretical works that emphasize the role of entry and exit for aggregate productivity growth, this paper shows that the extensive margin plays a negligible role in the dynamics of aggregate productivity growth and highlights the contribution of changes in the efficiency of resource allocation across firms. I show that changes in allocative efficiency are countercyclical and tend to stabilize the movements in aggregate productivity growth. Furthermore, I find no evidence in support of the cleansing effect of recession as the extensive margin component is not only small but also procyclical. However, it must be emphasized that these results give only the contemporaneous impact of entry and exit on aggregate productivity growth. The effects of entry and exit flows on long run productivity growth are not captured in this paper. New firms have a small contribution to aggregate productivity growth in the year they enter, but may have a large contribution on the long run if they have a higher productivity growth than incumbent and exiting firms.

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Appendix A: Separability of the aggregate production function

This appendix gives sufficient conditions for the separability of the aggregate production function with respect to firm-level productivity. Consider an economy with N heterogenous production units using a Cobb-Douglas technology : $Y_i = A_i K^{a_i} L^{b_i}$. There exists a real-valued function ψ such that the aggregate production function can be written:

$$Y = \text{TFP } F(K, L),$$

with TFP $= \psi(A_1, ..., A_N)$, $Y = \sum_{i=1}^{N} Y_i$, $K = \sum_{i=1}^{N} K_i$ and $L = \sum_{i=1}^{N} L_i$,
if the two following conditions are satisfied:

i. firms have the same factor elasticities:
$a_i = a$ and $b_i = b$, for all $i = 1, ..., N$

ii. the individual factor demand functions are of the form[26]:

$$X_i = \phi^X(r_t, w_t) g_i^X(A_i) \qquad \text{with } X = K, L$$

Proof: *Using the individual demand function, we can write:*

$$\begin{aligned} K_i &= \frac{g_i^K(A_i)}{\sum_{i=1}^{N} g_i^K(A_i)} K \\ L_i &= \frac{g_i^L(A_i)}{\sum_{i=1}^{N} g_i^L(A_i)} L \end{aligned}$$

The aggregate production function is then:

$$Y = \left(\frac{g_i^K(A_i)}{\sum_{i=1}^{N} g_i^K(A_i)} \right)^a \left(\frac{g_i^L(A_i)}{\sum_{i=1}^{N} g_i^L(A_i)} \right)^b K^a L^b.$$

With the factor demand functions given by equations (3) and (4), the equality of factor and demand elasticities ensure the separability of the input demand equations, and consequently that of the aggregate production function.

[26]In the more general case of CES productions functions, the decision rules of the firm must be such that the capital labor ratio is independent of firm level productivity. Formally, the aggregation of firm level TFP requires $g_i^K(A_i) = g^L(A_i) \equiv g(A_i)$. The aggregate production function reads:

$$Y = \underbrace{\sum A_i \left(\frac{g_i(A_i)}{\sum g_i(A_i)} \right)^\gamma}_{\text{TFP}} \left[\alpha K^\theta + \beta L^\theta \right]^{\frac{\gamma}{\theta}}$$

Appendix B: Deriving the sectoral aggregate production function

In this appendix, I derive explicitly the sectoral production functions. Using equations (6) and (7), we can write:

$$
\begin{aligned}
K_{it} &= \left(\frac{A_i^{\frac{1}{1-\gamma\theta_s}} (1+\tau_i^K)^{-\frac{1-\beta_s\theta_s}{1-\gamma\theta_s}} (1+\tau_i^L)^{-\frac{\beta_s\theta_s}{1-\gamma\theta_s}}}{\sum A_i^{\frac{1}{1-\gamma\theta_s}} (1+\tau_i^K)^{-\frac{1-\beta_s\theta_s}{1-\gamma\theta_s}} (1+\tau_i^L)^{-\frac{\beta_s\theta_s}{1-\gamma\theta_s}}} \right) K_{st} \\
L_{it} &= \left(\frac{A_i^{\frac{1}{1-\gamma\theta_s}} (1+\tau_i^K)^{-\frac{\alpha_s\theta_s}{1-\gamma\theta_s}} (1+\tau_i^L)^{-\frac{1-\alpha_s\theta_s}{1-\gamma\theta_s}}}{\sum A_i^{\frac{1}{1-\gamma\theta_s}} (1+\tau_i^K)^{-\frac{\alpha_s\theta_s}{1-\gamma\theta_s}} (1+\tau_i^L)^{-\frac{1-\alpha_s\theta_s}{1-\gamma\theta_s}}} \right) L_{st}
\end{aligned}
$$

