Employment protection, firm selection, and growth*

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Abstract

This paper analyzes the effect of firing costs on aggregate productivity growth. For this purpose, a model of endogenous growth through selection and imitation is developed. It is consistent with recent evidence on firm dynamics and on the importance of reallocation for productivity growth. In the model, growth is driven by selection among heterogeneous incumbent firms, and is sustained as entrants imitate the best incumbents. In this framework, firing costs not only induce misallocation of labor, but also affect growth by affecting firms' exit decisions. Importantly, charging firing costs only to continuing firms raises growth by promoting selection. Also charging them to exiting firms is akin to an exit tax, hampers selection, and reduces growth – by 0.1 percentage points in a calibrated version of the model. With job turnover very similar in the two settings, this implies that the treatment of exiting firms matters for welfare. In addition, the impact on growth rates is larger in sectors where firms face larger idiosyncratic shocks, as in services. This fits evidence that recent EU-US growth rate differences are largest in these sectors and implies that firing costs can play a role here. A brief empirical analysis of the impact of firing costs on the size of exiting firms supports the model's conclusions.

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1 Introduction

This paper analyzes the effect of labor market regulation on productivity growth, a topic that is much less researched than their impact on the level of productivity or on employment. For this purpose, a heterogeneous-firm model with endogenous growth is developed. Besides being consistent with recent evidence on firm dynamics, the model can also account for the fact that recent productivity growth differences between the US and the EU were particularly strong in the IT-using service sector. Employment protection legislation (EPL) here does not only affect the efficiency of the allocation of labor across plants or the incentive to work or to search as in most of the existing literature, but also affects the endogenous growth of aggregate productivity through its impact on the market selection process through the entry and exit margins.

Recent empirical research on firm dynamics has highlighted the importance of entry and exit and the heterogeneity of firms and plants. For example, Dwyer (1998) finds that productivity differs by a factor 3 between establishments in the 9th and the 2nd decile of the productivity distribution in the US textile sector. Foster, Haltiwanger and Krizan (2001) (FHK) find that in the US Census of Manufactures, more than a quarter of the increase in aggregate productivity between 1977 and 1987 was due to entry and exit. This is even more pronounced in the retail sector, as they find in their (2006) paper. The contribution of exit to aggregate productivity is positive in almost all of the 24 industrial and developing countries analyzed by Bartelsman, Haltiwanger and Scarpetta (2004) (BHS). Gabler and Licandro (2005) find in a calibration exercise that around half of US post-war productivity growth can be traced to the process of market selection, entry, and exit.[1]

The importance of entry and exit varies across industries. Generally, they contribute more to growth in sectors with high turbulence and with high TFP growth (BHS). These were precisely the sectors where Europe lagged US productivity growth in recent years (van Ark, Inklaar and McGuckin 2002, Blanchard 2004). To be precise, labor productivity in IT-using services,[2] a sector making up 26% of US GDP in 2000, grew by 5.4% yearly in the US and by only 1.4% in the EU in the period 1995-2000, and thereby made the largest contribution to the aggregate productivity growth difference of 2.5% vs 1.4% in that period. Differences in other sectors of

[1] Some extensive surveys of methods and results on firm-level dynamics for developed and developing countries are Baldwin (1995), Roberts and Tybout (1996), Sutton (1997), Haltiwanger (1997), Caves (1998), Bartelsman and Doms (2000), Tybout (2000), Foster, Haltiwanger and Krizan (2001, 2006), Bartelsman, Scarpetta and Schivardi (2003), Bartelsman, Haltiwanger and Scarpetta (2004), and references therein.

[2] These are defined as those service industries with an above-median ratio of IT capital services to capital services in US data for the year 2000.

comparable importance were much smaller.

Theory suggests that EPL imposes tighter constraints on firms in these more turbulent sectors (this idea is present in the literature at least since Bentolila and Bertola (1990)). Indeed, Pierre and Scarpetta (2004) provide empirical evidence that innovative firms feel particularly constrained by EPL. Going beyond this, Scarpetta, Hemmings, Tressel and Woo (2002) provide tentative evidence that EPL is negatively related to productivity growth both directly, and indirectly through reduced firm entry. Similarly, Gust and Marquez (2004) establish an empirical link between EPL and lower growth that passes through lower use of information technology.[3]

These pieces of evidence suggest the following account: productivity growth is higher in high-turbulence industries. In these industries, EPL constrains firms more strongly. With stricter EPL in continental Europe compared to the US, this fits the pattern of recent productivity growth differences showing up particularly in the IT-using service sector.

This paper takes this evidence as a point of departure. The mechanism of growth through selection and experimentation developed here fits many facts on firm dynamics and introduces a relationship between turbulence and growth. Imposing EPL in the form of firing costs then allows matching empirical productivity growth differences. The basic model is very similar to the one developed in Gabler and Licandro (2005). In its treatment of firing costs, the analysis is related to the seminal paper of Hopenhayn and Rogerson (1993), and the more recent ones by Alvarez and Veracierto (2001), Veracierto (2001), and Samaniego (2006*a*). These four all analyze the effect of firing costs on the level of aggregate productivity. They employ a setting of exogenous growth and concentrate on the static efficiency of the allocation of labor. Bertola (1994), conversely, analyzes the effect of hiring and firing costs on growth, using a model of endogenous growth through variety expansion. In such a setting, firing costs affect entry but not exit, so that the selection effect that is crucial here cannot arise.[4]

In the model developed here, firms receive idiosyncratic productivity shocks and therefore dif-

[3]Additional effects can arise through specialization. Scarpetta et al. (2002) find that industries with wider productivity dispersion have higher average productivity. If the high level of productivity dispersion is due to large variance of idiosyncratic shocks, employment protection legislation is more binding in these industries. Indeed, Cuñat and Melitz (2005) provide some evidence that high-EPL countries tend to specialize in low-dispersion industries, avoiding the industries where EPL has more bite. In a similar vein, Samaniego (2006*b*) analyzes how EPL can constrain technology adoption and shape specialization patterns in the presence of exogenous embodied technical progress. EPL might also induce firms to experiment less upon entry, and to choose more predictable business models. This fits with evidence from Haltiwanger, Jarmin and Schank (2003) that there is less productivity dispersion among entering firms in Germany compared to the US. As a result, high-EPL countries can have lower growth because they specialize in lower-growth industries.

