An augmented static Olley-Pakes productivity decomposition with entry and exit: measurement and interpretation[1]

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Abstract

Recent macroeconomic literature has stressed the importance of resource allocation across firms for aggregate productivity. This raises the question of how to measure allocative efficiency empirically. We consider this issue paying special attention to firm entry and exit. We develop an augmented Olley-Pakes (OP) decomposition that allows us to examine how entering and exiting firms contribute to the popular OP covariance measure. Applying the method to data that covers essentially all firms and plants in the Finnish business sector, we find that a large part of the OP covariance component can be attributed to entrants and exiting firms. In order to interpret the empirical results and assess the robustness of the OP covariance component as a measure of allocative efficiency, we build a model of firm dynamics that is consistent with our empirical results. We find that because of endogenous changes in firm entry and exit, the standard OP covariance component tends to increase with certain type of distortions. Therefore, it may provide a misleading impression of allocative efficiency.

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1 Introduction

It has been demonstrated that a substantial part of industry productivity growth can be attributed to factor reallocation from low to high productivity firms.[2] Lentz and Mortensen (2008) assess that 53 per cent of aggregate labor productivity growth among Danish firms can be attributed to such reallocation. It has also been argued that differences in resource allocation between firms explain a large part of cross-country variation in aggregate productivity levels (Banerjee and Duflo, 2005; Comin and Hobijn, 2004; Hsieh and Klenow, 2009). Related to this, model-based analyses such as Restuccia and Rogerson (2008), Guner, Ventura and Xu (2008), and Bartelsman et al. (2013), have shown that certain type of allocation distortions may lower aggregate productivity substantially by making resource allocation between firms less efficient.[3] Firm heterogeneity and firm-level allocative efficiency has also gained attention in the recent literatures of international trade, FDI and geography (e.g. Melitz 2003, Helpman et al. 2004, Baldwin and Okubo 2006, Helpman 2006, Melitz and Ottaviano 2008). These analyses show that competition, trade and economies of agglomeration may have a particularly large effect on aggregate productivity growth when firm heterogeneity provide potential for productivity-enhancing restructuring at the level of firms.

An important issue in this context is how to measure allocative efficiency empirically. An increasingly popular measure is the Olley-Pakes (OP) covariance component, i.e., the covariance between firm size and productivity (Olley and Pakes, 1996). It is an appealing measure because it is simple and intuitive. Clearly, starting from a fixed set of firms with varying labor productivity levels, aggregate output increases if some of the workers in low productivity firms move to high productivity firms. Thus, both aggregate labor productivity and the covariance between firm size and labor productivity simultaneously increase. Furthermore, the covariance component seems to do a good job in explaining developments in transition economies and the effects of allocation distortions (Bartelsman et al., 2013).

However, as noted by Bartelsman et al. (2009), the method does not allow for an examination of how entering and exiting firms contribute to aggregate productivity or its components. This is

[2] Bartelsman and Doms (2000) and Syverson and Syverson (2011) provide excellent surveys on the topic.

[3] See Rogerson and Restuccia (2013) for a survey of the literature studying the role allocation distortions.

unfortunate, as firm turnover is a key part of the process of creative destruction. Moreover, with entry and exit, it is no longer clear that productivity increasing changes in resource allocation always increase the OP covariance component. For instance, if a low productivity firm exits and its workers move to higher productivity firms, the covariance between firm size and productivity may decrease. In other words, the OP covariance is sensitive to an endogenous selection threshold.

Another popular measure of allocative (in)efficiency is productivity dispersion (Foster et al., 2008; Hsieh and Klenow, 2009).[4] A higher degree of productivity dispersion is interpreted as evidence of larger distortions, reflecting the assumption that absent distortions, competitive pressure should work to equalize firms' productivities. However, firms' productivities may also vary for reasons unrelated to distortions. In particular, some degree of productivity dispersion may be indicative of healthy industry dynamics rather than of allocation distortions. For instance, young firms often invest heavily in R&D or marketing before they produce much output and may therefore have low productivity. Over time, some of these entrants become highly productive and drive older firms from the market. Indeed, Bartelsman et al. (2012) show that the OP covariance outperforms productivity dispersion as a measure of allocative efficiency in several respects. However, this finding may derive from the fact that in Bartelsman et al.'s analysis, productivity dispersion refers to an unweighted standard deviation. Arguably, measures of dispersion that are weighted by input usage (e.g., employment weighted standard deviations) are more valid because they are more closely linked to aggregate productivity and more reliable because they are more robust to the effects of exceptionally small firms.

In this paper, we consider resource allocation and aggregate productivity, paying special attention to firm turnover. We first describe empirically how entering and exiting firms contribute to industry productivity using data covering essentially all firms and plants in the Finnish business sector during the 1995-2008 period. We then develop an augmented OP productivity decomposition that allows us to examine how entering and exiting firms contribute to the OP covariance component of industry productivity. Finally, we build a new model of firm dynamics that allows us to interpret the empirical results and evaluate alternative measures of allocative efficiency taking into account the role of entrants and exiting firms for aggregate productivity and resource allocation.

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[4] Productivity dispersion measures have also been used to gauge technical (in)efficiency (e.g., Baily, Hulten, & Campbell, 1992).

For our empirical decompositions, we classify firms into four mutually exclusive groups: long-lived entrants, short-lived entrants, exiting firms, and stayers. The distinction between long-lived entrants (that stay at least five years) and short-lived entrants (that exit within five years) is useful in gaining a richer understanding of firm dynamics. We refer to short-lived entrants as visitors[5] and to long-lived entrants as just entrants.

The empirical decomposition of aggregate productivity shows that the contributions of new firms (entrants and visitors) to productivity are minus 2.1 percent in the manufacturing sector industries and minus 3.5 percent in the service sector. These negative numbers indicate that new firms have lower productivity than old firms and thus that industry productivity would be higher in their absence.[6] Exiting firms in turn negatively contribute to aggregate industry productivity. Technically, this implies that had these firms already made their exit, current industry productivity would be higher than it is.

The standard OP covariance component within manufacturing industries is 33.9 %. Our augmented OP productivity decomposition method allows us to examine how visitors, entrants and exiting firms contribute to the covariance component of industry productivity through within-group and between-group effects. The within-group effect of entrants, for instance, depends on how much the covariance component among the entrants differs from that among the stayers. The between-group effect in turn depends on the size and productivity of the entrants relative to the size and productivity of the stayers. Our augmented OP decomposition shows that 18.3 per cent of the OP covariance can be attributed to the fact that new firms[7] are, on average, small and their productivity level is low. The corresponding number in the service sector is not less than 75.8 per cent. Further, more than one-half of these effects on the covariance component can be attributed to visitors. Additionally, exiting firms have a positive impact on the overall covariance component. On the other hand, resource allocation is less efficient among non-stayer firm groups than among stayers, which is indicated by a negative within-group component for the non-stayer firms.

[5] Visitors could also be described as immediate exits.

[6] It should be noted that here we ignore possible indirect effects that the entrants might have on the productivity levels of stayers. On the other hand, our approach seems well justified here, as we are focusing on the allocative effects.

[7] Including visitors and entrants.

The fact that a large part of the OP covariance component can be attributed to entering and exiting firms raises concerns regarding its role as a measure of allocative efficiency. In order to interpret the empirical results and assess the robustness of the OP covariance component as a measure of allocative efficiency, we develop a model of firm dynamics with entry and exit that is consistent with our main empirical findings. In particular, the model generates (endogenously) firm life cycles where both young firms and firms that are about to exit are typically relatively small and have low productivity. In this respect, a key feature of our model is that in order to grow and have high productivity, firms must accumulate 'knowledge capital' via R&D investments. Following Hall and Hayashi (1989), Jones (1995), and Klette and Johansen (1998), among others, we assume that existing knowledge capital and R&D are complements: existing knowledge capital makes R&D investments more effective. As a result, new firms that start with little knowledge capital grow only gradually. Firms also face exogenous productivity shocks and firms that are hit by adverse productivity shocks tend to allow their knowledge capital to depreciate. Therefore, firms typically become small before exiting.

We calibrate the model separately to the manufacturing and service sector data. We then use the model as a laboratory to test how well the OP covariance component and alternative measures capture various allocation distortions. Specifically, we experiment with four stylized allocation distortions in the model: 1) an output tax and subsidy scheme that favors low productivity firms over high productivity firms, 2) a payroll subsidy for small firms, 3) entry costs, and 4) exit costs.

The distortionary output tax and subsidy scheme and the payroll subsidy have the potential to lower aggregate productivity substantially. In contrast, exit and entry costs have only limited effects on aggregate productivity. Interestingly, the adverse effects of entry and exit costs are mitigated by the fact that by reducing firm entry and exit, these distortions decrease the employment share of young firms that typically have relatively low productivity. The output tax and subsidy scheme, in contrast, increases firm turnover thereby further magnifying non-stayer firms' negative contribution to aggregate productivity. We also find that the distortions have a larger impact on aggregate productivity in the manufacturing sector than in the service sector.

We find that despite large changes in firm turnover, the standard OP covariance component captures well the distortions that are potentially the most significant, namely the output tax and subsidy scheme and the payroll subsidy for small firms. As we increase these distortions, the covariance component declines roughly in line with aggregate productivity. In contrast, the OP covariance component fails to capture entry and exit costs. In fact, both entry and exit costs tend to *increase* with the covariance component. The reason for this is that these distortions extend firms' life cycles by making low productivity firms less likely to exit. As a result, the group of stayer firms includes more firms that are both small and have low productivity. Hence the covariance between firm size and productivity increases.

The result that certain distortions increase the covariance component suggests the need for caution in interpreting empirical OP decompositions. At the same time, this result may help explain why the covariance component is actually quite high in a number of poor countries, including Chile, Columbia, Portugal, Indonesia and Estonia and relatively low in some richer countries, such as Germany and the United Kingdom (Bartelsman et al., 2009). A combination of a relatively high covariance component and relatively low productivity may simply result from several distortions, all of which lower aggregate productivity and some of which increase the covariance component. In other words, one should not interpret countries with a high OP covariance component and low productivity as evidence against the conjecture that differences in resource allocation explain a large part of cross-country variations in aggregate productivity. In certain circumstances, similar concerns might also apply to changes over time within a country.

In line with Bartelsman et al. (2013), we find that unweighted productivity dispersion is a very poor measure of allocative distortions. It fails to capture even the highly distortive output tax and subsidy scheme. By contrast, employment weighted productivity dispersion seems to work relatively well. In fact, based on our results, it is arguably at least as a reliable a measure as the OP covariance component.

We proceed as follows. In section 2, we describe the augmented productivity decomposition method, the data and the empirical results. In section 3, we specify and calibrate the model. In section 4, we use the model to analyze different allocation distortions. We conclude in section 5.

2 Decomposition method and empirical results

2.1 A review on earlier productivity decompositions

Two broad approaches have been applied in the empirical literature of the micro-level sources of productivity: 1) a static one, which measures components of industry productivity *level* and 2) a dynamic one, which decomposes sources of industry productivity *growth*.

Olley and Pakes (1996) proposes a static decomposition (OP decomposition), where the industry productivity level is split into an unweighted average productivity level and a covariance component. The latter measures the contribution of resource allocation to the current industry productivity level. A positive covariance component indicates that a disproportionally large share of resources have been allocated to high productivity firms (e.g. typically high productivity firms are large). An obvious problem with this method is that it does not allow for an examination of the contribution of entry and exit.

This shortage can be tackled with various variants of popular dynamic productivity decompositions proposed by Baily, Hulten and Campbell (1992), Haltiwanger (1997), and Griliches and Regev (1995). However, as noted in Maliranta (2003), Böckerman and Maliranta (2007), and more recently in Diewert and Fox (2009), and Melitz and Polanec (forthcoming), a problem with these methods is that the productivity level of the entrants is compared to that of all firms in the past. As a result, the contribution of entry appears to be excessively positive especially when productivity growth of the stayers is high and/or when productivity growth has been measured over a long period of time (e.g. is based on the 5-year time-intervals instead of annual changes). Another problem is that the within component gives a misleading picture on the productivity growth of the stayers. This is because the sum of the weights of the stayer firms (that has a productivity growth by definition) is less than one (when there are at least some entries and/or exits in the industry) so that it is not a weighted average productivity growth. Consequently, the within component is not a suitable index for measuring productivity growth of the stayers, which makes its interpretation obscure.

Variants of more ideal methods for decomposing industry productivity growth are presented in Maliranta (2003), Böckerman and Maliranta (2007), and more recently in Diewert and Fox (2009), and Hyytinen and Maliranta (2013). These methods classify firms in three mutually exclusive groups: entrants (that appear in the end year but not in the initial year), exits (that appear in the initial year but not in the end year) and stayers (that appear both in the initial and end year). One great advantage of all these methods is that the productivity of the exiting and entering firms is compared with the stayer firms in the current year (the initial year in the case of exits and the end year in the case of entries).[8] Another attractive feature is that the within component is a symmetric and unbiased index measuring productivity growth of the stayers (i.e. for those firms that could have productivity growth in the period). [9] It also provides a counterfactual industry productivity growth in absence of any entry, exit or the reallocation of resources between the stayers (Maliranta, 2003).[10]

The method proposed by Melitz and Polanec (forthcoming) combines the features of more ideal dynamic decompositions with the standard static Olley-Pakes decomposition. In their decomposition the entry and exit components are similar to those of the more ideal dynamic decompositions. In the more ideal dynamic productivity decompositions discussed above, the aggregate productivity growth among stayers can be expressed as a sum of the within component and the between component (the latter indicates the contribution of reallocation of resources between the stayers). In the dynamic Olley-Pakes decomposition proposed by Melitz and Polanec (forthcoming), aggregate productivity growth rate of the stayer firms is the sum of the change of the unweigted average productivity growth and the change of the covariance component among stayers.

Some attractive features notwithstanding, the method proposed by Melitz and Polanec (forthcoming) has its shortcomings, however. It does not measure how entrants and exits contribute to the change of the covariance in the total industry, which would be of a special interest in the analysis of the evolution of industry, like in Bartelsman, Haltiwanger and Scarpetta (2013). Moreover, as a dynamic decomposition, it does not provide any indicators measuring the contribution of allocative efficiency to the current productivity level. Such moments would be useful in the calibration of stationary general equilibrium models of firm dynamics, for example.

A *static* measure of allocative (in)efficiency is needed for understanding the *level* of aggregate productivity. In addition, a static measure is helpful in interpreting the micro-level components of

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[8] Vainiomäki (1999, page 127) proposes a decomposition formula for detecting the forms of skill-upgrading that has a similar same idea. As for a static setting, see also Ottaviano, Kangasharju and Maliranta (2009)

[9] All these formulas make use of Bennet (1920) type method for productivity growth among stayers, which features symmetry as emphasized by Balk (2003), and which has a strong axiomatic justification, as shown in Diewert (2005).