and the sectoral production function is then:

$$
F_s(K_{st}, L_{st}, \widetilde{A}_{st}, \widetilde{\tau}_{st}) = \sum_i A_{it} \left(\frac{g_s^K(A_{it}, \tau_{it})}{\sum_i g_s^K(A_{it}, \tau_{it})} K_{st} \right)^{\alpha_s\theta_s} \left(\frac{g_s^K(A_{it}, \tau_{it})}{\sum_i g_s^K(A_{it}, \tau_{it})} L_{st} \right)^{\beta_s\theta_s}
$$

which can be written

$$
F_s(K_{st}, L_{st}, \widetilde{A}_{st}, \widetilde{\tau}_{st}) = \mathrm{TFP}_{st} K_{st}^{\alpha_s\theta_s} L_{st}^{\beta_s\theta_s}
$$

Hence, sectoral TFP is a function of both firm-level productivity $\widetilde{A}_{st}$ and distortions $\widetilde{\tau}_{st}$:

$$
\mathrm{TFP}_{st} = \frac{\sum_{i=1}^{N_s} g_s^Y(A_{it}, \tau_{it})}{\left(\sum_{i=1}^{N_s} g_s^K(A_{it}, \tau_{it})\right)^{\alpha_s\theta_s} \left(\sum_{i=1}^{N_s} g_s^L(A_{it}, \tau_{it})\right)^{\beta_s\theta_s}}.
$$

where the g functions are given by:

$g_s^Y(A_{it}, \tau_{it}) = A_i^{\frac{1}{1-\gamma\theta_s}} (1+\tau_i^K)^{-\frac{\alpha_s\theta_s}{1-\gamma\theta}} (1+\tau_i^L)^{-\frac{\beta_s\theta_s}{1-\gamma\theta_s}}$

$g_s^K(A_{it}, \tau_{it}) = A_i^{\frac{1}{1-\gamma\theta_s}} (1+\tau_i^K)^{-\frac{1-\beta_s\theta_s}{1-\gamma\theta_s}} (1+\tau_i^L)^{-\frac{\beta_s\theta_s}{1-\gamma\theta_s}}$

$g_s^L(A_{it}, \tau_{it}) = A_i^{\frac{1}{1-\gamma\theta_s}} (1+\tau_i^K)^{-\frac{\alpha_s\theta_s}{1-\gamma\theta_s}} (1+\tau_i^L)^{-\frac{1-\alpha_s\theta_s}{1-\gamma\theta_s}}$

Appendix C: Decomposition of sectoral and aggregate productivity: exact and approximate formulas

This appendix presents the decomposition of sectoral TFP. First, I describe the method and show how changes in sectoral TFP can be approximated. Then, I give the formulas for the exact decomposition.

From equation (10), the change in sectoral aggregate productivity can be computed as:

$$\frac{\Delta \mathrm{TFP}_{st}}{\mathrm{TFP}_{st}} \simeq \ln\left(\frac{\sum g_s^Y(A_{it},\tau_{it})}{\sum g_s^Y(A_{it-1},\tau_{it-1})}\right) - \alpha_s\theta_s \ln\left(\frac{\sum g_s^K(A_{it},\tau_{it})}{\sum g_s^K(A_{it-1},\tau_{it-1})}\right) - \beta_s\theta_s \ln\left(\frac{\sum g_s^L(A_{it},\tau_{it})}{\sum g_s^L(A_{it-1},\tau_{it-1})}\right)$$

Sectoral TFP growth can then be decompose into changes in within-firm productivity ($\Delta\mathrm{TE}_s$), changes in allocative efficiency ($\Delta\mathrm{AE}_s$) and changes in the extensive margin ($\Delta\mathrm{EX}_s$), by decomposing each component as follows:

$$\ln\frac{\sum g_s^Y(A_{it},\tau_{it})}{\sum g_s^Y(A_{it-1},\tau_{it-1})} = \underbrace{\ln\frac{\sum_{i\in C_s} g_s^Y(A_{it},\tau_{it-1})}{\sum_{i\in C_s} g_s^Y(A_{it-1},\tau_{it-1})}}_{\Delta\mathrm{TE}_Y} + \underbrace{\ln\frac{\sum_{i\in C_s} g_s^Y(A_{it},\tau_{it})}{\sum_{i\in C_s} g_s^Y(A_{it},\tau_{it-1})}}_{\Delta\mathrm{AE}_Y} + \underbrace{\ln\frac{1-\frac{\sum_{i\in X_s} g_s^Y(A_{it-1},\tau_{it-1})}{\sum_{i=1}^{N_{t-1}} g_s^Y(A_{it-1},\tau_{it-1})}}{1-\frac{\sum_{i\in E_s} g_s^Y(A_{it},\tau_{it})}{\sum_{i=1}^{N_t} g_s^Y(A_{it},\tau_{it})}}}_{\Delta\mathrm{EX}_Y}$$

with C_s is the set of continuing firms ($I_{it-1} \geq 0$ and $I_{it} \geq 0$), E_s the set of new entrants ($I_{it-1} < 0$ and $I_{it} \geq 0$) and X_s the set of exiting firms ($I_{it-1} \geq 0$ and $I_{it} < 0$) in sector s. Aggregate productivity growth can then be expressed as:

$$\frac{\Delta \mathrm{TFP}_{st}}{\mathrm{TFP}_{st}} \simeq \Delta\mathrm{TE}_s + \Delta\mathrm{AE}_s + \Delta\mathrm{EX}_s,$$

where the within-firm productivity component is defined as $\Delta\mathrm{TE}_s = \Delta\mathrm{TE}_Y - \alpha_s\theta_s\Delta\mathrm{TE}_K - \beta_s\theta_s\Delta\mathrm{TE}_L$, and the allocative efficiency $\Delta\mathrm{AE}_s$ and the extensive margin $\Delta\mathrm{EX}_s$ components are symmetrically defined.

The decomposition between changes in within-firm productivity and changes in allocative efficiency is similar to the decompositions we can find in the index number literature. In the expression given above the effects of within-firm productivity changes are measured with a Laspeyres-like index, while those of allocative efficiency ($\Delta\mathrm{AE}_Y$) are measured with a Paasche-like index. Using the expressions for g_s^Y, g_s^K and g_s^L, together with the approximation $ln(1+x) \simeq x$ yield the expression given in equations (12) to (14).

For simplicity, the main text only provides approximations. Let us now derive the exact formulas used to estimate the decomposition. The change in TFP can be broken down into three components.

$$\frac{\mathrm{TFP}_{st}}{TFP_{st-1}} = ITE\ IAE\ IEX$$

The extensive margin component is measured as follows:

$$IEX = \frac{\frac{1-\sum_{X_s} \frac{P_{it-1}Y_{it-1}}{P_{st-1}Y_{t-1}}}{1-\sum_{E_s} \frac{P_{it}Y_{it}}{P_{st}Y_t}}}{\left(\frac{1-\sum_{X_s} \frac{K_{it-1}}{K_{t-1}}}{1-\sum_{E_s} \frac{K_{it}}{K_t}}\right)^{\alpha_s\theta_s} \left(\frac{1-\sum_{X_s} \frac{L_{it-1}}{L_{t-1}}}{1-\sum_{E_s} \frac{L_{it}}{L_t}}\right)^{\beta_s\theta_s}}$$

To avoid any asymmetry induced by the functional form of the indexes, I measure the firm-level and allocative efficiency component with a Fisher-like index, i.e. the geometric mean of the Laspeyres-like and Paasche-like indexes. The Fisher-like index for within-productivity changes is computed as follows:

$$ITE = ITE0^{0.5} ITE1^{0.5}$$

where

$$ITE0 = \frac{\sum \left(\frac{A_{it}}{A_{it-1}}\right)^{\frac{1}{1-\gamma\theta_s}} \frac{p_{it}Y_{it-1}}{\sum p_{it}Y_{it-1}}}{\left[\sum \left(\frac{A_{it}}{A_{it-1}}\right)^{\frac{1}{1-\gamma\theta_s}} \frac{K_{it-1}}{\sum K_{it-1}}\right]^{\alpha_s\theta_s} \left[\sum \left(\frac{A_{it}}{A_{it-1}}\right)^{\frac{1}{1-\gamma\theta_s}} \frac{L_{it-1}}{\sum L_{it-1}}\right]^{\beta_s\theta_s}}$$