[4]A paper that analyzes efficient scrapping, albeit in the context of business cycles, is Caballero and Hammour (1996).

fer in their productivity and employment. Growth arises and is sustained endogenously through the interaction of selection (among incumbents) and imitation (by entrants). Each period, the least productive incumbents are eliminated, implying that the average productivity of remaining firms grows. Entry sustains growth: Entrants try to imitate firms close to the technological frontier. They do not succeed fully, but on average enter a constant fraction below it. Hence, there is a spillover from incumbents to entrants through the location of the frontier. Its strength depends on how much entry and exit, and thus selection, there is, so growth is driven by both selection and imitation. In addition, growth depends on the variance of productivity shocks. A higher variance, as observed in the service sector, makes high productivity draws more likely. While it also makes very low draws more likely, these are cut off by subsequent exit. As a result, selection is stricter, and growth is faster; however, there is a tradeoff between the dynamic gain of faster growth and the static loss due to the cost of higher, possibly excessive, entry and exit.

In this context, labor market regulation affects the entry and exit incentives of firms, and thereby the engines of growth in this model. It is well-known that firing costs, as one-sided adjustment costs, induce an inaction region in firms' employment policy when productivity is stochastic. As a consequence, labor is not optimally allocated across firms, implying lower aggregate productivity. Firm value is also lower, which is the mechanism leading to less entry and lower growth in Bertola (1994).

In the present paper, there is an additional effect through exit and selection. To analyze it, it is crucial to distinguish if exiting firms have to pay firing costs, or are exempt (or can default on them). This distinction is also made by Samaniego (2006*a*) in an environment of exogenous growth. The crucial observation is that firing costs have two distinct effects: they are not only an adjustment cost but also a tax on exit. The latter discourages exit of low-productivity firms, thereby weakening the selection process. This slows down productivity growth through selection and affects the productivity of entrants, since they are now targeting a worse distribution. As a result, growth is lower. When exiting firms are exempt, firing costs lower firm value, thereby promoting exit of low-productivity firms, strengthening selection, and increasing growth relative to the frictionless economy. The net welfare effect depends on the relative size of the static and the dynamic effects, i.e. if faster growth outweighs consumption losses due to misallocation of labor. Both effects are stronger when the variance of idiosyncratic shocks is larger – so EPL has a stronger effect on growth in the service sector.

To quantitatively evaluate the impact of labor market regulation on observed differences in productivity growth and in the behavior of entrants, the model is calibrated to the US business sector. Then the effects of introducing firing costs of one year's wages, close to the level observed in many continental European countries, is evaluated. Results show that charging firing costs only to continuing firms promotes selection and thereby growth. However, this is outweighed by the effect of the misallocation of labor, so welfare falls by an equivalent of 3.8% of permanent consumption. When firing costs are also charged to exiting firms they act as an exit tax and slow down growth by 0.1 percentage point, implying a welfare loss of 5.4%. These losses are higher in the service sector, with growth declining by 0.3 points when charging firing costs to exiting firms. Job turnover always drops significantly, but only marginally more when charging exiting firms. This suggests that even when there are technological costs of job turnover (which are not modeled here), e.g. when there are search frictions, achieving this small additional reduction in job turnover is probably not worth the cost it imposes in terms of lower growth.

Finally, we also provide some indicative empirical evidence, confirming that firing costs do indeed affect the selection process in the way modeled here. To do this, we investigate the impact of different types of firing cost on the average size of exiting firms in industry-level panel data for 10 OECD countries.

To summarize, the paper makes two main contributions. Firstly, it provides a growth model that is consistent with facts on firm dynamics, and that can account for the fact that recent productivity growth differences between the US and the EU were particularly strong in the IT-using service sector. Secondly, it provides a theoretical analysis of the effect of firing costs on productivity growth that highlights the importance of the treatment of exiting firms. In particular, charging firing costs to exiting firms reduces growth by hampering selection, with only a small additional reduction in job turnover. This shows that inhibiting the market selection mechanism comes at a cost.

The paper is organized as follows. In the next section, a simple heterogeneous firm model with growth by selection and experimentation is set up. In Section 3, it is solved for optimal behavior of all agents, equilibrium is defined, an algorithm for calculating it is given, and the determination of the growth rate is discussed. In the following section, the model is calibrated, and in Section 5, the quantitative effects of firing costs are explored. Section 6 provides some supporting empirical evidence, and section 7 concludes.

2 The Model Economy

Time is discrete and the horizon infinite. The economy is populated by a continuum of infinitely-lived consumers of measure one, a continuum of active firms of endogenous measure, a large pool of potential entrants, and a sector of perfectly competitive mutual funds.

Consumers value consumption and dislike working; this is summarized in the period utility function $u(\hat{c}_t, \hat{n}_t) = \ln \hat{c}_t - \theta \hat{n}_t$. They discount the future using a discount factor $\beta < 1$. They can consume or invest in shares $\hat{a}_t$ of the mutual funds that pay a net return r_t; wages and the return to the portfolio provide them with income.

The mutual funds finance investment in firms and transfer profits as dividends to shareholders. Since the sector is competitive, they do not make any profits and return the entire net profits of the production sector to consumers as dividends. Given perfect competition and assuming symmetry, they all hold the market portfolio and pay the same return r_t on assets. Hence, they can be summarized into one representative mutual fund.[5]

Firms: Firms produce a homogeneous good using labor as their only, variable input, with a positive and diminishing marginal product. This good serves as the numéraire of the economy. To remain active, firms also incur a fixed operating cost c_t^f each period; this grows over time at the growth rate of output, g. Moreover, there is an exogenous probability δ that a firm's production facilities break down after a period's production, forcing the firm to exit; this affects all firms in the same way.