[10] Assuming that entry, exit and reallocation do not have any impact on the reactions of the stayers, of course

aggregate productivity *growth*, and especially the role of productivity-enhancing restructuring that are analyzed by *dynamic* productivity decompositions. For instance, low-income countries might be catching-up richer countries at least partly through a process of creative destruction. To the best of our knowledge, our augmented Olley-Pakes method is the first that allows measuring the level of allocative (in)efficiency in a manner that shows the contribution of the entrants and exiting firms and the sub-components of these contributions. As we illustrate later, our augmented static OP decomposition is also useful when comparing heterogeneous firm models with the data. These models usually feature a stationary distribution without aggregate productivity growth.

2.2 Decomposition of industry productivity

In what follows we propose an augmented static Olley-Pakes decomposition with entry and exit. It contributes to the literature of productivity decomposition in two ways. First, it shows how stayers, entries and exits contribute to the standard static Olley-Pakes decomposition.[11] Second, our decomposition identifies two distinct mechanisms for each group of firms; a within group and between group effect.

Ultimately we are interested in the mechanisms that underlie industry productivity, which can be defined as follows:

$$\Phi_t = \sum_{i \in \Omega} s_{it} \varphi_{it} \tag{1}$$

where s_{it} and φ_{it} are the labor share of firm i in an industry and its productivity level, respectively, in year t, defined as:

$$s_{it} = \frac{L_{it}}{\sum_{i \in \Omega} L_{it}} \tag{2}$$

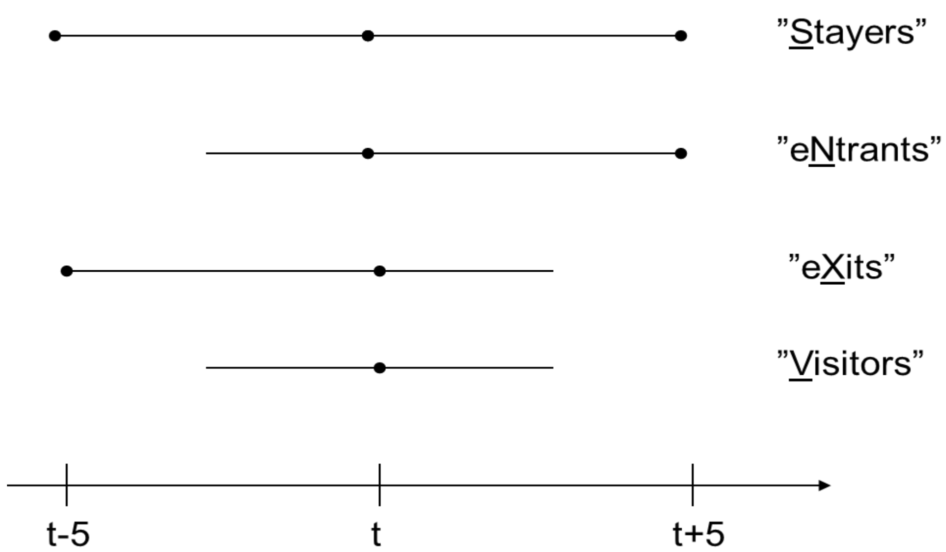
$$\varphi_{it} = \ln \frac{Y_{it}}{L_{it}} \tag{3}$$

where L_{it} and Y_{it} denote labor input and output, respectively, and Ω refers to all active firms in this period.

[11] Ottaviano, Kangasharju and Maliranta (2009) proposes a different version of a static Olley-Pakes productivity decomposition with entry.

To analyze the role of firm dynamics in industry productivity, we classify the firms in year t into four categories, as illustrated in Figure 1 (see Hyytinen, Ilmakunnas and Maliranta, 2010). The first group, called "stayers" (the set of which is denoted by Ω_S), consists of the continuing firms that also exist in year $t-5$ and in year $t+5$. The second category is "entrants" (Ω_N), which do not exist in year $t-5$ but do exist in year $t+5$. The third group is the "exits" (Ω_X), which exist in year $t-5$ (and in year t) but not in year $t+5$. Finally, the fourth group consists of firms that exist in year t but in neither year $t-5$ nor year $t+5$. These short-lived entrants (or young exiting firms) are called "visitors" (Ω_V). The groups are thus mutually exclusive, and it follows that $\Omega_S \cup \Omega_N \cup \Omega_X \cup \Omega_V = \Omega$.[12]

Figure 1. Classification of firms that are active in year t



We assess the contribution of the non-stayers (i.e., the entrants, exits and visitors) to industry productivity using two decompositions that are closely interrelated in a manner shown below.

The first productivity decomposition gauges *the effect of the non-stayers on the industry (or aggregate) productivity level*. We measure this effect as the difference between the aggregate productivity of all firms and the aggregate productivity of the stayer firms. This productivity difference provides an answer to the counterfactual question of how much higher (or lower)

[12] It should be noted that it is possible that some stayers did not operate in the market in years after t-5 and before t or after t and before t+5. Similar "holes" in the operation may exist also for the entrants and exits when the classification is implemented in this way. However, a more detailed classification of the firm groups would make interpretation of the results much more difficult without adding our insight on the issue.

industry productivity would have been in the absence of the non-stayer firms in year t, or, more precisely, if no entries had taken place and all exiting firms had already exited before year t.[13] Accordingly, the effect can be expressed as follows[14]:

$$\Phi_t - \Phi_t^S = \sum_{j=N,X,V} \frac{L_t^j}{L_t}\left(\Phi_t^j - \Phi_t^S\right) \tag{4}$$

where $L_t^j = \sum_{i\in\Omega_j} L_{it}$, $L_t = \sum_{i\in\Omega} L_{it}$, $\Phi_t^S = \sum_{i\in\Omega_S} \frac{L_{it}}{\sum_{i\in\Omega_S} L_{it}} \varphi_{it}$ and

$$\Phi_t^j = \sum_{i\in\Omega_j} \frac{L_{it}}{\sum_{i\in\Omega_j} L_{it}} \varphi_{it} = \sum_{i\in\Omega_j} \frac{L_{it}}{L_t^j} \varphi_{it} .$$

Equation (4) is the starting point the effect (or contribution) of the non-stayers, $\Phi_t - \Phi_t^S$, is dependent on the magnitude of the productivity gaps of the employment weighted average productivity levels between the non-stayer firm groups, Ω_j , $j \in \{N, X, V\}$, and the stayers, i.e., $\Phi_t^j - \Phi_t^S$, as well as the employment shares of the non-stayer firm groups, i.e., L_t^j / L_t, $j \in \{N, X, V\}$

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In what follows, we propose an augmented Olley-Pakes productivity decomposition method. The method is used to examine how the different non-stayer firm groups contribute to aggregate productivity via *the covariance component of the industry productivity level*. To do so, we combine the idea used in Equation (4) and the popular cross-sectional Olley and Pakes (1996) decomposition of the industry productivity level into average productivity and the covariance component. As the latter indicates the covariance between the employment share and productivity, the decomposition is defined as

$$\begin{aligned} \Phi_t &= \bar{\varphi}_t + \sum_i \left(s_{it} - \bar{s}_{it}\right)\left(\varphi_{it} - \bar{\varphi}_{it}\right) \\ &= \bar{\varphi}_t + \mathrm{cov}\left(s_{it}, \varphi_{it}\right) = \bar{\varphi}_t + \mathrm{cov}_t . \end{aligned} \tag{5}$$

Obviously, the same decomposition can be defined separately for each firm group. Hence we have $\Phi_t^j = \bar{\varphi}_t^j + \mathrm{cov}_t^j$, $j \in \{S, N, X, V\}$.

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[13] Note that the purpose of this accounting exercise is to measure allocative effects and therefore here we assume that the entrants (or exiting firms) do not have any indirect effect on the productivity levels of the entrants.

[14] For derivation of this equation, see Appendix 1.

Thus, the aggregate productivity gap between all firms and stayers can be presented, analogously to (4), as

$$\Phi - \Phi^S = \bar{\varphi} - \bar{\varphi}^S + \text{cov} - \text{cov}^S \qquad (6)$$

This gives us an expression for the covariance gap between all active firms and stayers in year t. It indicates how much higher or lower the covariance component would be in the absence of entrants, exiting firms and visitors[15]:

$$\text{cov}_t = \text{cov}_t^S + \underbrace{\sum_{j=N,X,V} \frac{L_t^j}{L_t}\left(\text{cov}_t^j - \text{cov}_t^S\right)}_{\textit{within-group effects}} + \underbrace{\sum_{j=N,X,V} \frac{N_t^j}{N_t}\left(\frac{\bar{L}_t^j}{\bar{L}_t} - 1\right)\left(\bar{\varphi}_t^j - \bar{\varphi}_t^S\right)}_{\textit{between-group effects}} \qquad (7)$$

where N_t is the total number of firms active in year t and $\bar{L}_t = \frac{L_t}{N_t}$. N_t^j denotes the number of firms in the firm group Ω_j, $\bar{L}_t^j = \frac{L_t^j}{N_t^j}$ and $\bar{\varphi}_t^j = \frac{\sum_{i \in \Omega_j} \varphi_{it}}{N_t^j}$, $j \in \{N, X, V\}$.

Equation (7) shows that each of the non-stayer firm groups (*j=N, X, V)* contributes to the covariance component via a within-group effect, whose sign depends on the term $\left(\text{cov}^j - \text{cov}^S\right)$, and a between-group effect, whose sign depends on the product $\left(\frac{\bar{L}_t^j}{\bar{L}_t} - 1\right)\left(\bar{\varphi}^j - \bar{\varphi}^S\right)$. The latter effect is positive, for example, if the average firm size is relatively small, $\frac{\bar{L}_t^j}{\bar{L}_t} < 1$, and the average productivity is low, $\bar{\varphi}^j < \bar{\varphi}^S$. The magnitude of the within-group effect depends on the employment share of the firm group, i.e., L_t^j / L_t, $j \in \{N, X, V\}$, and the magnitude of the between-group effect depends on the number of firms in a group as a share of all firms, i.e., N_t^j / N_t, $j \in \{N, X, V\}$.

[15] The derivation of this equation is shown in Appendix 1.

2.3 An empirical illustration

Figure 2 provides a graphical illustration of the intuition behind the decomposition formulas (4) and especially (7) by use of a firm-level data set for the food industry in the year 2003. Tables 1 and 2 report the productivity decomposition results.[16] The vertical axis represents the log of employment and the horizontal axis the log of the productivity level. The figure displays four important aspects.

First, firms are very heterogeneous, both in size and productivity level. Second, there is a clear positive relationship between size and productivity, especially among the stayer firms, indicated by a dashed fit line. Indeed, the covariance component among the stayer firms is 22.6 % (see Table 2). The figure provides some indication that the covariance terms are not greater among the non-stayer firm groups. Computations confirm this, indicating that the covariance components among the entrants, exits and visitors are 4.5 %, 5.7 % and 16.4 %, respectively. These values imply that the within-group effects of the non-stayer firm groups are negative, as shown in Table 2. Third, both the average size and productivity levels of the stayers are larger than those of the non-stayer firms groups, the visitors, in particular. The horizontal solid lines indicate the log of the average size and the vertical solid lines the average of the log productivity level by firm group. The very small average size and low average productivity level explains the large positive contribution of the visitors to the between-group component (3.0 percentage points), shown in Table 2. Other non-stayer firm groups have negative between-group effects as well. Fourth, the stayer firms have a much larger size dispersion (with a standard deviation of 246.1) than the entrants (17.5) or the visitors (11.5), but productivity dispersion is somewhat larger among the entrants (0.46) and the visitors (0.44) than the stayers (0.42) (see also Haltiwanger, Jarmin, and Schank, 2003). Fifth, as both the average productivity level and the covariance component of the non-stayer firm groups are lower than those of the stayer firm group, the non-stayer firm groups contribute negatively to industry productivity. In the absence of the non-stayer firm groups, the aggregate productivity level would have been 4.7 percent higher, as shown in Table 1. For example, if the exiting firms had exited before 2003, industry productivity would have been 2.1 percent higher.

[16] It should be emphasised that, although we use here real data (which will be described in greater detail below), the main purpose of the analysis at this point is to illustrate the intuition behind these productivity decompositions.. In order to prevent indirect disclosure of individual observations, we have also added a small amount of noise to the data presented in Figure 2.

Figure 2. Productivity and employment in firms, an illustrative example

Note: We have excluded firms whose log of labor productivity is less than 9 or greater than 12

Table 1. Decomposition of the contribution to the productivity level (%-points, exept employment share in %)

Firm group	Contribution (1) = (2) x (3)	Productivity gap (2)	Employment share (3)
Entrants	-1,8	-30,8	5,8
Exits	-2,1	-30,2	6,9
Visitors	-0,9	-34,1	2,5
Total of non-stayers	-4,7		

Note: Decomposition is made by applying (4). Components may not add up due to rounding.

Table 2. Decomposition of the contribution to the covariance component by the augmented Olley-Pakes productivity decomposition, firm data (%-points)

			Contibution of non-stayers	
	OP(All) (1)= (2)+(3)+(4)	OP(Stayers) (2)	Within groups (3)	Between groups (4)
Total	26,3	22,6	-2,4	6,1
Contributions				
Entrants			*-1,0*	*1,5*
Exits			*-1,2*	*1,6*
Visitors			*-0,2*	*3,0*

Notes: Decomposition is made by applying (7). Components may not add up due to rounding.

3 Empirical analysis

3.1 Data

We use the Structural Business Statistics data that exhaustively cover basically all firms in the Finnish business sector in the period 1995-2008.[17] Data are collected directly from firms through surveys (that typically employ at least 20 persons) and then complemented by exploiting the Tax Administration's corporate taxation records and Statistics Finland's Business Register (that cover

[17] The main exception is financial intermediation, which is not covered in the data. All 27 industries covered in our analysis are listed in Table A1 in Appendix

basically all firms).[18] As a result, our data have near-perfect coverage of the firm population. In our baseline analysis, we have included all firms employing at least one person (measured in full-time equivalent units) and that produce positive value added, which is needed to measure the log of labor productivity.

Some descriptive statistics on the data are provided in Table A.1 in Appendix 2. The table classifies firms into three sectors (manufacturing, construction and services) and into 27 industries. In our baseline analyses, the data cover 107,082 firms and 1,013,161 persons per year (the average of the years 2000-2003). Note that although our data cover the years from 1995 to 2008, we are able to carry out the computations for the years 2000-2003 only because we use 5-year windows backward and forward to categorize firms into four firm groups.

Table A.1 shows that the non-stayer firms (i.e., the entrants, exiting firms and visitors) account for a substantial fraction of total firms: 46.5% (= 100% – 53.5%) in the manufacturing sector and about two-thirds in the construction and service sectors. Yet the employment shares of the non-stayers are much smaller: 13.4% (= 5.3% + 5.8% + 2.3%) in the manufacturing sector and about one-third in the construction and service sectors. These numbers indicate that the relative size of the non-stayers is quite small.

It should be noted that all sector-level results (i.e., for manufacturing, construction[19] and services) reported above, as well as those that will be shown below, are the employment-weighted averages of the industry-level results (the first two columns in table A.1 are the exceptions). Thus, we focus on the effects within a typical industry of a sector and the effects of the industry structures are eliminated.