$$ITE1 = \frac{\left[\sum \left(\frac{A_{it-1}}{A_{it}}\right)^{\frac{1}{1-\gamma\theta_s}} \frac{K_{it}}{\sum K_{it}}\right]^{\alpha_s\theta_s} \left[\sum \left(\frac{A_{it-1}}{A_{it}}\right)^{\frac{1}{1-\gamma\theta_s}} \frac{L_{it}}{\sum L_{it}}\right]^{\beta_s\theta_s}}{\sum \left(\frac{A_{it-1}}{A_{it}}\right)^{\frac{1}{1-\gamma\theta_s}} \frac{p_{it}Y_{it}}{\sum p_{it}Y_{it}}}$$

The change in allocative efficiency is similarly computed. Then, each component of aggregate productivity growth is computed as $\Delta TE = ITE - 1$, $\Delta AE = IAE - 1$ and $\Delta EX = IEX - 1$.

I now provide some indications for the decomposition of aggregate productivity growth across sectors. The heterogeneity in elasticities makes the calculation more tedious. For simplicity, I will describe the method in the case where there is only one input ($\beta = 0$). In this case $Y = \sum_s \mathrm{TFP}_s K_s^{\alpha_s}$, with $K_s = K_s(P_s TFP_s, \omega_s, r)$

Taking the derivative with respect to TFP_s gives:

$$\frac{\partial F}{\partial \mathrm{TFP}_s}\frac{\mathrm{TFP}_s}{Y} = \sum_s \frac{Y_s}{Y}\frac{d\mathrm{TFP}_s}{\mathrm{TFP}_s} + \frac{\alpha_s}{1-\alpha_s}\frac{Y_s}{Y}\frac{d\mathrm{TFP}_s}{\mathrm{TFP}_s} + \alpha_s \frac{Y_s}{Y}\frac{\partial K_s}{\partial r}\frac{r}{K_s}\frac{dr}{r}$$

where dr/r is the change in interest rate induced by changes in firm-level efficiency holding fixed aggregate inputs and distortions. Using the implicit function theorem, this change can be computed as:

$$\begin{aligned} 0 &= -\sum_s \frac{1}{1-\alpha_s} K_s \frac{dr}{r} + \sum_s \frac{1}{1-\alpha_s} K_s \frac{d\mathrm{TFP}_s}{\mathrm{TFP}_s} \\ \frac{dr}{r} &= \frac{1}{\sum_s \frac{1}{1-\alpha_s} K_s} \sum_s \frac{1}{1-\alpha_s} K_s \frac{d\mathrm{TFP}_s}{\mathrm{TFP}_s} \end{aligned}$$

The derivative with respect to TFP_s can then be written:

$$\begin{aligned}\frac{\partial F}{\partial \text{TFP}_s}\frac{\text{TFP}_s}{Y} &= \sum_s \frac{1}{1-\alpha_s}\frac{Y_s}{Y} - \left(\frac{\sum_s \frac{\alpha_s}{1-\alpha_s}\frac{Y_s}{Y}}{\sum_s \frac{1}{1-\alpha_s}\frac{K_s}{K}}\right)\frac{1}{1-\alpha_s}\frac{K_s}{K}\frac{d\text{TFP}_s}{\text{TFP}_s} \\ &= \sum_s \frac{1}{1-\alpha_s}\left(\frac{Y_s}{Y} - \varepsilon_K \frac{K_s}{K}\right)\frac{d\text{TFP}_s}{\text{TFP}_s}.\end{aligned}$$

which gives the weights use in equations (17) to (19) with $\beta = \varepsilon_L = 0$. The changes in between-sector allocative efficiency and the factor elasticities are computed similarly. The latter are given by:

$$\begin{aligned}\varepsilon_K = &\left(\sum_s \frac{Y_s}{Y}\frac{\alpha_s}{1-\gamma_s\theta_s}\right)\frac{\sum_s \frac{1-\alpha_s\theta_s}{1-\gamma_s\theta_s}L_s}{\sum_s \frac{1-\alpha_s\theta_s}{1-\gamma_s\theta_s}L_s \sum_s \frac{1-\beta_s\theta_s}{1-\gamma_s\theta_s}K_s - \sum_s \frac{\beta_s\theta_s}{1-\gamma_s\theta_s}K_s \sum_s \frac{\alpha_s\theta_s}{1-\gamma_s\theta_s}L_s} \\ &+\left(\sum_s \frac{Y_s}{Y}\frac{\beta_s}{1-\gamma_s\theta_s}\right)\frac{\sum_s \frac{\alpha_s\theta_s}{1-\gamma_s\theta_s}L_s}{\sum_s \frac{\alpha_s\theta_s}{1-\gamma_s\theta_s}L_s \sum_s \frac{\beta_s\theta_s}{1-\gamma_s\theta_s}K_s - \sum_s \frac{1-\beta_s\theta_s}{1-\gamma_s\theta_s}K_s \sum_s \frac{1-\alpha_s\theta_s}{1-\gamma_s\theta_s}L_s}\end{aligned}$$

$$\begin{aligned}\varepsilon_L = &\left(\sum_s \frac{Y_s}{Y}\frac{\beta_s}{1-\gamma_s\theta_s}\right)\frac{\sum_s \frac{1-\beta_s\theta_s}{1-\gamma_s\theta_s}K_s}{\sum_s \frac{1-\alpha_s\theta_s}{1-\gamma_s\theta_s}L_s \sum_s \frac{1-\beta_s\theta_s}{1-\gamma_s\theta_s}K_s - \sum_s \frac{\beta_s\theta_s}{1-\gamma_s\theta_s}K_s \sum_s \frac{\alpha_s\theta_s}{1-\gamma_s\theta_s}L_s} \\ &+\left(\sum_s \frac{Y_s}{Y}\frac{\alpha_s}{1-\gamma_s\theta_s}\right)\frac{\sum_s \frac{\beta_s\theta_s}{1-\gamma_s\theta_s}K_s}{\sum_s \frac{\alpha_s\theta_s}{1-\gamma_s\theta_s}L_s \sum_s \frac{\beta_s\theta_s}{1-\gamma_s\theta_s}K_s - \sum_s \frac{1-\beta_s\theta_s}{1-\gamma_s\theta_s}K_s \sum_s \frac{1-\alpha_s\theta_s}{1-\gamma_s\theta_s}L_s}\end{aligned}$$

Appendix D: Data

Data used are collected by the French tax administration and controlled for inconsistencies and combine with the responses to the annual business surveys in the INSEE unified system for business statistics (SUSE). I consider firms that declare under the “normal" regime (SUSE-BRN) from 1989 to 2007. This tax regime is mandatory for firms with sales above 763 000 euros (230 000 in the service sector), but is also widely chosen by firms which are below the threshold: in 2003 46% of the sample restricted to the manufacturing sector had sales below 763 000 euros. As described in section 4.2, this dataset is corrected for spurious entry and exit flows, as well as for outliers in terms of productivity growth.

Description of variables

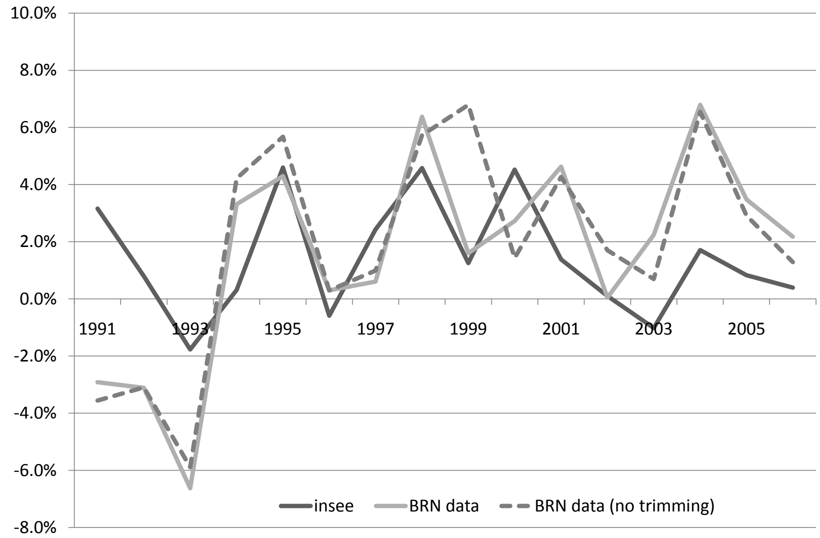
Output: gross value added less operating subsidies plus taxes, deflated by the NES36 sectoral price index published by the national accounts (INSEE, base 2000).