Firms differ in productivity. This arises because each firm receives idiosyncratic productivity shocks; more precisely, its log productivity follows a random walk. This is a very simple way of capturing the role of idiosyncratic shocks established by the empirical literature.[6] It also renders the persistence of firm level productivity found in the data. This production technology can be summarized in Assumption 1 and in the production function

$$\hat{y}_{it} = \exp(\hat{s}_{it})\ \hat{n}_{it}^{\alpha}, \quad 0 < \alpha < 1, \tag{1}$$

where $\hat{y}_{it}$ denotes output of firm i in period t, $\exp(\hat{s}_{it})$ is its productivity level, and $\hat{n}_{it}$ employment.

Assumption 1 *Log productivity evolves according to*

$$\hat{s}_{it} = \hat{s}_{i,t-1} + \epsilon_{it}, \tag{2}$$

[5] The mutual funds do not play a role in themselves, they just serve as a device to abstract from liquidity constraints of firms.

[6] Empirical work on firm dynamics agrees on the importance of idiosyncratic shocks to firm-level productivity. Without going to a detailed dynamic analysis of firm-level data, this can be inferred from the high correlation of contemporaneous entry and exit rates for most industries (this does not fit well with aggregate or industry-level shocks as main driver of firms' fate), from the fact that productivity differences among firms are larger within than between industries (FHK), and from the fact that there are frequent changes in the identity of industry leaders.

where the innovation ϵ is distributed normally with mean zero and variance σ^2.

Firing costs: Adjusting employment is costless in the benchmark case. This will be compared to the case with employment protection legislation (EPL) in the form of firing costs of c^n times a period's wages for each worker fired. This policy can take two forms, one where firing costs always have to be paid when firing a worker, including upon exit (denoted by $F_x = 1$), and another one where firing costs only have to be paid if the firm also remains active in the subsequent period; i.e. exiting firms are exempted from firing costs (denoted by $F_x = 0$). An active firm's profit function can then be written as

$$\hat{\pi}_{it} = \pi(\hat{s}_{it}, \hat{n}_{it}, \hat{n}_{i,t-1}, \hat{w}_t) = \exp(\hat{s}_{it})\ \hat{n}_{it}^{\alpha} - \hat{w}_t \hat{n}_{it} - c_t^f - h(\hat{n}_{it}, \hat{n}_{i,t-1}), \tag{3}$$

where $\hat{w}_t$ denotes the period-t wage and the function $h(\hat{n}_{it}, \hat{n}_{i,t-1})$ summarizes firing costs. It is given by

$$h(\hat{n}_{it}, \hat{n}_{i,t-1}) = c^n \hat{w}_t \cdot \begin{cases} \max(0, \hat{n}_{i,t-1} - \hat{n}_{it}) & \text{if } F_x = 1, \\ \max(0, \hat{n}_{i,t-1} - \hat{n}_{it}) & \text{if } F_x = 0 \wedge \hat{n}_{it} > 0, \\ 0 & \text{if } F_x = 0 \wedge \hat{n}_{it} = 0. \end{cases} \tag{4}$$

The dependence of $h(\cdot)$ on previous period's employment makes the employment choice a dynamic decision when there are firing costs, and implies that a firm's individual state variables are $(\hat{s}_{it}, \hat{n}_{i,t-1})$.

At the beginning of any period, firms can decide whether to exit at the end of that period. This is costless in the benchmark case and when exiting firms are exempt from firing costs ($F_x = 0$); otherwise ($F_x = 1$), the exiting firm has to cover the firing cost for reducing its workforce from $\hat{n}_{i,t-1}$ to 0. As shown below, it is optimal for firms to exit if their productivity falls below a certain threshold. With $F_x = 0$, this threshold depends on past employment.

Entry: Entering firms have to pay a sunk entry cost c_t^e that grows at the same rate as output. This can be interpreted as an irreversible investment into setting up production facilities.[7] Entrants try to imitate the best firms in the economy; for the sake of concreteness, assume that they identify the best 1% of firms with the frontier of the economy. Varying this figure does not affect results. Denote average productivity of the target group with $\hat{s}_t^{\max}$. In practice, entrants are on average less productive then incumbents; for instance, FHK report that active firms that

[7] Empirical evidence shows that in practice, a large part of investment is irreversible in the sense that the resale value of assets is very low. This is more pronounced the more specific and the less tangible the asset, and the thinner the resale market. For evidence, see e.g. Ramey and Shapiro (2001).

entered within the last 10 years are on average 99% as productive as incumbents. One possible explanation is that they cannot copy incumbents perfectly due to tacitness of knowledge embodied in these firms. Assumption 2 formalizes the imitation process.

Assumption 2 *Entrants draw their initial productivity $\hat{s}_{it}^{0}$ from a normal distribution with mean $\hat{s}_t^{\max} - \kappa$ ($\kappa > 0$) and variance σ_e^2. Denote its pdf by $\eta_t(\hat{s}^0)$.*

Because $\kappa > 0$, entrants are on average less productive than the best incumbents. The assumption implies that, as the distribution of incumbents moves rightward, the distribution of entrants' log productivity tracks it at a constant distance κ.

Assumption 2 describes an externality; incumbents' productivity spills over to entrants. Together with the selection process, this externality drives growth. It can be interpreted in other ways besides imitation. For instance, entrants' productivity could be related to the technological and institutional conditions in an economy; these are already captured in the productivity distribution of incumbents.

The intensity of experimentation, parametrized by σ_e^2, is related to growth. A higher σ_e^2 implies that the probability of drawing an extreme, including very high, productivity rises. On the other hand, the larger probability of bad draws means that the entry process consumes more resources, making the net effect ambiguous. For the purpose of this paper, take σ_e^2 as fixed by technology.