3.2 Results

As background, Table A.2 in Appendix 2 describes some important empirical patterns in our data concerning heterogeneity in productivity. Variation in productivity levels between firms (within industries) is, indeed, substantial. To measure heterogeneity in the productive use of resources in an industry, the employment-weighted standard deviation of labor productivity (the log of value added

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[18] For more detailed information, see http://www.stat.fi/meta/til/tetipa_en.html (accessed 29 May, 2012).

[19] However, note that the construction sector consists of a single industry.

per person) provides a natural alternative. As shown in the first column, the value of this measure is 46.9% in the manufacturing sector. The corresponding numbers for the construction and service sectors are 41.0% and 59.6%, respectively. The second column reports unweighted standard deviations, which have been popular measures in the literature. As can be read from the table, unweighted standard deviations are larger than those with employment weights. This likely reflects the fact that the role of heterogeneous entrants in overall allocative efficiency is greater when their small size is not adjusted in the indicator. As a result, the unweighted standard deviations can be expected to be more sensitive to the role of firm turnover than the weighted standard deviations. The following columns show that the groups of non-stayer firms have especially low productivity. For instance, the gap in the unweighted average productivity level between entrants and stayer firms in the manufacturing sector is -15.1 percent (in log-units), and the corresponding gaps for exiting firms and visitors are -14.3 and -37.2 percent, respectively. Importantly, the table also shows that these gaps are much larger when measured by a weighted average (that is, aggregate) productivity level. The productivity gaps are also large in the construction and service sectors.

Table 3 represents the decomposition of productivity levels by use of Equation (4). We find that in all three sectors, the non-stayer firms contribute negatively to industry productivity. This results from the fact that the non-stayer firm groups have lower productivity levels than the stayer firms (i.e., they have negative productivity gaps). In manufacturing, the effect is -3.4%, a contribution that is spread quite evenly between the three non-stayer groups. The industry-level results reported in Table A.3 in Appendix 2 indicate similar patterns but with some variation and a couple of exceptions. The main exceptions include a few service industries (real estate services and other business services in particular) where non-stayers positively contribute to industry productivity. However, these findings should be interpreted as an indication of the usual measurement problems in the service sector.

Table 3. Decomposition of the contribution to the aggregate productivity level by firm groups (%-points)

	Contribution of	Contribution of			Productivity gap		
	non-stayers	entrants	exits	visit.	entrants	exits	visit.
	(1)=(2)+(3)+(4)	(2)	(3)	(4)	(5)	(6)	(7)
Manufacturing	-3,4	-1,2	-1,3	-0,9	-30,8	-33,2	-53,0
Construction	-5,4	-2,0	-1,0	-2,3	-12,7	-11,4	-28,2
Services	-4,0	-1,5	-0,5	-2,0	-10,0	-4,3	-26,5

The results obtained by use of the augmented Olley-Pakes decomposition, i.e., Equation (7), for three main sectors are represented in Table 4. In the manufacturing sector, the standard OP covariance component for all firms and stayer firms is 33.9 % and 27.8 %, respectively. The difference between these figures (6.1 %) derives from the within-group component (where the group is that of non-stayers), which is -1.1 %, and the between-group component, which is +7.2 %. The table also shows that the entrants' contribution to the between-group component is 2.5 percentage points, the visitors' contribution is 3.7 percentage points and the exiting firms' contribution is 1.0 percentage point. In other words, 18.3% (= (2.5 % + 3.7 %)/33.9 %) of the standard OP covariance component can be attributed to the between-group component of the young firms (less than 5 years old). Our earlier findings concerning their relative size and productivity levels imply that the positive contribution is because these firms are, on average, small and have low weighted average productivity levels. The corresponding figures for the construction and service sectors are much more striking. No less than 61.8 % (= (1.6 % + 2.6 %)/6.8 %) of the OP covariance component in the construction sector and 75.8 % (= (4.3 % + 5.7 %)/13.2 %) in the service sector can be attributed to the between-group components of the young firms.

Table 4. Augmented Olley-Pakes productivity decomposition, firm data (%-points)

Panel A: Manufacturing

			Contibution of non-stayers	
	OP(All) (1)= (2)+(3)+(4)	OP(Stayers) (2)	Within groups (3)	Between groups (4)
Total	33,9	27,8	-1,1	7,2
Contributions				
Entrants			*-0,4*	*2,5*
Exits			*-0,5*	*1,0*
Visitors			*-0,2*	*3,7*

Panel B: Construction

			Contibution of non-stayers	
	OP(All) (1)= (2)+(3)+(4)	OP(Stayers) (2)	Within groups (3)	Between groups (4)
Total	6,8	4,2	-1,6	4,2
Contributions				
Entrants			*-0,7*	*1,6*
Exits			*-0,2*	*0,0*
Visitors			*-0,7*	*2,6*

Panel C: Services

			Contibution of non-stayers	
	OP(All) (1)= (2)+(3)+(4)	OP(Stayers) (2)	Within groups (3)	Between groups (4)
Total	13,2	-0,4	3,2	10,5
Contributions				
Entrants			*1,5*	*4,3*
Exits			*0,8*	*0,5*
Visitors			*0,9*	*5,7*

Notes: The numbers refer to the weighted average of industries within sector (weighted by the employment share of the industry) and the average of years 2000-2003, calculated by firm data. Components may not add up due to rounding.

The negative within-group component of the augmented OP method indicates that the relationship between productivity and size is stronger in the stayer group than in the non-stayer groups. Indeed, while the covariance component is 27.8% among the stayers in the manufacturing sector, the corresponding numbers for the entrants, exiting firms and visitors are 12.2%, 9.0% and 10.0%, respectively (not reported in the table). However, the contributions to the within-group component in absolute terms are modest because the employment shares of non-stayer firm groups are rather small, especially in the manufacturing sector, as documented in Table A.1 in Appendix 2. Table 4 also shows that the non-stayer groups contribute negatively to the within-group component in the construction sector but, perhaps somewhat surprisingly, positively in the service sector.

Again, the sector level results of Table 4 are the employment weighted averages from the industry-level results reported in Tables A.4a and A.4b. Given that manufacturing industries differ greatly from one another in various ways, the similarity in the basic patterns of the industry-level results is noteworthy. With only a few exceptions, the signs of these decompositions are identical and the magnitudes are similar.

3.3 Extensions and robustness checks

We have performed a number of additional analyses to complement and check the robustness of our baseline results reported above. An issue of a high importance is the identification of entrants (and exiting firms) needed to classify firms into stayers, entrants, exiting firms and visitors. In the course of our empirical analysis, we recognized that entrants and visitors, which are identified by the appearance of a new firm code in the data, included some firms that were much larger than the other new firms. A more careful inspection revealed that the appearance of large new firms is evidently associated with the disappearance of large firms in the same industry. Clearly, there were some artificial entries and exits of large firms in our data, resulting from changes in firm code that occurred when the legal form of a firm had changed.[20] Importantly, we perceived that few artificial entrants would be highly consequential in this context. This is because, unsurprisingly, exceptionally large new entrants usually also have exceptionally high productivity levels. In our baseline analysis, we have reclassified an entrant as a stayer if it employs more than 100 persons. This is because it seems highly unlikely that a firm so large would make be a genuine entrant. In a robustness check, we used 250 persons as an alternative criterion and found that the results were quite similar to those of our baseline analysis.[21] These experiments further confirmed our view that our results are robust when a few exceptional new firms are eliminated from the analysis.

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[20] Bartelsman, Haltiwanger and Scarpetta [20] and Bartelsman, Haltiwanger and Scarpetta (2009) make a similar observation concerning Finnish firm-data in their footnote 17.

[21] In addition to the reclassification, we have also experimented with removal of suspicious entrant observations. Again, the results were generally consistent with our baseline analysis.

3.3.1 Analysis with plant-level data

Another approach to testing the robustness of our empirical analysis is the use of plant-level data. The advantage of these data is that the plant code stays intact as long as the location and industry group do not change. As changes in ownership or organization do not lead to changes in plant code, there should be no need to remove or reclassify suspicious entrants or visitors. Perhaps the greatest disadvantage of plant-level data is that the measure of labor productivity (log of sales per person) may not be the most suitable measure.

A less-than-ideal productivity measure notwithstanding, the main results are surprisingly similar to our baseline analysis made with the firm-level data, as can be seen by comparing Table 3 with Table A.5 in Appendix 2 and Table 4 with Table A.6. First, the non-stayer firm groups make broadly similar negative contributions to industry productivity levels. Second, the non-stayers and especially the visitors make a large positive contribution to the OP covariance term via the between-groups component. Third, the entrants, visitors and exiting firms negatively contribute to the within-group component of the OP covariance term.[22] This is because, for example, in the manufacturing sector, the covariance terms among the entrants, exits and visitors are 16.3%, 24.9% and 13.6% (not reported in the table), respectively, whereas the corresponding number for the stayers is 33.5%. Thus, the covariance term among new plants is only one-half that of the stayer plants, as was the case with the firm-level data. This means, according to the augmented OP productivity decomposition formula (7), that these plant groups contribute negatively to the overall covariance component via the within-group component.

3.3.2 The effect of cut-off limit

Our baseline analysis included all firms that employ at least one person (in full-time units). To check whether our findings are sensitive to this threshold, we replicated the decompositions of productivity levels and covariance terms using alternative thresholds. The results of this experiment for the manufacturing sector are reported in Table A.7 (level decomposition) as well as in Tables A.8a and A.8b (covariance decomposition) in Appendix 2. The results for the contribution of the non-stayer groups to industry productivity levels are remarkably insensitive to changes in the inclusion threshold. Changes in the threshold most affect the covariance term of the stayers. This

[22] The entrants in the service sector are the only exception here.

term declines substantially when smaller firms are excluded (see column (2) in Table A.8a). Additionally, the between-group component of the OP covariance term falls, although this term is relatively high under all alternative thresholds (see column (4) in Table A.8a). As for the within-group component of the OP covariance term, the impact of excluding smaller firms is quite inconsequential. Visitors' contribution to the between-group component, unsurprisingly, declines quite substantially with increases in the threshold, but is still high even when the analysis covers only firms employing at least 20 persons (see column (8) in Table A.8b).

3.3.3 Cyclical variation

Our baseline results are computed by averaging over years in order to mitigate the possible effects of business cycles on the decomposition of the productivity level and the covariance term. The results for the decompositions by year are also reported in Table A.7, Table A.8a and Table A.8b in Appendix 2. The table shows that the results vary between years but that the basic patterns are unchanged.

3.3.4 Price levels of firms

The measurement of firm/plant performance has been based on an indicator that Foster, Haltiwanger and Syverson (2008) call revenue labor productivity. Obviously, if all firms had identical price levels at each point in time, as usually assumed in the literature, our indicator would be equivalent to that of physical labor productivity. However, if there are systematic differences in the price levels among firms, our indicator should rather be interpreted as a measure of profitability than of productive efficiency. For instance, Foster et al. (2008) find, using US data on selected manufacturing industries, that entrants (plants that are less than 5 years old) have prices 1-4 percent lower than those of stayers. In our analysis, a price gap of that magnitude would imply only a modest change in entrants' contribution to aggregate productivity. This is because the revenue labor productivity gap between stayers and entrants was -30.8 percent, while that between stayers and visitors was -53.0 percent.

The effect on the results with the augmented OP decomposition method are not, however, quite clear. This is especially true for the within-group component. This is because the average price level of a firm group (e.g., entrants or stayers) may hide systematic price differences between efficient and inefficient firms *within* the firm group. An important question is therefore whether the relationship between efficiency (i.e., physical productivity) and the price level is different within different firm groups. For instance, if the relationship between efficiency and the price level is more strongly negative among entrants than among stayers, the contribution of entrants to the within-group component would be less negative than we found above.

4 Model of firm dynamics

In this section we describe our model of firm dynamics and calibrate to it match the main patterns revealed by the empirical results in the previous section.

As regards the model, our main contribution is to incorporate a similar accumulation equation for 'knowledge capital' as in Klette and Johansen (1998) into a general equilibrium heterogeneous firms model à la Hopenhayn (1992). [23] The key feature of the accumulation equation for knowledge capital is that existing knowledge capital and new R&D investments are complementary. That is, greater initial knowledge tends to increase the amount of new knowledge obtained from a given amount of R&D. This idea was first developed in aggregate growth models (see e.g. Jones 1996). Klette and Johansen (1998) argued that complementarity between existing knowledge capital and new R&D is important in explaining the persistent differences in R&D intensity across firms that can be observed in the data. As we discuss below, we find that it also allows us to replicate the main empirical patterns of resource allocation and firm turnover described above. In particular, in our model entering firms grow gradually. In many other models, including Bartelsman et al. (2013), entering firms grow immediately to their optimal long-run size.

As in Hopenhayn (1992), our model features idiosyncratic productivity shocks, a fixed cost of production and an entry cost. These assumptions are crucial for the model to generate a stationary, non-degenerate distribution of firms. Following Bartelsman et al. (2013), we model the fixed cost as overhead labor, which implies that labor productivity tends to be higher in larger firms. Our model also features endogenous entry and exit. Related models often feature more limited dynamics with respect to entry and exit. In some models, there is no entry and exit at all while in other models firm exit is exogenous. Examples of models featuring endogenous entry and exit decisions include Fattal

[23] Intangible capital, which is essentially the same as our knowledge capital, has been found to be roughly one-half of the total capital stock. In addition, an important part of total factor productivity growth (as measured traditionally by ignoring intangible capital) can be attributed to the growth of intangible capital (e.g., Corrado, Hulten, & Sichel, 2009; Jalava, Aulin-Ahmavaara, & Alanen, 2007)

Jaef (2012) and Gabler and Poschke (2013). However, these models are not calibrated to match similar life cycle aspects regarding firm size and productivity that we consider important for our analysis.

4.1 Set-up

Time is discrete and there is a continuum of profit maximizing firms that take prices as given. We consider only stationary equilibria, where the firm distribution remains constant over time.

In the beginning of each period, incumbent have a certain amount of knowledge capital a and they observe the current value of an exogenous and stochastic productivity state z. They then hire labor for current production and R&D. R&D increases next-period knowledge capital. In addition, firms decide whether to exit or stay in the market until the next period. A firm that exits must pay a fixed exit cost $c_x \geq 0$. We will later interpret a strictly positive exit cost as one type of distortion.

Output y is determined as

$$y = \exp(z)a^{\alpha}(l - f)^{\gamma-\alpha}, \qquad (8)$$

where l denotes the number of production workers and $f > 0$ is overhead labor. We assume $\alpha > 0$ and $\alpha < \gamma < 1$, implying decreasing returns to scale. The assumption of decreasing returns to scale guarantees that firms do not grow infinitely large. A fixed overhead labor in turn implies that firms exit before becoming arbitrarily small. In what follows, we sometimes refer to $\exp(z)a^{\alpha}$ as "technology".

The exogenous productivity state z evolves as a first-order a Markov process with a bounded support $Z = [\underline{z}, \overline{z}]$. Specifically, we assume the following law-of-motion:

$$z' = \max\{\min\{\overline{z}, \rho z + \varepsilon\}, \underline{z}\}, \qquad (9)$$

where prime refers to next period, $0 < \rho < 1$, and ε is a normally distributed productivity shock with mean zero and standard deviation σ_{ε}.