Labour: average number of employees over the year.

Capital: constructed using the perpetual inventory method. Real capital stock are computed from the previous period undepreciated stock and the period’s real investment in tangible and intangible assets. I use a linear sector-specific depreciation rate, based on Sylvain (2003) estimates of equipments life span. The the NES36 sectoral investment deflator is derived from the national accounts (INSEE, base 1995 and 2000). As Dunne et al. (1989), the initial year capital stock is estimated by assuming that the firm’s relative real capital stock is equal to its relative book value of assets.

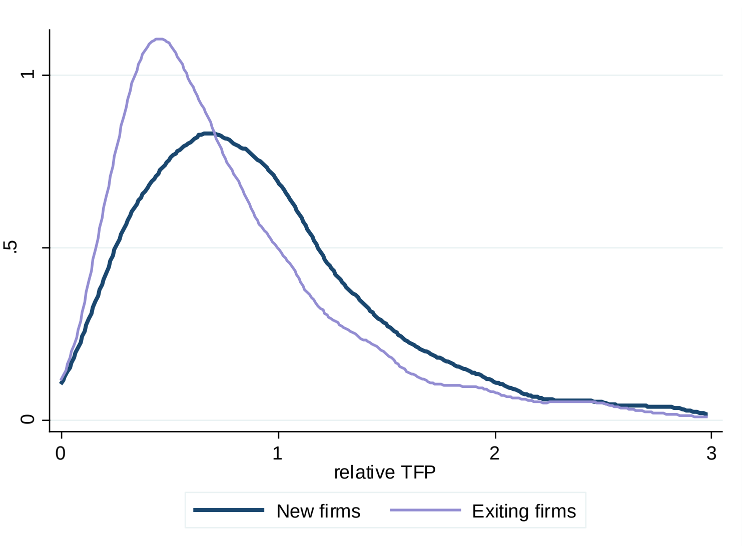
Sectoral labor share: computed at the N36 level from BRN data as 1- ratio of the sectoral gross operating surplus over value added.

Figure A.1: Growth of real value added in the manufacturing industry: national accounts vs SUSE-BRN



Appendix E: Additional tables and figures

Figure A.2: New firms vs exiting firms: relative TFP density



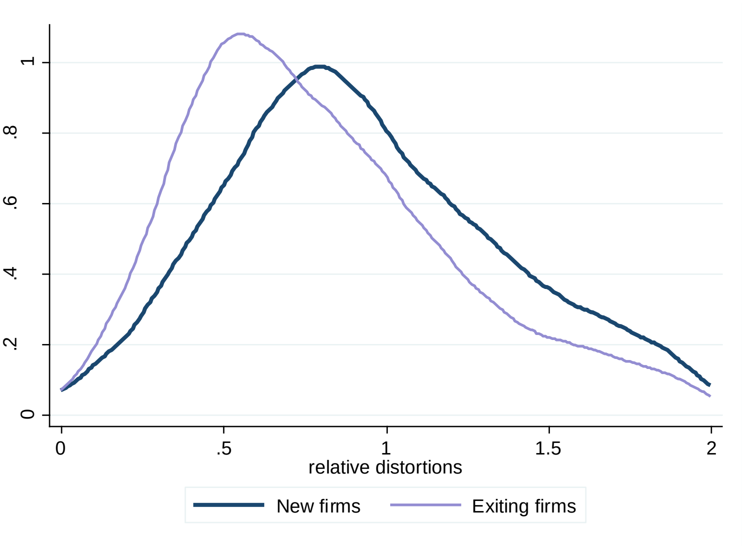
Note: computed in 2000 for the whole manufacturing industry, relative to the median TFP value

Table A.1: Entry and Exit rates in the manufacturing industry

	Entry rate	Exit rate	Entry rate (empl.weighted)	Exit rate (empl.weighted)
1991	0.125	0.158	0.044	0.057
1992	0.134	0.170	0.037	0.062
1993	0.212	0.267	0.052	0.085
1994	0.161	0.120	0.048	0.054
1995	0.106	0.114	0.041	0.046
1996	0.095	0.099	0.037	0.048
1997	0.115	0.088	0.041	0.040
1998	0.082	0.073	0.032	0.037
1999	0.080	0.076	0.031	0.039
2000	0.096	0.081	0.035	0.041
2001	0.099	0.099	0.042	0.043
2002	0.081	0.057	0.031	0.038
2003	0.077	0.069	0.030	0.036
2004	0.077	0.067	0.031	0.034
2005	0.080	0.063	0.027	0.034
2006	0.084	0.065	0.029	0.034
average	0.107	0.104	0.037	0.045