Let $\hat{\tilde{\mu}}(\hat{s}, \hat{n}_{-1}) \equiv \hat{M}\hat{\mu}(\hat{s}, \hat{n}_{-1})$ be the measure of firms with states $(\hat{s}, \hat{n}_{-1})$, where $\hat{M}$ is the number of firms in the economy, and $\hat{\mu}(\hat{s}, \hat{n}_{-1})$ is a density function. The assumption of a continuum of firms that are all independently affected by the same stochastic process, together with the absence of aggregate uncertainty, implies that the aggregate distribution evolves deterministically. As a consequence, although the identity of firms with any $(\hat{s}, \hat{n}_{-1})$ is not determined, their measure is deterministic. Moreover, the underlying probability distributions can be used to describe the evolution of the cross-sectional distribution.[8]

Timing: The structure of the economy implies the following timing. At the beginning of any period, firms decide if they stay or exit, and potential entrants decide whether to enter. All firms that stay or enter pay the fixed operating cost c_t^f, and entrants in addition pay the entry cost c_t^e. Then incumbent firms receive their productivity innovations and entrants draw their initial productivity. Firms demand labor, workers supply it, and the wage adjusts to clear the labor

[8]Formally, this follows from the Glivenko-Cantelli Theorem (see e.g. Billingsley 1986). For a more thorough discussion, see Feldman and Gilles (1985) and Judd (1985).

market. Production occurs, agents consume, and profits are realized. Firms that reduced labor or exited pay the firing cost. After this, the whole process resumes. Hence, the dynamic choices of entry, exit, and employment are all made based on firms' expectations of future productivity.

3 Equilibrium

This section starts with the derivation of optimal behavior for all agents. Then, equilibrium is defined, and an algorithm for calculating it is given. A discussion of the selection mechanism and of the determination of the growth rate follows.

3.1 Optimal Behavior

Consumers maximize utility by choosing asset holdings and labor supply. Firms maximize the expected discounted flow of profits by choosing employment, entry, and exit. These decisions shape the law of motion of the firm productivity distribution, and thereby determine the growth rate.

Consumers: The consumer problem is completely standard. Utility maximization yields the Euler equation

$$\frac{\hat{c}_{t+1}}{\hat{c}_t} = \beta(1 + r_t). \tag{5}$$

Defining g^c as the growth rate of consumption, this implies that the prevailing gross interest rate in the economy is $1 + r_t = (1 + g_t^c)/\beta$. Moreover, consumers supply labor in accordance with the first order condition $\hat{c}_t = \hat{w}_t/\theta$.

Employment: Active firms face a standard dynamic optimization problem. This is particularly simple in the case with no firing costs, since then it is a sequence of static problems, and a firm's productivity $\hat{s}$ is the only firm-level state variable. Call labor demand for this case $n_0(\hat{s}, \hat{w})$. With firing costs, last period's employment $\hat{n}_{-1}$ also becomes a state variable for the firm. The aggregate state variable is the firm productivity distribution $\hat{\mu}$. Together with firms' employment policies, it determines the labor-market clearing wage $\hat{w}$. To underline this dependence, in the following, both are used as arguments of the firm's value and policy functions, although for the firm, the aggregate state matters only because it drives the wage. So denote the firm's employment policy for the more general problem (with firing costs) by $n(\hat{s}, \hat{n}_{-1}, \hat{w}; \hat{\mu})$.

The associated Bellman equation is

$$V(\hat{s}, \hat{n}_{-1}, \hat{w}; \hat{\mu}) = \max_{\hat{n}} \left\{ \pi(\hat{s}, \hat{n}, \hat{n}_{-1}, \hat{w}) + \frac{1-\delta}{1+r} \max \left(E[V(\hat{s}', \hat{n}, \hat{w}'; \hat{\mu}')|\hat{s}], V^x \right) \right\}, \tag{6}$$

where the profit function includes the fixed cost and the adjustment cost of labor, the inner max operator indicates the option to exit, and V^x denotes the value of exit as detailed in (7) below. Note that, since aggregates are deterministic, the firm faces uncertainty only about its own future productivity $\hat{s}'$, not about future wages and firm distributions.

This is a standard problem, existence and uniqueness of the value function follow from standard arguments. In addition, two properties carry over from the profit function: The value function is increasing and convex in $\hat{s}$ given $\hat{n}_{-1}$, and weakly decreasing in $\hat{n}_{-1}$ given $\hat{s}$ if there are firing costs. Whereas the employment policy $n(\hat{s}, \hat{n}_{-1}, \hat{w}; \hat{\mu})$ increases monotonically in $\hat{s}$ in the frictionless economy, it features a constant part around $\hat{n}_{-1}$ when $c^n > 0$. This is a standard effect of non-convex adjustment costs. It is illustrated in Figures 1 ($F_x = 1$) and 2 ($F_x = 0$). Intuitively, when a firm's productivity increases a little, it will not immediately raise employment because productivity might fall again, and reducing employment again then would be costly. Analogously, when a firm's productivity falls slightly, it will not immediately fire workers because productivity might recover and it would have paid the firing cost prematurely. When firms are exempted from paying the firing cost upon exit ($F_x = 0$), firms that suffer a negative productivity shock so large that they are forced to exit will not adjust employment downward immediately, but keep it constant and fire all workers upon exit. So given an $\hat{n}_{-1}$, the employment policy is constant for $\hat{s}$ very low or around $\hat{n}_{-1}$, and strictly increasing elsewhere. This translates into the "canyon" in Figure 2. Denoting the domains of $\hat{s}$ and $\hat{n}_{-1}$ with S and N respectively, the employment policy function and the law of motion for $\hat{s}$ then jointly define a transition function $\hat{Q} : S \times N \to S \times N$ that moves firms over productivity and employment states. They also define a transition probability function $\hat{q} : (S \times N) \times (S \times N) \to [0, 1]$ that gives the probability of going from state $(\hat{s}, \hat{n}_{-1})$ to state $(\hat{s}', \hat{n})$.[9]

The value of incumbent firms and their employment also decrease in the wage $\hat{w}$. Moreover, better (in the first-order stochastic dominance sense) future firm distributions, by implying future higher wages, decrease firm value and employment.