Following Klette and Johansen (1998), knowledge capital is assumed to evolve as

$$a' = a^{v} r^{1-v}, \tag{10}$$

where r is the number of R&D workers and v satisfies $0 < v < 1$. The key implication of this accumulation equation is that it takes time for a new firm to grow. Together with the overhead labor, this feature allows the model to replicate e.g. the fact that young firms are on average relatively small and have a low labour productivity.

There is also a continuum of potential entrants that enter the market if and only if it is profitable in expected terms. Firms that enter the market must first pay a fixed entry cost, $c_n > 0$, to learn their initial exogenous productivity state, which is drawn from distribution $\varphi(z)$. We assume that φ is the truncated normal distribution over Z. The standard deviation of the underlying normal distribution is denoted by σ_z. Once a potential entrant has drawn its initial productivity, it decides whether to enter and start production. All firms start with an initial knowledge capital level $\underline{a} > 0$. The initial level of knowledge capital must be strictly positive because otherwise entrants could never start to grow.

We also allow for a distortionary output tax (or subsidy) and a payroll subsidy. The output tax may depend on firms technology and is denote by $\tau(z,a)$. The payroll subsidy s in turn may depend on the number of employees and is denoted by $s(w, r+l)$. We normalize the price of one unit of production to one and denote the wage rate, which will be determined via a free entry condition, by w. The model is closed by assuming that the aggregate labor supply is fixed. Without loss of generality, we normalize it to $\overline{L} = 1$. The mass of firms is determined so that the demand for labor equals its supply.

4.2 Problem of the firm

We can now define the problem of an incumbent firm recursively as follows:

$$V(a,z;w) = \max_{r\geq 0, l\geq f}\{(1-\tau(z,a))\exp(z)a^{\alpha}(l-f)^{\gamma-\alpha} - w(r+l) \\ +s(w,r+l) + \max[-c_x, \beta EV(a',z';w)]\} \quad (11)$$

subject to (9) - (10). The second max-operator relates to the exit decision. The firm exits whenever expected losses increase the exit cost.

While the decision related to R&D workers is a dynamic optimization problem, the decision related to production labor is a static one. Given the state variables, and assuming $s=0$, the optimal number of production workers is[24]

$$l = \left(\frac{(\gamma-\alpha)(1-\tau(\text{z,a}))\exp(z)a^{\alpha}}{w}\right)^{\frac{1}{1-\gamma+\alpha}} + f. \quad (12)$$

4.3 Stationary equilibrium

The free-entry condition reads as

$$\int \max\{0, V(\underline{a},z;w)\}\varphi(dz) - c_n \leq 0. \quad (13)$$

As long as there is entry, this condition holds with equality and pins down the wage rate.

In order to define a stationary equilibrium, let us first define a measure μ such that for all $(a,z)\in A\times Z,\ \mu(\text{a,z})$ denotes the mass of firms in state (a,z). The stationary equilibrium consists of the distribution $\mu(a,z)$, the wage rate w, a value function $V(a,z;w)$, and policy functions $r(a,z;w)$ and $l(a,z;w)$, such that:

i) The value and policy functions solve the firm problem in (11).

[24] Solving for the optimal demand for production workers is somewhat more complicated in the case with a payroll subsidy that depends on the number of production workers. However, it is still a static problem.

ii) The free-entry condition (13) is satisfied.

iii) The labor market clears:

$$\int l(a,z;w)\mu(da,dz)=\overline{L}.$$

iv) The firm distribution is time invariant; i.e., for all $\mathbf{a}\times\mathbf{z}\subseteq\mathbf{A}\times\mathbf{Z}$

$$\mu(\mathbf{a},\mathbf{z})=\begin{cases}\int_{A\times Z} T(a,z,\mathbf{a},\mathbf{z})\mu(da,dz) \text{ if } \underline{a}\notin\mathbf{a}\\ \int_{A\times Z} T(a,z,\mathbf{a},\mathbf{z})\mu(da,dz)+BP(\mathbf{z}) \text{ if } \underline{a}\in\mathbf{a}\end{cases},$$

where the transition function $T(a,z,\mathbf{a},\mathbf{z})$ gives the probability that a firm in state (a,z) will be in a state belonging to $\mathbf{a}\times\mathbf{z}$ next period, B is the mass of firms that enter the market, and $P(\mathbf{z})$ is the probability that an entrant's exogenous productivity state belongs to $\mathbf{z}$ (recall that firms' initial level of knowledge capital is $\underline{a}$). Function T is formally defined as:

$$Tr(a,z,\mathbf{a},\mathbf{z})=\int\chi(a(a,z;w)^{v}r(a,z;w)^{1-v},\mathbf{a})Q(\mathbf{z},z)\mu(da,dz),$$

where $\chi(a',\mathbf{a})$ is an indicator function that equals 1 if next period knowledge capital a' belongs to $\mathbf{a}$ and $Q(\mathbf{z},z)$ is the probability that the exogenous productivity state moves from z to $\mathbf{z}$.

4.4 Calibration and the benchmark economy

Before solving the model, we must specify all parameter values. We first calibrate certain parameters exogenously. We then calibrate the remaining parameters endogenously so as to replicate the key features of resource allocation in the empirical data. We calibrate the model separately to the manufacturing sector and services sector data. As our empirical results illustrated, these two sectors are quite different in terms of resource allocation across different firm groups. When calibrating the model to the data, we set the output tax, the payroll subsidy, and the exit cost at zero. This reflects our view that as regards resource allocation in the business sector, Finland is a relatively undistorted economy.

We interpret the model period as one year and set the discount factor at $\beta=0.95$, reflecting an annual discount rate of approximately 5%. We set returns to scale at $\gamma=0.95$. This reflects the evidence that returns to scale are close to constant (see e.g., Burnside, 1996; Syverson, 2004). We specify the bounds of the exogenous productivity state as $\underline{z} = -4\sigma_\varepsilon / \sqrt{1-\rho^2}$ and $\bar{z} = 4\sigma_\varepsilon / \sqrt{1-\rho^2}$.

We are left with the following eight parameters: overhead labor f, the share of current knowledge capital in the accumulation equation v, the autocorrelation parameter ρ, standard deviations of productivity shocks and initial productivity drawings σ_ε and σ_z, entry cost c_e, initial knowledge capital $\underline{a}$, and the share of knowledge capital in the production function α. We set these parameter values so as to roughly match the following statistics in the data: i) the OP covariance component for all firms, ii-iv) the productivity gaps of entrants, exiting firms, and visitors relative to stayer firms, v)-vii) the employment shares of entrants, exiting firms, and visitors, and viii) the employment share of R&D personnel. The employment share of R&D personnel is roughly the same across the sectors.[25] For simplicity, we target the same R&D employment share of 20%, for both sectors. Other targeted moments are sector specific.

Formally, we minimize the sum of squared relative errors for these targets. When the model is calibrated to the manufacturing sector, the resulting parameter values are: $f = 0.19$, $v = 0.58$, $\rho = 0.64$, $\sigma_\varepsilon = 0.23$, $\sigma_z = 0.20$, $c_n = 0.042$, $\underline{a} = 0.02$, $\alpha = 0.20$. When the model is calibrated to the services sector, the resulting values are: $f = 0.20$, $v = 0.46$, $\rho = 0.64$, $\sigma_\varepsilon = 0.15$, $\sigma_z = 0.24$, $c_n = 0.047$, $\underline{a} = 0.024$, $\alpha = 0.24$.

Table 5 displays the targeted moments in the two calibrations and the data. In our view, both calibrations match the targets relatively well. The fact that the service sector calibration features a much smaller overall covariance term, smaller productivity gaps and higher employment share of entrants than the manufacturing sector calibration is largely the result of a smaller share of current knowledge capital v in its accumulation function. Intuitively, a smaller share of current knowledge capital means that young firms can grow faster. In addition to increasing their employment share, this works to increase their productivity relative to older firms.

[25] The share of "Managers" and "Professionals" was 18% in the Finnish non-farm business sector and 19% in the manufacturing in 2011. The share of "Technicians and associate professionals" was around 15%. From these figures we made a rough estimate that 20% of the employees are significantly associated with the firms' efforts to develop their products, processes or organization.

Table 5. Calibration targets (%-points)

Target (%)	Manufacturing Model	Manufacturing Target	Services Model	Services Target
covariance term	35,0	33,9	12,5	13,2
PROD GAPS RELATIVE TO STAYERS				
entrants	-25,3	-30,8	-17,5	-10
exiting firms	-22,7	-33,2	-5,1	-4,3
visitors	-59,6	-53,0	-25,3	-26,5
EMPLOYMENT SHARES				
entrants	6,9	5,3	17,0	15
exiting firms	5,8	5,8	15,1	7,8
visitors	1,2	2,3	5,0	7,3
R&D employment share	18,0	20,0	21,9	20,0

Note: Data refer to the empirical results concerning the manufacturing sector

In relative terms, the largest mismatch between the model and the data concerns the employment share of visitors in the manufacturing sector. In the model, this share is about half of its value in the data. The problem appears to be that we cannot alter the employment share of visitors independently of the employment share of entrants. If we were to match the employment share of visitors, the employment share of entrants would become far too large.

Table 6 presents the covariance decomposition (Equation (7)). In the manufacturing sector, the covariance component is 35.0 percent among all firms and 22.4 percent among stayers. The effect of the non-stayers is thus approximately 12.6 percent. This effect comes almost entirely via the between-group effect, leaving only a modest positive role for the within-group effect. The further breakdown of the within and between-group effects shows that exiting firms contribute the most to the between-group effect (4.0 percentage points). In the service sector calibration, the covariance component is 12.5 percent among all firms and 5.7 percent among stayers.

Table 6. Augmented Olley-Pakes productivity in the model (%)

Panel A: Manufacturing			Contibution of non-stayers	
	OP(All) (1)= (2)+(3)+(4)	OP(Stayers) (2)	Within groups (3)	Between groups (4)
Total	35,0	22,4	1,3	11,3
Contributions				
Entrants			*0,5*	*3,4*
Exits			*0,7*	*4,0*
Visitors			*0,0*	*3,9*
Panel B: Services			Contibution of non-stayers	
	OP(All) (1)= (2)+(3)+(4)	OP(Stayers) (2)	Within groups (3)	Between groups (4)
Total	12,5	5,7	1,9	4,9
Contributions				
Entrants			*1,8*	*1,9*
Exits			*-0,2*	*0,3*
Visitors			*0,2*	*2,7*

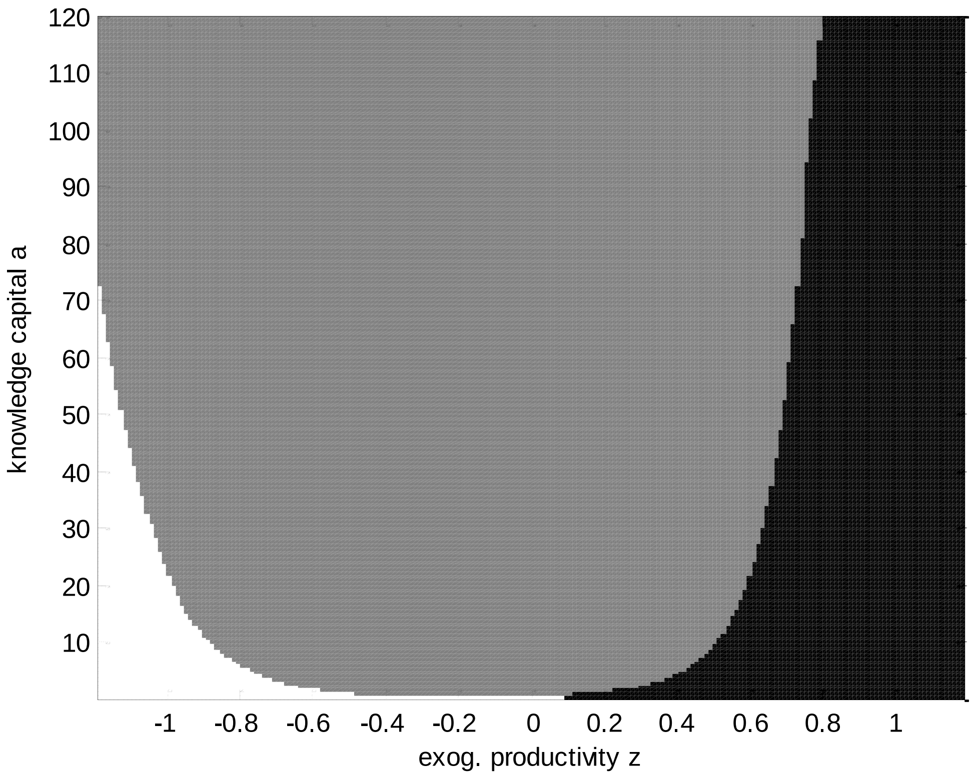
Comparing Table 6 to Panels A and C of Table 4 reveals that the main patterns of this augmented OP decomposition are broadly in line with our empirical results. In particular, as in the empirical decomposition, a large part of the covariance component in the model stems from the between-group effect of entrants, visitors and exiting firms. Moreover, in relative terms, the contribution of non-stayers is especially important in the service sector. Perhaps the main difference between the model and the empirical data is that in the service sector the within-group effect of non-stayer firms is negative in the data but positive in the model. In other words, the covariance between size and productivity among non-stayer firms is too high in the model relative to the data.

4.5 Firm dynamics

According to the model, the reason why the OP covariance component is closely related to firm entry and exit is twofold: First, because of overhead labor, labor productivity increases with firm size. Second, and more importantly, because of the complementarity between new R&D and already acquired knowledge, it is usually optimal for firms to let their knowledge capital increase or decrease only gradually. On one hand, it takes time for new firms that start with little knowledge capital to grow to large, high productivity firms. On the other hand, firms that are hit by adverse productivity shocks tend to allow their knowledge capital to depreciate slowly. Therefore, firms typically become small, low productivity firms before exiting altogether.

Figure 3 illustrates these dynamics. It divides the state space into regions where firms choose to i) grow (i.e. increase their knowledge capital), ii) shrink (decrease their knowledge capital), or iii) exit. Firms enter the market with a very low initial knowledge capital. If their exogenous productivity state is sufficiently high, they choose to invest in R&D, thereby increasing their knowledge capital. They continue to grow as long as the exogenous productivity state is sufficiently high relative to their knowledge capital. However, due to the mean reversion in the exogenous productivity state, at some point they are likely to find it optimal to let their knowledge capital decrease. Firms that are hit by a relatively adverse exogenous productivity shock exit immediately unless they have a lot of knowledge capital.

Figure 3: Firm's exit and R&D policy: black area=grow; grey area=shrink; white area=exit.



5 Distortions, firm turnover and productivity

In this section, we use the model to analyze two related issues. First, we ask whether the standard OP covariance component is a reliable measure of allocative efficiency in a set-up with endogenous firm turnover. Related to this, we also compare the covariance component to two alternative measures that relate directly to productivity dispersion, namely, the unweighted and weighted standard deviation of log labor productivity. Second, we ask whether allocation distortions should have different effects across sectors.