Note: This table presents entry and exit rate and their employment weighted counterparts. Note that the data are corrected for temporary exits and outliers as described in section 4.1

Figure A.3: New firms vs exiting firms: relative labor distortions density



Note: computed in 2000 for the whole manufacturing industry, relative to the median distortion value

Table A.2: Decomposition of the manufacturing industry TFP growth

	ΔTFP	$\Delta\overline{\text{TE}}$	$\Delta\overline{\text{AE}}_{\text{within}}$	$\Delta\overline{\text{EX}}$	$\Delta\overline{\text{AE}}_{\text{between}}$
1991	-0.92	-2.08	0.80	0.06	0.56
1992	0.32	-1.69	2.08	-0.06	0.33
1993	-1.92	1.77	-2.49	-0.23	0.56
1994	4.74	4.44	-0.77	-0.28	0.36
1995	4.01	1.46	1.88	0.21	0.24
1996	1.17	1.82	-0.39	0.00	0.15
1997	0.65	3.46	-2.61	-0.28	0.14
1998	6.24	6.42	-0.16	0.13	-0.08
1999	1.57	1.23	0.57	-0.13	0.09
2000	1.95	5.50	-1.86	-0.60	0.22
2001	2.97	6.87	-0.78	-0.86	-0.08
2002	0.13	0.85	-0.33	0.25	-0.32
2003	2.29	5.05	-2.67	0.53	-0.25
2004	7.28	11.76	-4.04	0.26	-0.98
2005	4.73	7.02	-1.96	0.21	-0.19
2006	2.90	13.94	-6.89	-0.17	-1.05

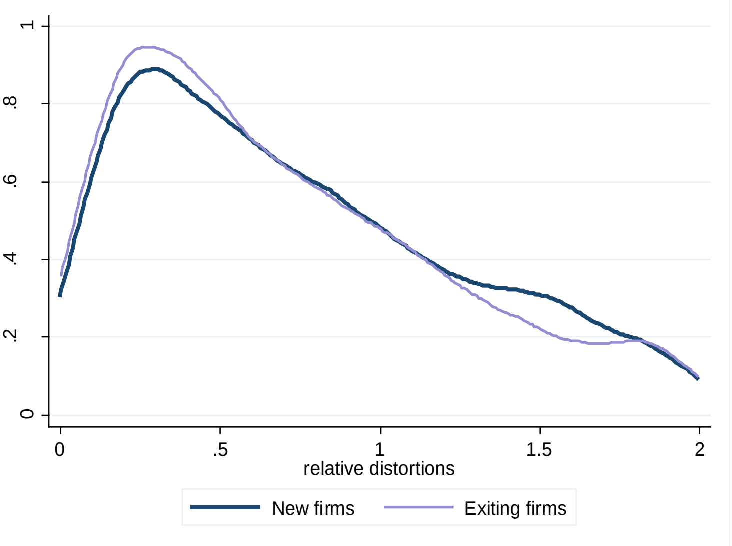
Note: This table presents the decomposition of productivity growth in the manufacturing industry (ΔTFP) into a aggregate firm-level efficiency component ($\Delta\overline{\text{TE}}$), an aggregate within-sector allocative efficiency component ($\Delta\overline{\text{AE}}_{\text{within}}$), an aggregate extensive margin component ($\Delta\overline{\text{EX}}$) and a between-sector allocative efficiency component ($\Delta\overline{\text{AE}}_{\text{between}}$). The aggregate productivity growth has been computed using equation (**??**) and its components have computed using equations (17) to (20). Because of approximation errors, the sum of the components does not exactly equal changes in aggregate TFP.