Exit: Firms exit if the expected value of continuing conditional on current states is less than that of exiting. The latter is equal to firing costs due if these have to be paid upon exit, and

[9] Although both $\hat{Q}$ and $\hat{q}$ also depend on $\hat{w}$ and $\hat{\mu}$, these arguments are omitted for simplicity.

zero otherwise:[10]

$$V^x = -F_x c^n\,\hat{w}\,\hat{n} = \begin{cases} 0 & \text{if } c^n = 0 \vee F_x = 0, \\ -c^n\,\hat{w}\,\hat{n} & \text{if } F_x = 1. \end{cases} \tag{7}$$

This is constant in $\hat{s}$. Since the value function is strictly increasing in $\hat{s}$ for any $\hat{n}_{-1}$, there is a unique threshold $\hat{s}_x$ where the expected value of continuing equals the value of exit. Firms exit when they draw an $\hat{s}$ below this. The exit threshold then is a function of $\hat{n}_{-1}$, $\hat{w}'$, and $\hat{\mu}'$, defined by

$$\hat{s}_x(\hat{n}_{-1}, \hat{w}; \hat{\mu}) = \{\hat{s} | E[V(\hat{s}', \hat{n}, \hat{w}'; \hat{\mu}') | \hat{s}] = V^x\}. \tag{8}$$

Taking into account the exit decision leads to a modification of the transition function to become $\hat{Q}_x : \bar{S} \times N \rightarrow (\bar{S} \cup \underline{S}) \times N$, where now the support of the productivity state s is partitioned into $\bar{S} = \{\hat{s} | \hat{s} \geq \hat{s}_x(\hat{n}_{-1}, \hat{w}'; \hat{\mu}')\}$ (continue) and $\underline{S} = \{\hat{s} | \hat{s} < \hat{s}_x(\hat{n}_{-1}, \hat{w}; \hat{\mu}')\}$ (exit). The latter is an absorbing state. Note that the partition may differ across different elements of N. The probability of going from $(\hat{s}, \hat{n}_{-1}) \in \bar{S} \times N$ to $(\hat{s}', \hat{n}) \in (\bar{S}(N) \cup \underline{S}(N)) \times N$ then is given by a function $\hat{q}_x(\cdot)$.

The dependence of the exit threshold on the other variables is crucial for the selection effect. Clearly, $\hat{s}_x$ increases in $\hat{w}'$. It also increases in the future productivity of other firms, $\hat{\mu}'$. As the value function is weakly decreasing in $\hat{n}_{-1}$, the exit threshold is weakly *in*creasing in it. Finally, with firing costs upon exit, the value of exit is lower, and so is the exit threshold. In this sense, firing costs on exiting firms act as a tax on exit and discourages exit, particularly of low-productivity firms. By worsening the distribution of surviving firms, this can slow down growth, as shown below.

Entry: Potential entrants enter until the expected net value of doing so is driven to zero. So in equilibrium, the free entry condition

$$E[V^e(\hat{s}^0, \hat{w}_t; \hat{\mu}_t)] = c^e_t \tag{9}$$

holds. (Alternatively, if $E[V^e(\hat{s}^0, \hat{w}_t; \hat{\mu}_t)] < c^e_t$, no entry takes place.) Since the distribution of $\hat{s}^0$ and c^e_t are exogenous features of technology, this equation pins down the wage, given a firm distribution. A wage below (above) its equilibrium value would trigger additional (reduced) entry, driving up (down) the wage.

[10] Exiting firms can enter again, but this has zero net value due to free entry – see equation (9) below.

All firms' decisions combined and the process for idiosyncratic shocks yield the law of motion for the firm productivity distribution $\hat{\mu}(\cdot)$

$$\hat{\mu}'(\hat{s}', \hat{n}) = \begin{cases} \int_N \int_{\bar{S}(N)} (1-\delta)\ \hat{\mu}(\hat{s}, \hat{n}_{-1})\ \hat{q}(\hat{s}', \hat{n}|\hat{s}, \hat{n}_{-1})\ \mathrm{d}\hat{s}\ \mathrm{d}\hat{n}_{-1} & \text{if } \hat{n} > 0, \\ \eta(\hat{s}^0 = \hat{s}')/M & \text{if } \hat{n} = 0. \end{cases} \tag{10}$$

with firing costs, and simply $\hat{\mu}'(\hat{s}') = \int_{\bar{S}} (1-\delta)\ \hat{\mu}(\hat{s})\ \hat{q}(\hat{s}'|\hat{s})\ \mathrm{d}\hat{s} + \eta(\hat{s}^0 = \hat{s}')/M$ otherwise. In both cases, the integral describes the motion of incumbents. Exit is captured by the restriction of the domain of the integral to surviving firms, and entry is given by $\eta(\cdot)$. All elements for analyzing equilibrium of this economy have been assembled now. The next steps now are to define a competitive equilibrium, describe briefly how to compute its balanced growth path, and analyze the determination of the growth rate.

3.2 Equilibrium Definition

Define a *competitive equilibrium* of this economy as sequences of real numbers $\{\hat{w}_t\}_{t=0}^{\infty}$ and $\{\hat{M}_t\}_{t=0}^{\infty}$, functions $n(\hat{s}, \hat{n}_{-1}, \hat{w}; \hat{\mu})$, $V(\hat{s}, \hat{n}_{-1}, \hat{w}; \hat{\mu})$, and $\hat{s}_x(\hat{n}_{-1}, \hat{w}; \hat{\mu})$, and a sequence of probability density functions $\{\hat{\mu}_t(\hat{s}, \hat{n}_{-1})\}_{t=0}^{\infty}$ such that:[11]

(i) Consumers choose consumption, asset holdings, and labor supply optimally, so the interest rate is given by equation (5);