5.1 Distortions

We consider four different types of distortions, which we think of as stylized approximations of different real world distortions. The first distortion is an output tax and subsidy scheme where firms with relatively high technology are taxed, while those with relatively low technology are subsidized. We specify it as follows:

$$\tau(z,a)=\begin{cases}-\chi+\dfrac{\chi\exp(z)a^{\alpha}}{\overline{\exp(z)a^{\alpha}}}, & \text{for } \exp(z)a^{\alpha}\leq\overline{\exp(z)a^{\alpha}}\\ \chi-\dfrac{\chi\overline{\exp(z)a^{\alpha}}}{\exp(z)a^{\alpha}}, & \text{for } \exp(z)a^{\alpha}>\overline{\exp(z)a^{\alpha}}\end{cases},$$

where $\overline{\exp(z)a^{\alpha}}$ is the unweighted average of $\exp(z)a^{\alpha}$ across all firms in the benchmark economy (without distortions) and the parameter $0\leq\chi\leq1$ measures the tax and subsidy rate. When $\chi>0$, firms that have relatively high technology face a positive output tax, while firms with relatively low technology face a negative output tax. The absolute value of the tax or subsidy rate increases with χ. In reality, this kind of distortion can arise, for instance, from various policies that aim at protecting existing jobs, either by discouraging the use of new labor saving technologies, or by supporting declining industries.

The second distortion is a payroll subsidy for small firms. We specify it as follows:

$$s(w,r+l)=\begin{cases}\kappa w(r+l), & \text{for } r+l<\underline{e}\\ 0, & \text{for } r+l\geq\underline{e}\end{cases}, \qquad (14)$$

where $\kappa \geq 0$ is the subsidy date and $\underline{e} > 0$ is cut-off employment level determining which receive the subsidy. That is, as long as the firm is small enough (in terms of the number of employees), it receives a subsidy that is proportional to its payroll. We choose the cut-off employment level so that 10% of firms in the benchmark distribution are above the limit. In the data, the limit would correspond to 20 employees (90% of the firms in our data have less than 20 employees). We think of this subsidy as a proxy for various real world policies that seem to favor small firms at the expense of larger firms. In France, for instance, various labor regulations take effect when a firm reaches a threshold of 50 employees (Garicano et al. 2013). In Italy, a similar threshold of 15 employees can be identified (Schivardi and Torrini 2008).

The third distortion is an increase in the entry cost c_n, while the fourth distortion is an increase in the exit cost c_x (which is zero in the baseline calibrations). As discussed by Restuccia and (2008), there are large differences in entry costs across countries and at least part of this variation can be attributed to policies that create barriers to entry. The entry cost parameter is a proxy for such policies. Exit costs in turn can be related to layoff costs as well as various contract contingencies with buyers and suppliers.

5.2 Distortions and the OP decomposition

Figures 4 and 5 show how the distortions affect industry productivity and its determinants, as identified by the OP decomposition, namely, the unweighted average productivity and the covariance component. In the figure, the change in the covariance is displayed in percentage points. Figure 4 relates to the manufacturing sector calibration and Figure 5 to the service sector calibration. Figures A1 and A2 in the appendix provide further information about the effects of the distortions in the model that is calibrated to the manufacturing sector. Figure A1 displays how the distortions affect firm entry by showing the number and labor shares of entrants and visitors. Figures A2 show the decomposition of aggregate productivity.

Consider first aggregate productivity in the manufacturing calibration. The output tax and subsidy scheme lowers aggregate productivity by up to approximately 15 %. By further increasing this distortion, we can generate an arbitrarily large fall in aggregate productivity. A payroll subsidy decreases aggregate productivity by up to approximately 7 %. A further increase in the subsidy does not affect aggregate productivity very much. This is because at the highest payroll subsidy considered, nearly all firms are small enough to obtain the subsidy. Entry and exit costs have much more moderate effects on aggregate productivity, lowering aggregate productivity by only up to approximately 1 %. One cannot generate much larger declines in productivity by increasing these costs further. This is because, as shown in Figure A1, there is already very little entry (and exit) at the highest entry and exit costs considered. Eventually, the same set of firms would stay in the market forever, and further increases in entry or exit costs would have no effect in this set-up.

Qualitatively, the productivity effects of the distortions are similar in the service sector. However, all effects are much smaller in absolute terms. This may relate to the fact that the OP covariance term is much smaller in the service sector than in the manufacturing sector. Intuitively, distortions based on firm size or productivity are less harmful in a sector where firm size and productivity are not that tightly linked.

Figure A2 reveals that in all cases, the productivity decline can be largely attributed to stayer firms. Interestingly, the productivity contribution of stayer firms falls substantially, even with entry and exit costs. One reason why entry and exit costs do not substantially affect aggregate productivity is that they decrease the number of low productivity entrants.

Figure 4. Aggregate productivity and its OP decomposition: the effect of distortions in the manufacturing sector calibration, covariance change (%-points).

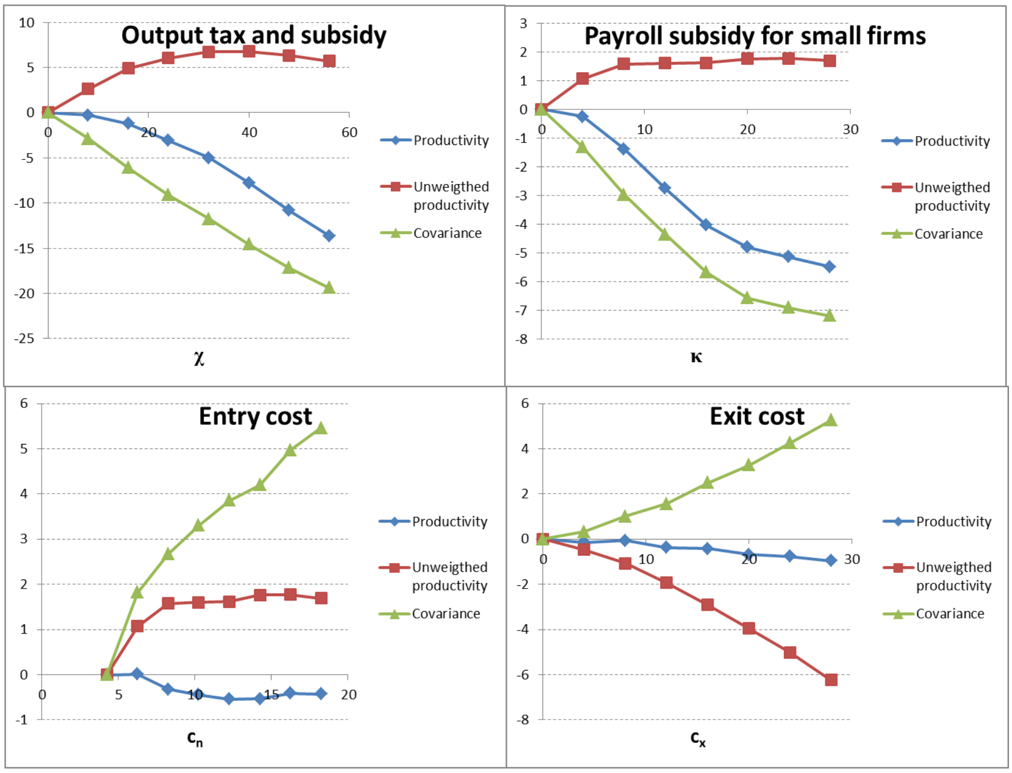
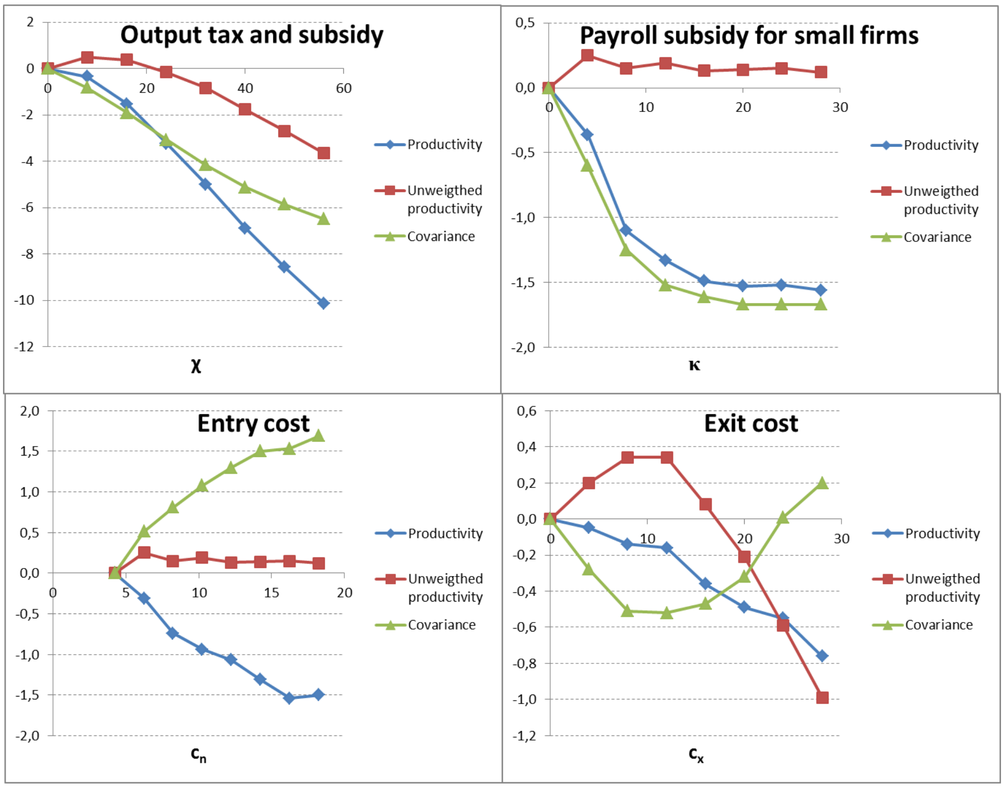


Figure 5. Aggregate productivity and its OP decomposition: the effect of distortions in the service sector calibration, covariance change (%-points).



How well does the OP covariance component capture these distortions? Figures 4 and 5 reveal that as we increase the output tax and subsidy scheme or the payroll subsidy, the covariance component declines roughly in line with aggregate productivity. In other words, it seems to capture these distortions very well. However, in the case of the manufacturing sector, increases in both entry and exit costs are associated with a substantial *increase* in the covariance component. Hence, in these cases, the covariance component gives a misleading impression of allocative efficiency. The OP covariance component does not react consistently to entry and exit costs in the service sector calibration either. However, it does not increase nearly as much as in the manufacturing sector calibration. In fact, it first slightly decreases with the exit cost.

The result that increasing entry or exit costs may work to increase the covariance component is perhaps surprising. Obviously, these costs decrease firm turnover (see Figure A1), and we have shown that in an accounting sense the entrants and exiting firms contribute positively to the covariance component. One might therefore expect that entry and exit costs would work to decrease the covariance component. Figures 6 and 7, which are based on our augmented OP decomposition, reveal that the contribution of non-stayer firms indeed decreases with entry and exit costs, mainly via the between-effect. At the same time, however, the contribution of stayer firms increases. The increase in the contribution of stayer firms tends to dominate, especially in the manufacturing sector.

The mechanism here is that both entry and exit costs decrease the equilibrium wage rate. Therefore, some low productivity firms that would exit in the baseline economy stay in the market when entry or exit costs are increased. As a result, the number of small low productivity firms increases among stayer firms. This is in turn increases the OP covariance component.

Figure 6. Distortions and contributions to the covariance component by firm group and mechanism with augmented OP decomposition in the manufacturing sector calibration.

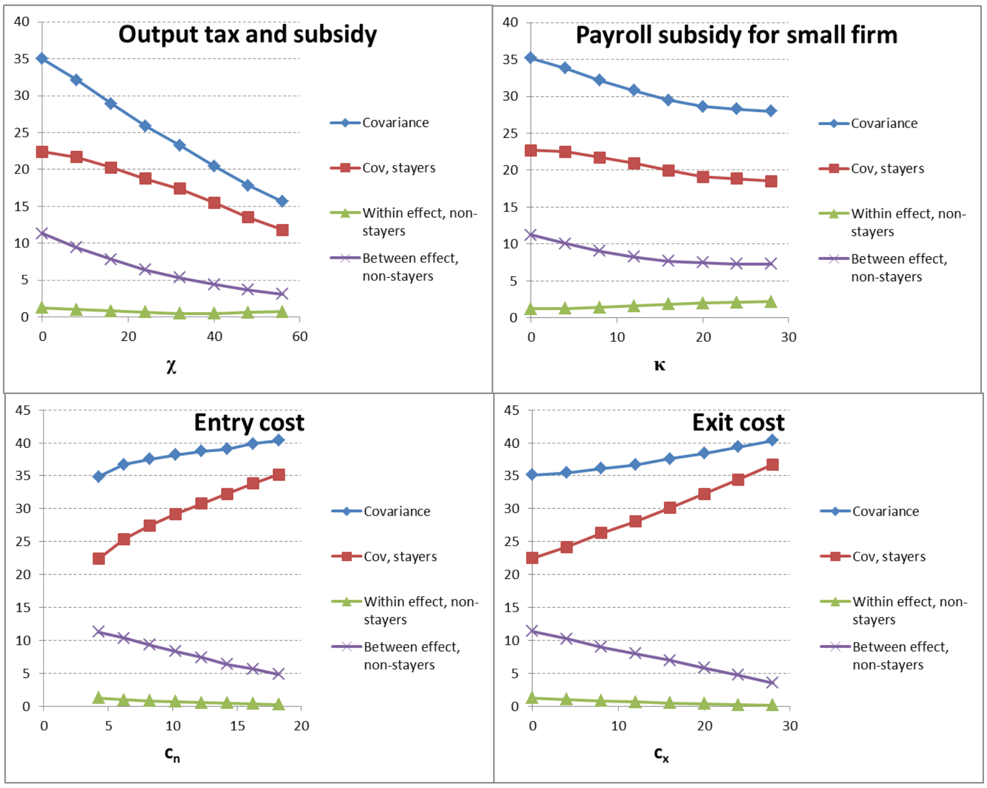
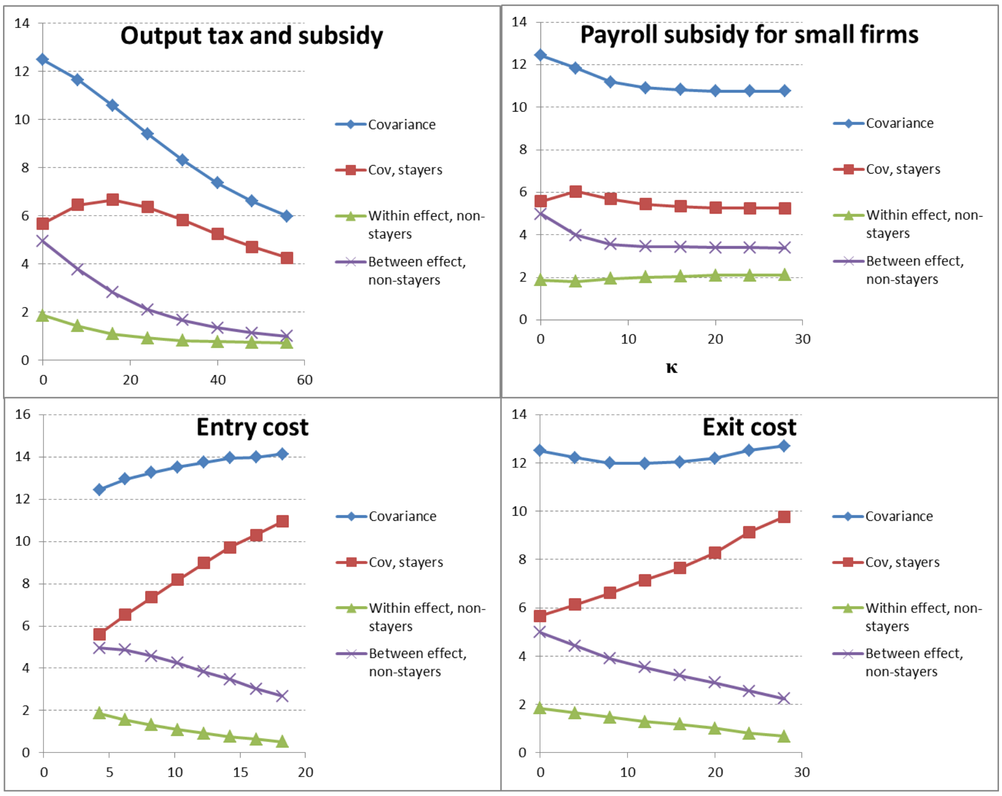


Figure 7. Distortions and contributions to the covariance component by firm group and mechanism with augmented OP decomposition in the service sector calibration.