Table A.3: Decomposition of the manufacturing industry TFP growth (Foster Haltiwanger and Krizan's method)

	Δ ln TFP	within	reallocation	cross term	net entry
1991	-1.08	-3.54	-1.63	3.02	0.87
1992	0.99	-2.25	-0.80	3.30	0.83
1993	-3.01	-4.35	-2.25	3.14	0.48
1994	4.65	2.19	-0.03	2.73	-0.22
1995	3.60	1.35	-1.31	2.64	0.87
1996	1.90	-0.65	-0.65	2.67	0.52
1997	2.29	-1.19	0.66	2.70	0.13
1998	6.25	3.73	-0.44	2.69	0.31
1999	0.68	-0.38	-2.11	2.87	0.31
2000	1.93	0.92	-2.53	3.31	0.28
2001	0.92	-0.21	-3.35	4.54	-0.05
2002	0.69	-2.19	-0.62	3.32	0.20
2003	3.59	-1.06	0.67	2.94	1.08
2004	8.01	4.61	0.13	3.18	0.17
2005	4.27	2.06	-1.03	3.01	0.14
2006	3.96	0.14	-0.09	0.03	0.00

Note: This table presents the decomposition proposed by Foster et al. (2001). The components are computed as described in equation (22).

Figure A.4: New firms vs exiting firms: relative capital distortions density



Note: computed in 2000 for the whole manufacturing industry, relative to the median distortion value

Figure A.5: Aggregate productivity growth: comparison with FHK approach

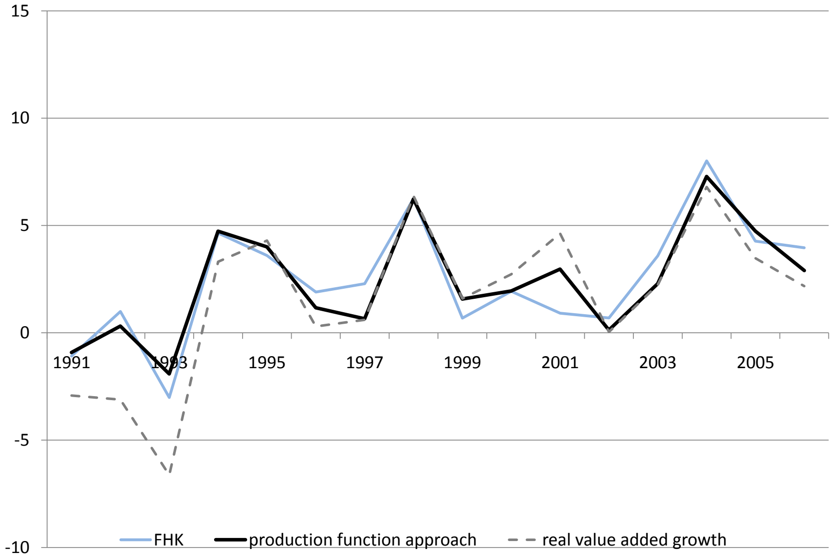


Figure A.6: Firm-level efficiency and allocative efficiency (elasticity of substitution equal to 6)

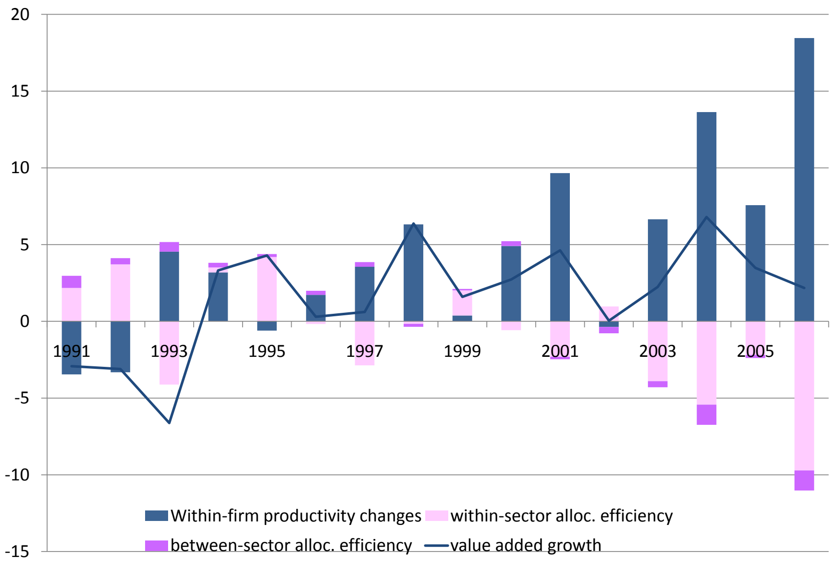


Figure A.7: The extensive margin (elasticity of substitution equal to 6)