(ii) all active firms choose employment optimally according to the employment policy $n(\cdot)$, yielding value $V(\cdot)$ as described by equation (6) for all $(\hat{s}, \hat{n}_{-1}, \hat{w}; \hat{\mu})$;

(iii) exit is optimal: $\hat{s}_x(\cdot)$ is given by equation (8) and firms exit if they draw an $\hat{s} < \hat{s}_x(\cdot)$, given $\hat{n}_{-1}$, $\hat{w}$, $\hat{\mu}$, and V^x;

(iv) entry is optimal and free: given a distribution $\eta(\hat{s}^0)$ over entrants' productivities $\hat{s}^0$, an entry cost c_t^e, $\hat{w}$ and $\hat{\mu}$, firms enter until the net value of entry equals its cost (equation (9));

(v) the labor market clears: given $\hat{M}$, $\hat{w}$ and $\hat{\mu}$, aggregate labor demand equals supply as chosen by households; and

(vi) the firm distribution is defined recursively by equation (10) given $\hat{\mu}_0$, $\hat{M}_t$ and $\hat{s}_{xt}$.

[11] Time and firm subscripts have been dropped where this does not cause confusion.

The last condition implies that the sequence of firm distributions is consistent with the law of motion generated by the entry and exit rules.

Existence of equilibrium for similar economies is proved e.g. by Hopenhayn (1992); the proof here would proceed along very similar lines.

3.3 Balanced growth

In the following, the analysis will be restricted to the balanced growth path (BGP) of this economy. Define this as a situation where output, consumption, wages, and aggregate productivity grow at a constant rate g, the firm productivity distribution shifts up the productivity scale in steps of g, its shape is invariant, and the firm employment distribution, the interest rate, the number of firms, the firm turnover rate, and other dynamic characteristics of the firm distribution are constant.

To show that such a situation can arise, suppose that the firm log productivity distribution shifts rightward by constant increments g (i.e. $\hat{\mu}'(\hat{s}) = \hat{\mu}(\hat{s} - g)$). This raises labor demand by a factor $(1 + g)$ every period, inducing an equivalent rise in the wage. It follows from consumers' first order condition for labor supply that their consumption rises at the same rate. From the aggregate resource constraint $\hat{y}_t = \hat{c}_t + \hat{M}_t c_t^f + c_t^e$, output then also grows at a rate g. (Remember that operating costs and entry costs are assumed to increase at the growth rate of output.) Hence, there is a BGP equilibrium if a g consistent with equilibrium exists. To find it, it is useful to transform the model such that all variables would be constant in a stationary equilibrium.

To do this, apply the transformation $z_t = \hat{z}_t e^{-gt} = z$ for all growing variables $\hat{z}$, $x_t = \hat{x}_t = x$ for all constant variables $\hat{x}$, and $s_{it} = \hat{s}_{it} - gt$ for the firm-level productivity state. (The stationarized variables do not carry hats. Note that the transformation of $\hat{s}$ also affects the transition functions $\hat{Q}$ and $\hat{q}$.) This implies that in the stationarized economy, firm productivity evolves according to

$$s_{it} = s_{i,t-1} - g + \epsilon_{it}. \tag{11}$$

Firm productivity now follows a random walk with downward drift (for positive growth rates) because the whole firm productivity distribution shifts up at rate g, so in expectation, firms fall back by g every period relative to the distribution.[12] For this reason, the wage w and the growth

[12] Due to the downward drift g, expected firm lifetime is finite for any s. This ensures that there is a stationary firm distribution in the transformed economy. More formally, what is crucial here is that starting with some initial firm distribution, the variance of the firm distribution remains finite as time goes by. This is the case if the variance of the productivity distribution of all cohorts of active firms remains finite. This holds here, despite

rate g are sufficient to characterize firms' value and policy functions on the BGP; knowledge of the whole firm distribution μ is not needed.

3.4 Algorithm for finding a stationary equilibrium

The numerical implementation is as follows. (This assumes parameters are fixed as detailed in the Section 4 below.) The state space $S \times N$ is discretized into a grid of 100×400 points. Using more points does not significantly affect results. The N grid is chosen such that it contains as a subset the optimal employment quantities chosen by a firm in the frictionless economy for the points in S. Firm value can be obtained by value function iteration for each (s, n_{-1}) pair given g and w. This also yields the exit thresholds $s_x(n_{-1}, w, g)$ as defined in equation (8), and the transition function Q_x, given g and w. For any fixed g, equation (9) determines the equilibrium wage w, and thereby the exit threshold and transition function for that g. Using these, the ergodic firm productivity distribution can be obtained; in the frictionless case directly as $\tilde{\mu} = (I - Q_x')^{-1}\eta$, and in the case with firing cost by iteration on the law of motion for μ (equation (10)). The mean of entrants' initial log productivity s^0 can be normalized to 0. The correct g then is the one that implies a μ and an $s^{\max}$ consistent with Assumption 2.

3.5 The growth rate

The growth rate g is driven by the selection process and by the distance κ between entrants' and incumbents' mean productivity. Intuitively, the process is as follows. In the growing economy, the productivity of incumbents follows a random walk. This implies that for a given set of firms, each firm's productivity is constant in expectation, but the variance of those firms' productivity distribution grows over time. However, with exit, the exit threshold truncates the firms' productivity distribution from below. As a result, the distribution can only expand upwards, and average productivity of this set of firms grows. Hence, selection drives growth. However, as time goes by, firms keep on exiting, and the distribution thins out. (This process bears some similarity to the one in Jovanovic (1982).) This is why entry is needed to sustain growth: In a stationary equilibrium (of the stationarized economy), the measure of firms is constant, and

the underlying random walk, because of exit. Without exit, the variance of the productivity distribution of each cohort would rise linearly in t. Exit mitigates this. The probability of surviving beyond period $t+1$ conditional on having survived until t is a decreasing function of t that goes to zero as t goes to infinity because of the downward drift. This means that the probability of any firm in a cohort to survive beyond $t+1$ decreases at an increasing rate. Hence, the variance of a cohort's surviving firms does not diverge; firms exit "fast enough" for the firm distribution to keep finite variance. (Note that this would not necessarily be the case if there was just an exogenously given exit probability affecting all firms in the same way; then the size of this probability would matter.)

exiting firms are replaced by entering ones. Yet while exiting firms are at the bottom of the distribution, entering firms are more productive – otherwise they would not enter. As a result, the productivity distribution shifts to the right: the bottom firms are replaced by more productive entrants, while some firms in the upper part of the distribution are lucky, receive positive shocks, and move that part of the distribution to the right.