5.3 Alternative measures of allocative efficiency

What about alternative measures of allocative efficiency? Figures 8 and 9 compare the covariance component with dispersion measures, showing the relative changes in these measures. We consider both the weighted and unweighted standard deviation of labor productivity. To ease the interpretation of the figures, the dispersion measures are plotted against an inverted right hand scale (greater dispersion should reflect lower allocative efficiency).

Figure 8. Measures of allocative efficiency: the effect of distortions in the manufacturing sector calibration, relative to baseline calibration.

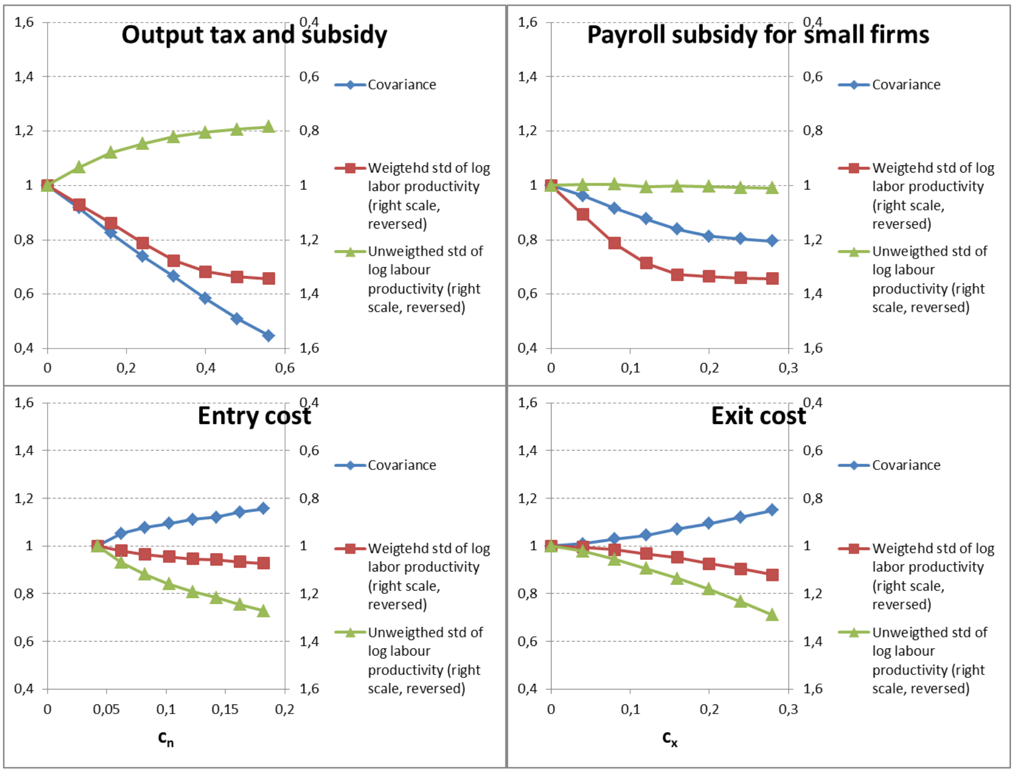
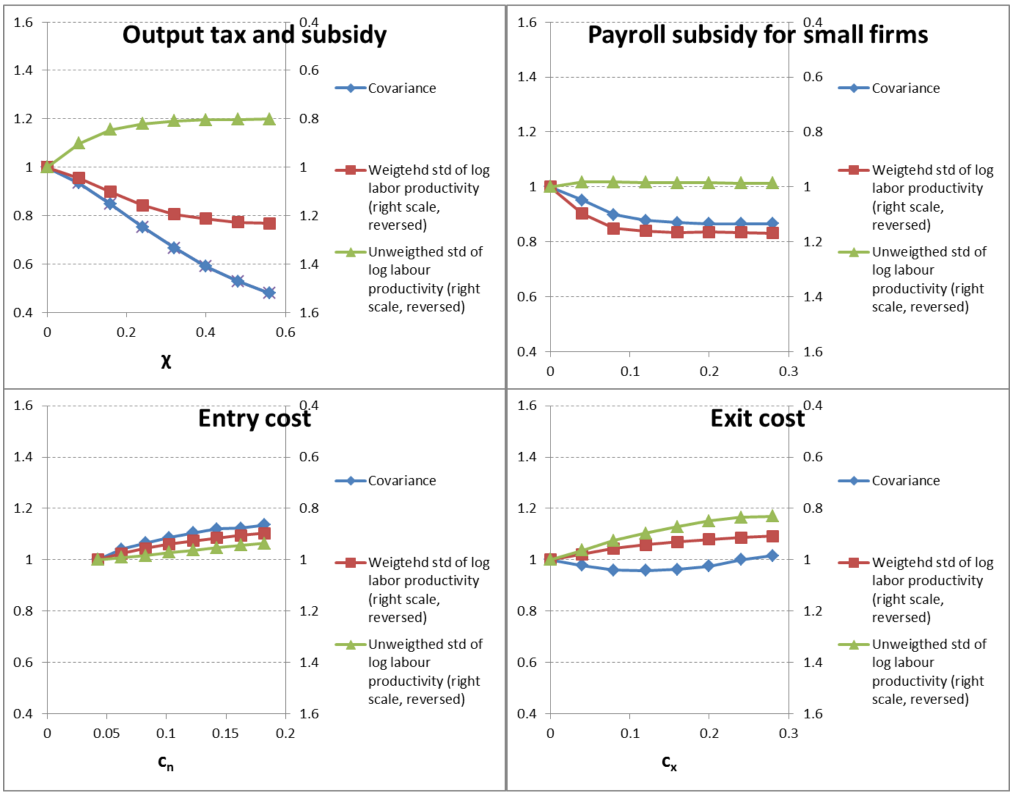


Figure 9. Measures of allocative efficiency: the effect of distortions in the service sector calibration, relative to baseline calibration.



None of the three measures reacts consistently to all the distortions in both calibrations. Arguably, however, it is the weighted standard deviation of labor productivity that works best. While it slightly decreases with entry and exit costs in the service sector calibration, it increases with all four distortions in the manufacturing calibration. This result appears to be at odds with Bartelsman et al. (2013), who argue that OP covariance outperforms productivity dispersion as a measure of allocative efficiency. However, Bartelsman et al. (2013) consider only an *unweighted* dispersion measure. In our view, input-weighted measures of productivity dispersion seem a priori more appealing than unweighted measures, as they are more directly linked to the aggregate productivity level, which is a weighted average of productivity levels across firms. The unweighted standard deviation of log labor productivity is indeed a very poor measure of allocative efficiency in our model economy as well. In Figure 8, for instance, it falls substantially (indicating increasing allocative efficiency) with the highly distortive output tax and subsidy scheme.

6 Discussion and conclusions

Recent macroeconomic literature has stressed the importance of resource allocation between firms for aggregate productivity. An important issue, therefore, is how to empirically measure allocative efficiency. We argued that measures of allocative efficiency used in the literature may be misleading because they do not account for firm entry and exit.

To study the role of firm turnover in resource allocation, we classified firms at a given point in time into mutually exclusive groups based on how recently they have entered the market and how soon they will exit. We used two productivity decomposition methods that together enabled us to examine the different mechanisms through which these firm groups contribute to industry productivity. The first of these measures the contribution of different firm groups to industry productivity. The second decomposition, which we refer to as the augmented Olley-Pakes (1996) productivity decomposition method, is developed here to examine the role of entrants and exiting firms in *resource allocation* in greater detail. This method allows us to study how the different firm groups contribute to the covariance component of industry productivity. As the covariance component is the most popular measure of allocative efficiency in the literature, our method provides an important extension by incorporating the role of firm turnover into the analysis of allocative efficiency in a way that is easy to interpret.

Application of these methods to comprehensive firm- and plant-level data sets that cover basically the whole business sector of Finland provides us with a rich description of the micro-level mechanisms that underlie industry productivity. Our empirical results reveal some important and systematic patterns that are robust across different industries. In particular, entrants and exiting firms make a large positive contribution to the covariance component of all firms. This latter effect is due entirely to the fact that entrants and exiting firms are typically relatively small and have low productivity. In the augmented OP decomposition, this effect is capture by the *between-group component*. On the other hand, resource allocation is less efficient among non-stayer firm groups (i.e., entrants, visitors and exiting firms) than among stayers, which is indicated by the negative *within-group component* for the non-stayer firms in our decomposition.

To understand the mechanisms behind our empirical results and to test alternative measures of allocative efficiency, we developed a model of firm dynamics that is roughly consistent with the main patterns revealed by our empirical productivity decompositions. The key element of the model is complementarity between existing knowledge capital and current R&D investment, together with entry and exit decisions.

In line with previous literature, we found that an output tax and subsidy scheme, which systematically favors low productivity firms over high productivity firms, or a payroll subsidy that is targeted to small firms, have the capacity to lower aggregate productivity substantially. Entry and exit costs, in contrast, have only a modest negative effect on aggregate productivity in the model. Their effect on aggregate productivity is mitigated by the fact that by reducing firm turnover, they also reduce the employment share of young firms that tend to have relatively low productivity.

We found that both the distortionary output tax and subsidy scheme and the payroll subsidy are well captured by the OP covariance component. That is, as we increase these distortions, the OP covariance component decreases together with aggregate productivity. In contrast, both entry and exit costs work to *increase* the OP covariance component and the effect can be substantial. The reason is that by lowering the wage rate, these distortions lengthen the life cycles of low productivity firms. As these firms are also small, this results in an increase in the covariance component.

We also considered labor productivity dispersion as an alternative measure of allocative efficiency. We found it to be crucial to use an input weighted measure of dispersion. While *unweighted* standard deviation of labor productivity fails to capture even the highly distortionary output tax and subsidy scheme, *weighted* standard deviation works much better. In fact, our results suggest that as a measure of allocative efficiency, it is at least as reliable as the OP covariance component.

It would be interesting to further explore the robustness of weighted productivity dispersion as a measure of allocative efficiency. On the other hand, it is unlikely that any single measure captures all potentially relevant distortions. More generally, our results highlight the need to use structural models together with empirical measures of allocative efficiency. An interesting avenue for future research would be to apply our augmented productivity decompositions to a set of different countries. One could then use a structural model to try to determine what types of country-specific distortions can explain the differences.

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Appendix 1. Derivation of decomposition formulas

Derivation of Equation (4):

By definition, the industry productivity level is a weighted average of the aggregate productivity levels of the firm groups:

$$\Phi_t = \frac{L_t^S}{L_t}\Phi_t^S + \sum_j \frac{L_t^j}{L_t}\Phi_t^j,\ j = N, X, V \tag{A.1}$$

Inserting $\frac{L_t^S}{L_{t\ t}} = 1 - \sum_j \frac{L_t^j}{L_t}\Phi_t^j$ into (A.1), we obtain

$$\Phi_t - \Phi_t^S = \sum_j \frac{L_t^j}{L_t}\left(\Phi_t^j - \Phi_t^S\right) \tag{A.2}$$

Derivation of Equation (7):

By use of the Olley-Pakes productivity decomposition, the difference in aggregate productivity levels between all firms and stayers can be represented as

$$\Phi_t - \Phi_t^S = \bar{\varphi}_t + \mathrm{cov}_t - \bar{\varphi}_t^S - \mathrm{cov}_t^S \tag{A.3}$$

Thus, the corresponding difference in the covariance component can written as

$$\mathrm{cov}_t - \mathrm{cov}_t^S = \Phi_t - \Phi_t^S - \left(\bar{\varphi}_t - \bar{\varphi}_t^S\right) \tag{A.4}$$

We then have

$$\begin{aligned} \mathrm{cov}_t - \mathrm{cov}_t^S &= \left(\frac{L_t^S}{L_t}\Phi_t^S + \sum_{j=N,X,V}\frac{L_t^j}{L_t}\Phi_t^j - \Phi_t^S\right) - \left(\frac{N_t^S}{N_t}\bar{\varphi}_t^S + \sum_{j=N,X,V}\frac{N_t^j}{N_t}\bar{\varphi}_t^j - \bar{\varphi}_t^S\right) \\ \Leftrightarrow \mathrm{cov}_t - \mathrm{cov}_t^S &= \sum_{j=N,X,V}\frac{L_t^j}{L_t}\left(\Phi_t^j - \Phi_t^S\right) - \sum_{j=N,X,V}\frac{N_t^j}{N_t}\left(\bar{\varphi}_t^j - \bar{\varphi}_t^S\right) \end{aligned} \tag{A.5}$$

By inserting into this expression the term for average employment, we obtain

$$\mathrm{cov}_t - \mathrm{cov}_t^S = \sum_{j=N,X,V}\frac{N_t^j \bar{L}_t^j}{N_t \bar{L}_t}\left(\Phi_t^j - \Phi_t^S\right) - \sum_{j=N,X,V}\frac{N_t^j}{N_t}\left(\bar{\varphi}_t^j - \bar{\varphi}_t^S\right) \tag{A.6}$$