For a more formal analysis, the law of motion of the firm distribution can be decomposed and rewritten.[13] Now and in the following, in a slight abuse of notation, denote the output-weighted average log productivity for a firm distribution μ with $\mathsf{E}\mu$. On the BGP, $\hat{\mu}'(\hat{s}) = \hat{\mu}(\hat{s} - g)$. So the same holds for the mean:

$$\mathsf{E}\hat{\mu}' - \mathsf{E}\hat{\mu} = g. \tag{12}$$

This implies that the growth rate can be decomposed as follows, using the law of motion of $\hat{\mu}$:

$$g = (1-e)\,[\mathsf{E}(\hat{Q}_x\hat{\mu}) - \mathsf{E}\hat{\mu}] + e\,(\hat{s}_t^{\max} - \kappa - \mathsf{E}\hat{\mu}), \tag{13}$$

where e is the entry (= exit) rate.[14] The first term in the sum gives the effect of selection, i.e. the difference between the mean productivity of surviving firms, $\mathsf{E}(\hat{Q}_x\hat{\mu})$, and that of all firms active in the preceding period, $\mathsf{E}(\hat{\mu})$. The tougher market selection is, and the more firms at the low end of the productivity distribution exit, the larger this term. This also makes it clear that the growth rate and welfare do not have to behave in the same way; in the extreme, eliminating all but the most efficient firms would imply a strong selection effect, but harm welfare due to decreasing returns to scale at the firm level and the direct cost of turnover (financing a lot of entry every period). The second term in (13) is the effect of entry, or imitation. It decreases in κ. Splitting $\hat{\mu}$ into the distributions of continuing and exiting firms, $\hat{\mu}_{cont}$ and $\hat{\mu}_{exit}$, and using $\mathsf{E}\hat{\mu}' = (1-e)\mathsf{E}\hat{Q}\hat{\mu}_{cont} + e\mathsf{E}\eta'$, the growth rate can be further rewritten as

$$\begin{aligned} g &= (1-e)(\mathsf{E}\hat{Q}\hat{\mu}_{cont} - \mathsf{E}\hat{\mu}_{cont}) + e(\mathsf{E}\eta' - \mathsf{E}\hat{\mu}_{exit}) \\ &= e(\mathsf{E}\eta' - \mathsf{E}\hat{\mu}_{exit}), \end{aligned} \tag{14}$$

where the second equality holds because the expectation of the untruncated log productivity process is constant. The expression shows very neatly that the growth rate is positive if on average, entrants are more productive than exiting firms.

[13] The following analysis is for the frictionless case, for the sake of simplicity. The reasoning carries over to the case with firing costs, at the cost of significantly more complicated notation.

[14] Note that equation (13) cannot be used directly for calculating the equilibrium growth rate since $\hat{Q}_x$, and thereby $\hat{\mu}'$, depend on g. This is why finding g is a fixed-point problem.

How does turnover affect the growth rate? Changes in turnover can be due to changes in the exit threshold s_x (induced e.g. by changes in the entry cost or in the fixed operating cost), to changes in the variance σ^2 of the idiosyncratic shock, or to changes in the variance σ_e^2 of the distribution of entrants. The derivative of g with respect to the exit threshold is

$$\frac{\partial g}{\partial \hat{s}_x} = e\left(\frac{\partial \mathsf{E}\eta'}{\partial \hat{s}_x} - \frac{\partial \mathsf{E}\hat{\mu}_{exit}}{\partial \hat{s}_x}\right) + \frac{\partial e}{\partial \hat{s}_x}(\mathsf{E}\eta' - \mathsf{E}\hat{\mu}_{exit}). \tag{15}$$

The second term is positive since clearly, for a given distribution, the exit rate e increases in the exit threshold. The first term, however, is negative, since although raising the exit threshold pushes up both $\mathsf{E}\eta'$ and $\mathsf{E}\hat{\mu}_{exit}$, the second term reacts more strongly. This is because raising the exit threshold makes firms exit that are more productive than previously exiting firms; a very direct effect. The positive effect on entry is only indirect through an improvement in the average productivity of the whole firm distribution. Combining the two terms, the growth rate increases in the exit threshold up to a point, and falls afterwards. Numerical analysis shows that this turning point lies far to the right of the exit threshold in the benchmark economy. Hence, in the empirically relevant region, an increase in the exit threshold affects the growth rate positively.

Entry affects the selection process in the sense that a more dispersed distribution of entrants in the previous period (higher σ_e^2) raises turnover and strengthens the selection effect. In addition, because firm value is convex in $\hat{s}$, it raises the expected value of entry by Jensen's inequality. This drives up the wage (so that the free entry condition (9) holds) and the exit threshold, further promoting growth.

Higher variance of idiosyncratic shocks also promotes selection since, given an exit thresholds, more firms go "over the cliff" every period. It also increases the dispersion of the distribution, raising average productivity of surviving firms and thereby the target productivity of entrants, implying a higher wage and higher exit threshold. These effects raise growth. There is also an effect in the other direction: by Jensen's inequality, higher σ^2 raises expected continuation value for any $\hat{s}$, pushing down the exit threshold. The net reaction of the exit threshold to these two effects is ambiguous. Numerical exercises show that around the benchmark economy the growth rate increases in σ^2 even when growth and turnover rates are very high or very low, i.e. the selection effect of a higher σ^2 is stronger than the expected value effect. Turbulence and firm turnover hence are positively related to growth, whether caused by changes in the exit threshold or in the variance of the shocks.