Rearranging and using the Olley-Pakes decomposition of aggregate productivity yields

$$\mathrm{cov}_t - \mathrm{cov}_t^S = \sum_{j=N,X,V}\frac{N_t^j}{N_t}\left(\frac{\bar{L}_t^j}{\bar{L}_t}\left(\bar{\varphi}_t^j - \bar{\varphi}_t^S + \mathrm{cov}_t^j - \mathrm{cov}_t^S\right) - \left(\bar{\varphi}_t^j - \bar{\varphi}_t^S\right)\right) \tag{A.7}$$

which finally yields the following equation:

$$\text{cov}_t = \text{cov}_t^S + \sum_{j=N,X,V} \frac{L_t^j}{L_t}\left(\text{cov}_t^j - \text{cov}_t^S\right) + \sum_{j=N,X,V} \frac{N_t^j}{N_t}\left(\frac{\bar{L}_t^j}{\bar{L}_t} - 1\right)\left(\bar{\varphi}_t^j - \bar{\varphi}_t^S\right) \quad \text{(A.8)}$$

Appendix 2. Additional tables and figures

Table A.1. Descriptive statistics, averages over the period 2000-2003, firms

	Number of firms	Number of persons	Share of firms (%)				Share of emp. (%)			
			Stayers	Entrants	Exits	Visitors	Stayers	Entrants	Exits	Visitors
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Manufacturing	14 993	350 301	53,5	21,6	12,7	12,2	86,6	5,3	5,8	2,3
Construction	17 413	108 656	35,2	34,8	9	20,9	67	15,6	9,1	8,2
Services	74 677	554 204	33,1	35,1	10,5	21,4	69,9	15	7,8	7,3
TOTAL	107 082	1 013 161								
MANUFACTURING										
Food (15-16)	1 263	33 664	45,8	25,7	13,6	14,8	86,4	5,1	6,3	2,1
Textiles (17-19)	1 058	13 059	41,6	22,5	16,4	19,5	77,7	6,7	11,8	3,8
Wood (20)	1 376	19 112	46,8	24,7	11,7	16,8	78,9	9,1	7,2	4,7
Paper (21),	150	38 045	72,9	10,6	9,9	6,7	98,5	0,7	0,6	0,2
Printing (22)	1 642	28 087	52,8	18,9	17,0	11,3	83,5	5,4	8,8	2,3
Chemicals (24)	201	12 625	60,9	18,9	11,9	8,3	92,7	3,7	3,0	0,6
Rubber (25)	504	14 707	58,7	17,9	14,2	9,2	87,0	4,8	6,4	1,7
Non-met. minerals (26)	551	13 736	55,2	20,9	12,8	11,1	87,3	5,1	5,7	1,9
Basic metals (27)	111	15 043	59,9	16,6	16,8	6,7	94,8	2,0	2,8	0,5
Metal products (28)	3 008	35 383	51,5	23,8	11,9	12,8	75,3	10,2	10,4	4,0
Machinery (29)	2 089	46 438	49,3	24,9	12,1	13,7	85,1	6,0	6,1	2,7
Electr. mach.(30-31)	384	12 014	57,1	19,0	14,4	9,6	83,2	6,9	7,2	2,8
Telec. eq.&instr. (32-33)	752	37 200	51,8	25,0	11,8	11,4	93,2	2,8	2,9	1,1
Vehicles (34-35)	524	18 061	49,3	25,0	9,4	16,3	91,0	4,1	3,1	1,8
Other manuf. (36-37)	1 384	13 129	45,5	25,7	12,0	16,8	75,0	9,9	9,8	5,4
CONSTRUCTION										
Construction (45)	17 413	108 656	35,2	34,8	9,0	20,9	67,0	15,6	9,1	8,2
SERVICES										
Trade (50-52)	27 266	213 348	38,4	30,5	11,9	19,2	70,7	14,0	8,6	6,7
Hotels and rest. (55)	7 381	50 281	25,2	32,8	11,5	30,5	62,0	17,1	9,1	11,8
Transport (60-63)	17 673	91 343	22,3	52,9	4,7	20,2	68,8	19,5	4,9	6,9
Post and telecomm. (64)	332	37 757	41,2	27,6	10,2	21,0	95,0	2,0	1,4	1,7
Real estate activities (70)	3 703	18 138	36,8	31,8	12,8	18,6	53,1	24,4	12,8	9,7
Renting (71)	462	3 282	32,9	31,7	11,0	24,4	64,7	16,6	8,4	10,3
Computer activities (72)	2 130	29 533	27,3	35,1	12,4	25,2	68,4	13,8	8,6	9,3
R&D (73)	154	1 983	28,9	36,6	10,1	24,3	68,5	19,2	5,6	6,7
Legal services (741)	5 811	26 970	37,5	30,7	12,4	19,4	62,5	17,1	10,2	10,1
Engineering serv. (742-743)	3 893	26 438	42,3	30,6	12,2	15,0	67,7	14,4	12,5	5,3
Other bus. Serv. (744-748)	5 872	55 130	27,2	36,5	10,4	25,9	69,3	15,6	7,4	7,7

Table A.2. Variation in productivity levels, averages over the period 2000-2003, firms (%)

	std of log productivity		Productivity gap to stayers					
			Unweighted average			Weighted average		
	Weight	Unw.	Entr.	Exits	Visit.	Entr.	Exits	Visit.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Manufacturing	46,9	57,6	-15,1	-14,3	-37,2	-30,8	-33,2	-53,0
Construction	41,0	53,5	-8,0	-9,9	-19,8	-12,7	-11,4	-28,2
Services	59,6	68,1	-21,3	-16,2	-40,1	-10,0	-4,3	-26,5
MANUFACTURING								
Food (15-16)	43,7	59,0	-17,1	-19,0	-43,7	-32,3	-31,7	-58,5
Textiles (17-19)	48,6	63,6	-22,7	-25,8	-42,9	-30,0	-29,1	-44,1
Wood (20)	44,8	59,9	-15,4	-15,7	-35,4	-11,1	-15,7	-38,7
Paper (21),	44,5	59,0	-22,5	-21,1	-60,8	-51,9	-68,2	-91,5
Printing (22)	49,2	58,8	-14,6	-11,6	-32,4	-20,9	-10,3	-45,1
Chemicals (24)	55,2	92,3	-36,0	-23,0	-53,3	-29,6	-31,0	-50,0
Rubber (25)	39,2	54,3	-17,0	-17,3	-35,5	-8,9	-13,4	-19,4
Non-met. minerals (26)	40,7	56,4	-26,6	0,2	-48,4	-43,6	-9,7	-44,1
Basic metals (27)	40,4	46,4	-11,6	-1,9	-45,9	-43,5	-33,2	-60,5
Metal products (28)	35,5	46,7	-8,8	-10,2	-25,5	-10,8	-15,3	-26,1
Machinery (29)	41,1	52,4	-7,7	-12,3	-19,0	-16,0	-24,1	-28,6
Electr. mach.(30-31)	37,9	52,1	-12,2	-10,3	-39,9	-16,8	-19,9	-46,6
Telec. equip.&instr. (32-33)	78,6	63,4	-8,0	-16,4	-32,7	-74,1	-86,0	-108,0
Vehicles (34-35)	38,8	59,2	-11,8	-5,5	-26,6	-11,6	-6,2	-37,9
Other manuf. (36-37)	44,3	57,1	-21,9	-15,9	-46,0	-17,0	-14,2	-31,7
CONSTRUCTION								
Construction (45)	41,0	53,5	-8,0	-9,9	-19,8	-12,7	-11,4	-28,2
SERVICES								
Trade (50-52)	59,6	74,2	-28,7	-22,1	-56,0	-17,0	-11,0	-40,1
Hotels and restaurants (55)	51,8	62,5	-21,5	-16,7	-41,3	-11,1	-6,8	-31,1
Transport (60-63)	43,0	47,7	-17,5	-14,0	-25,2	-20,7	-21,3	-31,2
Post and telecomm. (64)	74,1	76,9	-21,1	-10,4	-34,9	6,1	38,7	-2,0
Real estate activities (70)	100,3	94,3	8,4	3,6	-0,6	39,6	-7,6	7,8
Renting (71)	82,8	92,3	-35,6	-18,1	-61,8	-39,0	-4,8	-60,1
Computer activities (72)	66,8	81,7	-25,6	-18,8	-40,8	-48,4	-26,3	-49,0
R&D (73)	90,2	81,4	-7,0	10,0	-22,4	46,0	68,2	28,5
Legal services (741)	67,9	69,9	-10,1	-10,6	-24,6	-11,6	-11,8	-22,1
Engineering serv. (742-743)	44,4	58,2	-12,6	-13,1	-27,3	-14,7	-3,7	-25,8
Other bus. Serv. (744-748)	68,0	63,5	-15,3	-10,5	-31,2	31,7	36,8	19,6

Note: The sector level numbers are employment weighted averages of the industry level numbers.

Table A.3. Decomposition of the productivity levels by industries, firms (%)

	Contr. of non-stayers	Contribution of			Productivity gap		
		Entrants	Exits	Visit.	Entrants	Exits	Visit.
	(1)= (2)+(3)+(4)	(2)	(3)	(4)	(5)	(6)	(7)
MANUFACTURING							
Food (15-16)	-4,9	-1,6	-2,0	-1,3	-32,3	-31,7	-58,5
Textiles (17-19)	-7,1	-2,0	-3,5	-1,7	-30,0	-29,1	-44,1
Wood (20)	-3,9	-1,0	-1,0	-1,8	-11,1	-15,7	-38,7
Paper (21),	-1,0	-0,4	-0,4	-0,2	-51,9	-68,2	-91,5
Printing (22)	-3,1	-1,1	-0,9	-1,0	-20,9	-10,3	-45,1
Chemicals (24)	-2,1	-1,0	-0,9	-0,2	-29,6	-31,0	-50,0
Rubber (25)	-1,8	-0,5	-0,8	-0,5	-8,9	-13,4	-19,4
Non-met. minerals (26)	-3,6	-2,2	-0,6	-0,8	-43,6	-9,7	-44,1
Basic metals (27)	-2,0	-0,8	-0,9	-0,2	-43,5	-33,2	-60,5
Metal products (28)	-3,7	-1,1	-1,6	-1,0	-10,8	-15,3	-26,1
Machinery (29)	-3,2	-1,0	-1,5	-0,8	-16,0	-24,1	-28,6
Electr. mach.(30-31)	-3,9	-1,2	-1,4	-1,3	-16,8	-19,9	-46,6
Telec. equip.&instr. (32-33)	-5,0	-1,8	-2,1	-1,1	-74,1	-86,0	-108,0
Vehicles (34-35)	-1,5	-0,4	-0,3	-0,8	-11,6	-6,2	-37,9
Other manuf. (36-37)	-4,8	-1,7	-1,4	-1,7	-17,0	-14,2	-31,7
CONSTRUCTION							
Construction (45)	-5,4	-2,0	-1,0	-2,3	-12,7	-11,4	-28,2
SERVICES							
Trade (50-52)	-6,0	-2,4	-0,9	-2,7	-17,0	-11,0	-40,1
Hotels and restaurants (55)	-6,2	-1,9	-0,6	-3,7	-11,1	-6,8	-31,1
Transport (60-63)	-7,3	-4,1	-1,0	-2,1	-20,7	-21,3	-31,2
Post and telecom. (64)	0,6	0,1	0,5	0,0	6,1	38,7	-2,0
Real estate activities (70)	9,5	9,7	-1,0	0,8	39,6	-7,6	7,8
Renting (71)	-13,3	-6,5	-0,6	-6,2	-39,0	-4,8	-60,1
Computer activities (72)	-13,5	-6,7	-2,3	-4,6	-48,4	-26,3	-49,0
R&D (73)	15,5	9,3	4,3	1,9	46,0	68,2	28,5
Legal services (741)	-5,4	-2,0	-1,2	-2,2	-11,6	-11,8	-22,1
Engineering serv. (742-743)	-3,9	-2,1	-0,5	-1,3	-14,7	-3,7	-25,8
Other bus. serv. (744-748)	9,1	5,0	2,6	1,5	31,7	36,8	19,6

Table A.4a. Augmented OP productivity decomposition by industry (%)

	OP(All)	OP(Stayers)	Within groups	Between groups
	(1)=(2)+(3)+(4)	(2)	(3)	(4)
MANUFACTURING				
Food (15-16)	48,6	43,0	-1,1	6,7
Textiles (17-19)	12,8	8,1	-2,4	7,1
Wood (20)	34,5	24,9	0,0	9,6
Paper (21),	55,6	51,7	-2,3	6,3
Printing (22)	25,2	22,0	1,3	2,0
Chemicals (24)	8,7	-3,9	2,8	9,8
Rubber (25)	15,2	11,7	-1,2	4,7
Non-met. minerals (26)	5,8	1,0	-1,2	5,9
Basic metals (27)	41,0	29,2	4,2	7,5
Metal products (28)	17,4	15,6	-1,7	3,4
Machinery (29)	30,2	28,1	-1,1	3,2
Electr. mach.(30-31)	38,2	35,8	-1,3	3,8
Telec. equip.&instr. (32-33)	115,9	124,2	-15,2	6,9
Vehicles (34-35)	8,8	5,7	-2,0	5,1
Other manuf. (36-37)	6,6	4,9	-3,2	4,9
CONSTRUCTION				
Construction (45)	18,3	19,1	-3,8	3,0
SERVICES				
Trade (50-52)	30,0	21,2	2,4	6,5
Hotels and restaurants (55)	0,4	-0,1	-1,3	1,9
Transport (60-63)	29,5	26,0	-2,3	5,8
Post and telecom. (64)	-3,0	8,0	-4,1	-6,9
Real estate activities (70)	-9,7	-8,1	1,2	-2,9
Renting (71)	10,1	-0,4	7,8	2,7
Computer activities (72)	11,7	6,6	-0,8	5,9
R&D (73)	-7,4	-11,1	-4,5	8,2
Legal services (741)	11,0	15,1	-3,4	-0,7
Engineering serv. (742-743)	10,2	8,2	1,2	0,8
Other bus. serv. (744-748)	-27,0	-29,5	-1,7	4,2

Table A.4b. Augmented OP productivity decomposition by industry, contributions by firm groups (%)

	Within groups	Contribution of			Between groups	Contribution of		
		entrants	exits	visitors		entrants	exits	visitors
	(1)= (2)+(3)+(4)	(2)	(3)	(4)	(5)= (6)+(7)+(8)	(6)	(7)	(8)
MANUFACTURING								
Food (15-16)	-1,1	-1,1	0,4	-0,4	6,7	2,5	1,1	3,1
Textiles (17-19)	-2,4	-0,5	-1,5	-0,4	7,1	0,7	1,6	4,8
Wood (20)	0,0	0,8	-0,4	-0,3	9,6	2,0	1,9	5,7
Paper (21),	-2,3	-2,0	0,0	-0,3	6,3	2,0	1,4	2,9
Printing (22)	1,3	1,8	-0,2	-0,3	2,0	0,0	0,4	1,6
Chemicals (24)	2,8	2,1	0,4	0,2	9,8	2,0	1,9	5,8
Rubber (25)	-1,2	-0,3	-0,6	-0,3	4,7	0,8	1,2	2,7
Non-met. minerals (26)	-1,2	-1,4	0,1	0,2	5,9	0,4	2,2	3,3
Basic metals (27)	4,2	-0,2	0,0	4,5	7,5	2,3	3,2	2,1
Metal products (28)	-1,7	-1,1	-0,2	-0,4	3,4	1,0	0,7	1,7
Machinery (29)	-1,1	-0,9	0,2	-0,4	3,2	0,8	0,7	1,7
Electr. mach.(30-31)	-1,3	0,2	-1,2	-0,3	3,8	1,3	0,4	2,0
Telec. equip.&instr. (32-33)	-15,2	-5,7	-8,1	-1,5	6,9	2,6	0,6	3,7
Vehicles (34-35)	-2,0	-3,1	1,0	0,1	5,1	1,5	0,4	3,2
Other manuf. (36-37)	-3,2	0,6	-3,7	-0,1	4,9	0,9	0,9	3,1
CONSTRUCTION								
Construction (45)	-3,8	-1,6	-0,7	-1,4	3,0	1,0	0,1	1,9
SERVICES								
Trade (50-52)	2,4	1,3	0,8	0,2	6,5	1,4	1,0	4,0
Hotels and restaurants (55)	-1,3	-0,1	-0,7	-0,6	1,9	0,2	0,4	1,3
Transport (60-63)	-2,3	-1,0	-0,6	-0,6	5,8	3,9	0,1	1,8
Post and telecom. (64)	-4,1	0,4	-3,7	-0,8	-6,9	-1,2	3,5	-9,2
Real estate activities (70)	1,2	1,3	-0,9	0,7	-2,9	-0,6	-0,4	-1,9
Renting (71)	7,8	5,1	1,1	1,7	2,7	1,3	-0,1	1,4
Computer activities (72)	-0,8	1,4	-1,2	-1,0	5,9	1,7	0,0	4,3
R&D (73)	-4,5	-1,4	-2,4	-0,7	8,2	1,7	-0,3	6,8
Legal services (741)	-3,4	-1,3	-1,3	-0,8	-0,7	-0,2	-0,2	-0,3
Engineering serv. (742-743)	1,2	0,7	0,4	0,2	0,8	0,1	0,0	0,7
Other bus. serv. (744-748)	-1,7	0,2	-2,9	1,1	4,2	1,6	-0,5	3,1

Table A.5. Decomposition of the contribution to the aggregate productivity level by plant groups (%)

	Contribution of non-stayers	Contribution of			Productivity gap		
		entrants	exits	visit.	entrants	exits	visit.
	(1)= (2)+(3)+(4)	(2)	(3)	(4)	(5)	(6)	(7)
Manufacturing	-5,2	-1,9	-2,4	-1,0	-31,5	-27,4	-59,0
Construction	-8,3	-3,2	-1,8	-3,3	-19,7	-15,5	-36,3
Services	-5,2	-2,2	-1,3	-1,7	-13,9	-10,9	-27,8

Table A.6. Augmented Olley-Pakes productivity decomposition, plant data (%)

Panel A: Manufacturing

			Contibution of non-stayers	
	OP(All)	OP(Stayers)	Within groups	Between groups
	(1)=(2)+(3)+(4)	(2)	(3)	(4)
Total	36,9	33,5	-2,2	5,5
Contributions				
Entrants			*-1,0*	*1,4*
Exits			*-1,0*	*1,1*
Visitors			*-0,2*	*3,0*

Panel B: Construction

			Contibution of non-stayers	
	OP(All)	OP(Stayers)	Within groups	Between groups
	(1)=(2)+(3)+(4)	(2)	(3)	(4)
Total	18,3	19,1	-3,8	3,0
Contributions				
Entrants			*-1,6*	*1,0*
Exits			*-0,7*	*0,1*
Visitors			*-1,4*	*1,9*

Panel C: Services

			Contibution of non-stayers	
	OP(All)	OP(Stayers)	Within groups	Between groups
	(1)=(2)+(3)+(4)	(2)	(3)	(4)
Total	15,4	11,3	0,0	4,2
Contributions				
Entrants			*0,5*	*1,4*
Exits			*-0,4*	*0,5*
Visitors			*-0,1*	*2,2*

Notes: The numbers refer to the weighted average of industries within sector (weighted by the employment share of the industry) and the average of years 2000-2003, calculated by plant data. Components may not add up due to rounding.

Table A.7. Decomposition of the aggregate productivity level, manufacturing, sensitivity checks (%)

Manufacturing	Contribution of non-stayers	Contribution of			Productivity gap		
		entrants	exits	visit.	entrants	exits	visit.
	(1)= (2)+(3)+(4)	(2)	(3)	(4)	(5)	(6)	(7)
Cut-off threshold (*)							
more than 0	-3,4	-1,2	-1,3	-0,9	-30,6	-33,4	-51,4
at least 1	**-3,4**	**-1,2**	**-1,3**	**-0,9**	**-30,8**	**-33,2**	**-53,0**
more than 1	-3,3	-1,0	-1,4	-0,9	-29,4	-33,6	-51,9
at least 5	-3,2	-1,1	-1,3	-0,8	-30,2	-33,7	-48,4
at least 10	-3,2	-1,1	-1,3	-0,9	-28,3	-34,1	-48,6
at least 20	-3,5	-1,1	-1,4	-0,9	-29,4	-38,3	-48,4
Year (**)							
2000	-3,1	-1,2	-1,1	-0,8	-25,9	-27,9	-46,8
2001	-3,7	-1,2	-1,6	-0,9	-34,3	-37,6	-52,6
2002	-3,2	-0,9	-1,4	-0,9	-29,4	-33,7	-50,2
2003	-3,8	-1,3	-1,4	-1,1	-33,6	-33,7	-62,5
Average	**-3,4**	**-1,2**	**-1,3**	**-0,9**	**-30,8**	**-33,2**	**-53,0**

Construction	Contribution of non-stayers	Contribution of			Productivity gap		
		entrants	exits	visit.	entrants	exits	visit.
	(1)= (2)+(3)+(4)	(2)	(3)	(4)	(5)	(6)	(7)
Cut-off threshold (*)							
more than 0	-4,7	-1,7	-1,1	-1,9	-11,0	-12,4	-24,3
at least 1	**-5,4**	**-2,0**	**-1,0**	**-2,3**	**-12,7**	**-11,4**	**-28,2**
more than 1	-5,0	-1,6	-1,1	-2,3	-12,3	-10,9	-26,6
at least 5	-5,4	-2,0	-0,8	-2,6	-12,9	-9,1	-25,5
at least 10	-5,5	-2,0	-0,7	-2,8	-13,9	-10,5	-28,8
at least 20	-5,4	-1,8	-0,9	-2,7	-12,2	-8,8	-29,0
Year (**)							
2000	-5,9	-2,5	-0,8	-2,5	-13,9	-9,7	-31,1
2001	-5,3	-1,7	-1,3	-2,3	-11,2	-13,8	-26,4
2002	-4,7	-1,5	-1,1	-2,1	-11,3	-11,3	-25,8
2003	-5,6	-2,2	-0,9	-2,4	-14,2	-10,9	-29,6
Average	**-5,4**	**-2,0**	**-1,0**	**-2,3**	**-12,7**	**-11,4**	**-28,2**

Services	Contribution of non-stayers	Contribution of			Productivity gap		
		entrants	exits	visit.	entrants	exits	visit.
	(1)= (2)+(3)+(4)	(2)	(3)	(4)	(5)	(6)	(7)
Cut-off threshold (*)							
more than 0	-4,1	-1,7	-0,6	-1,8	-11,2	-5,6	-25,6
at least 1	**-4,0**	**-1,5**	**-0,5**	**-2,0**	**-10,0**	**-4,3**	**-26,5**
more than 1	-3,1	-0,7	-0,6	-1,8	-6,5	-3,6	-22,6
at least 5	-0,9	0,2	-0,1	-1,0	-0,1	2,8	-12,5

at least 10	-0,3	0,5	0,0	-0,9	1,9	4,9	-10,5
at least 20	-1,3	0,0	-0,3	-1,1	-1,9	1,2	-15,2
Year (**)							
2000	-3,4	-1,5	-0,3	-1,7	-8,7	2,4	-22,7
2001	-3,7	-1,3	-0,4	-2,0	-9,0	-2,5	-25,4
2002	-3,9	-1,2	-0,8	-1,9	-9,6	-8,8	-26,9
2003	-5,1	-2,0	-0,6	-2,4	-12,9	-8,1	-31,2
Average	**-4,0**	**-1,5**	**-0,5**	**-2,0**	**-10,0**	**-4,3**	**-26,5**

Note: Computations are made with firm data
(*) the average of years 2000-2003
(**) firms employing at least one person

Table A.8a. Augmented OP productivity decomposition, manufacturing sector, sensitivity checks (%)

	OP(All)	OP(Stayers)	Within groups	Between groups
	(1)=(2)+(3)+(4)	(2)	(3)	(4)
Cut-off threshold (*)				
more than 0	33,8	30,0	-1,6	5,4
at least 1	**33,9**	**27,8**	**-1,1**	**7,2**
more than 1	31,7	27,3	-1,3	5,7
at least 5	27,2	24,2	-1,5	4,5
at least 10	25,6	23,5	-1,8	4,0
at least 20	25,2	22,3	-1,6	4,4
Year (**)				
2000	28,4	23,3	-1,0	6,1
2001	35,0	30,7	-1,6	5,9
2002	33,1	28,9	-1,2	5,4
2003	39,0	28,4	-0,6	11,2
Average	**33,9**	**27,8**	**-1,1**	**7,2**

Note: Computations are made with firm data

(*) the average of years 2000-2003

(**) firms employing at least one person

Table A.8b. Augmented OP productivity decomposition, manufacturing sector, sensitivity checks (%)

	Within groups	Contribution of			Between groups	Contribution of		
		entrants	exits	visitors		entrants	exits	visitors
	(1)= (2)+(3)+(4)	(2)	(3)	(4)	(5)= (6)+(7)+(8)	(6)	(7)	(8)
Cut-off threshold (*)								
more than 0	-1,6	-0,7	-0,6	-0,4	5,4	1,7	0,9	2,8
at least 1	**-1,1**	**-0,4**	**-0,5**	**-0,2**	**7,2**	**2,5**	**1,0**	**3,7**
more than 1	-1,3	-0,5	-0,6	-0,2	5,7	1,5	1,3	2,9
at least 5	-1,5	-0,6	-0,7	-0,2	4,5	1,4	1,2	1,9
at least 10	-1,8	-0,7	-0,7	-0,3	4,0	0,9	1,0	2,1
at least 20	-1,6	-0,6	-0,5	-0,4	4,4	1,0	1,7	1,7
Year (**)								
2000	-1,0	-0,4	-0,5	-0,2	6,1	3,0	0,7	2,4
2001	-1,6	-0,6	-0,8	-0,3	5,9	1,7	1,0	3,2
2002	-1,2	-0,5	-0,5	-0,2	5,4	1,0	1,3	3,1
2003	-0,6	-0,2	-0,3	0,0	11,2	4,2	0,9	6,1
Average	**-1,1**	**-0,4**	**-0,5**	**-0,2**	**7,2**	**2,5**	**1,0**	**3,7**

Note: Computations are made with firm data

(*) the average of years 2000-2003

(**) firms employing at least one person

Figure A1. Distortions and the shares of firms and employment in the manufacturing sector calibration.

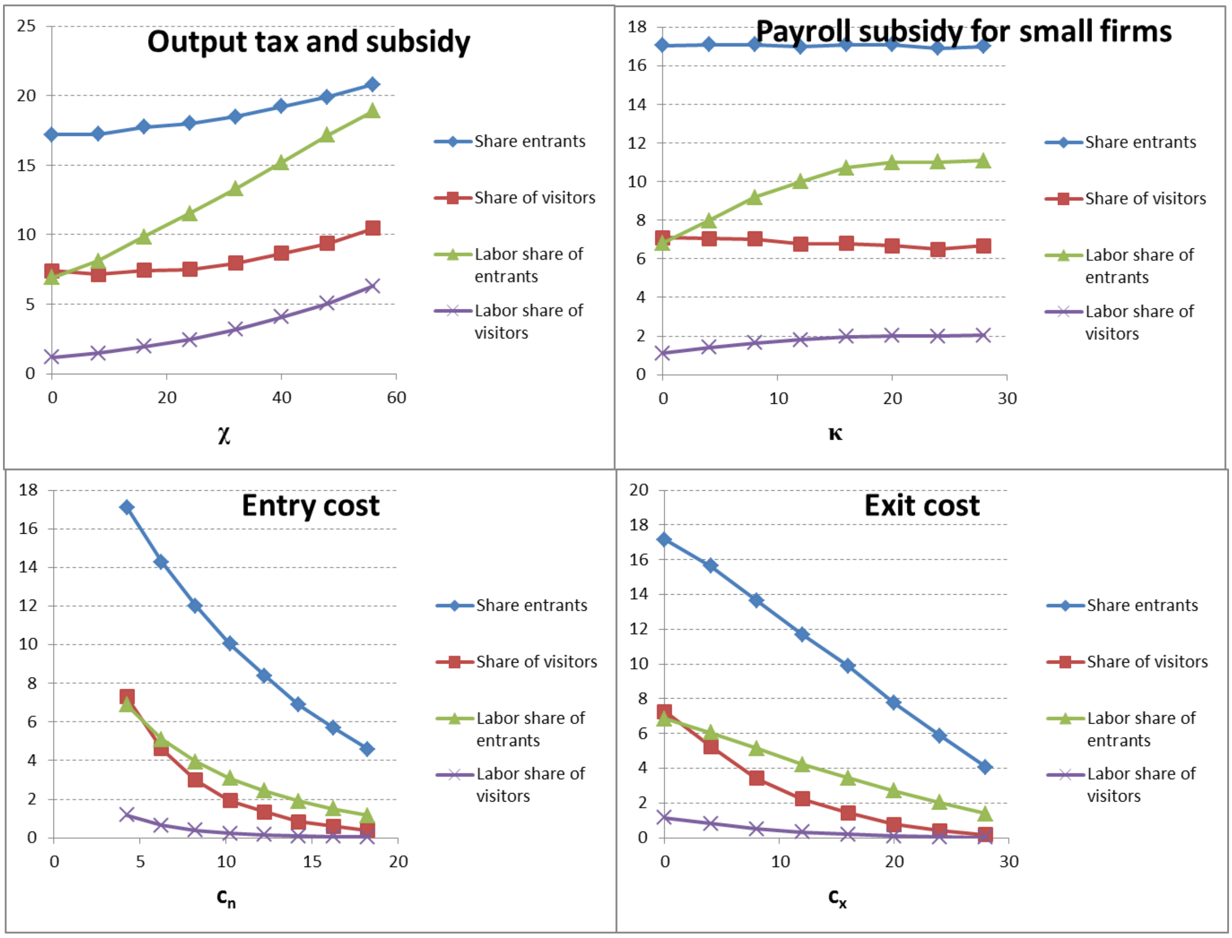

Figure A2. Distortions and contributions to aggregate productivity by firm group in the manufacturing sector calibration.