3.6 Optimality

Growth in this economy is driven by selection among surviving firms and a spillover to entering firms. In the decentralized equilibrium, firms do not take this into account. In particular, in their exit decision, firms do not take into account how their decision to exit or to remain active influences the productivity of entering firms. Likewise, entrants only consider private benefits. Therefore, a social planner could improve upon the decentralized equilibrium by taking this into account. The following paragraphs provide a brief discussion about where the decentralized equilibrium deviates from the optimal outcome, and with which instruments a planner could implement the optimal outcome as a competitive equilibrium.

Suppose that there is a benevolent social planner that maximizes the representative consumer's utility. Further suppose that the planner faces the same technological constraints as firms in the decentralized equilibrium, but can directly impose an exit threshold s_x for all firms in the economy. This then determines the firm distribution and the growth rate. The planner also faces the decision of how much output to allocate to consumption, and how much to the construction and operation of firms.[15]

This intertemporal decision yields the condition

$$c^e = EV^e. \tag{16}$$

This is analogous to the free entry condition in the competitive equilibrium. In addition, the planner can influence the expected value of entering firms EV^e by the choice of exit threshold. That choice aims at obtaining the best tradeoff between a high-productivity firm distribution and a high growth rate on the one hand, and the associated cost of firm turnover on the other hand. (More exit implies more selection and faster growth as discussed above, but also higher costs of financing entry investment.) This implies choosing s_x to maximize the value of a portfolio of firms minus the social cost of turnover. The stationary formulation of the problem thus is

$$\max_{s_x} \int \mu(s)V(s)\,\mathrm{d}s - ec^e = \max_{s_x} \int_{\bar{S}} (Q\mu)(s)V(s)\,\mathrm{d}s + e\int \eta(s)V(s)\,\mathrm{d}s - ec^e, \tag{17}$$

subject to the law of motion of μ. (Remember that $\bar{S}$ denotes the set of continuing firms, i.e. $\bar{S} = \{s | s \geq s_x(n_{-1}, w, g)\}$.) In this objective, $\bar{S}$, μ, e, and V all depend on s_x. Using

[15] Note that this tradeoff is reflected in the valuation of firms: Their social value is in terms of the contribution of their output to the representative agent's utility, i.e. in terms of marginal-utility weighted output, not profits. However, as this is also the case for the cost side, the marginal utility terms drop out in all equations, so firm value is again in terms of output below. This also makes the comparison with competitive equilibrium conditions easier.

$QV(s,\cdot) = E[V|s]$ and differentiating with respect to s_x yields the first order condition

$$- \mu(s_x)E[V|s_x] + \int_{\bar{S}} \frac{\partial \mu(s)}{\partial s_x} E[V|s]\,\mathrm{d}s + \int_S \mu(s) \frac{\partial E[V|s]}{\partial s_x}\,\mathrm{d}s + \frac{\partial e}{\partial s_x}\left(EV^e - c^e\right) = 0. \qquad (18)$$

Note that the third term combines changes in expected value for both continuing and entering firms. Inserting (16) into (18) yields the simplified condition

$$\mu(s_x)E[V|s_x] = \int_{\bar{S}} \frac{\partial \mu(s)}{\partial s_x} E[V|s]\,\mathrm{d}s + \int_S \mu(s) \frac{\partial E[V|s]}{\partial s_x}\,\mathrm{d}s. \qquad (19)$$

Compare this to the exit condition (8) in the decentralized equilibrium. There, firms exit if their expected value is smaller than the value of exit, V^x. The planner, in contrast, takes into account the impact of the exit decision on the remaining distribution (first term on the right-hand side (RHS)) and on the value of other firms (second term). The former is positive. The latter is positive for low s_x and negative for large ones, for the same reason as there is a unique s_x in the competitive equilibrium: Firm value is negative for low s due to the fixed cost; and the option to exit is valuable in that situation. Hence, there is a range of s_x for which the RHS is positive, and it may become negative for high s_x.

To evaluate if the competitive equilibrium is optimal, insert two equilibrium conditions from there into equation (19). First, privately optimal choice of s_x implies that $\partial E[V|s]/\partial s_x = 0$. Hence, the second term on the RHS of (19) is zero.[16] Second, the left-hand side (LHS) of equation (19) equals $\mu(s_x)V^x$ by the exit condition (8). The fact that the first term on the RHS of (19) is positive (the selection effect) now implies that the LHS should also be positive to achieve a social optimum, i.e. $V^x > 0$. Since $V^x = 0$ in the competitive equilibrium without firing cost or with $F_x = 0$, and $V^x < 0$ when $F_x = 1$, the decentralized equilibrium is not optimal. Charging firing costs to exiting firms – an exit tax – is even worse, as detailed in Section 5.

This reasoning also shows how the optimal allocation can be implemented as a competitive equilibrium: by an exit subsidy (so $V^x > 0$) that makes (19) hold with equality. Since V is continuous and monotonic in s, every s_x can be achieved in (8) by setting the right V^x. In the benchmark calibration, the subsidy needed equals 14% of the entry investment c^e, and the

[16] This expression arises as a first order condition (FOC) when slightly rewriting the firm's exit problem. Above, it was written as choosing the max of the continuation value and the exit value for any s. Alternatively, let $V^*(s, s_x)$ be the firm value for a firm with productivity state s that applies an exit threshold s_x. Then the problem becomes $\max_{s_x} E[V^*]$, with the attached FOC $\partial E[V^*]/\partial s_x = 0$. (The objective is concave in s_x, so the FOC is also sufficient.) Since $V^*(s, s_x)$ for the optimal s_x is the same as the firm value function given in (6), this condition is exactly the same as the one used in the text.

resulting allocation yields 2.6% higher welfare. If the subsidy could be financed via lump-sum taxes, this would imply a net gain of 0.8%.

Finally, an exit subsidy is not the only instrument that could be used to affect the exit threshold. Anything that reduces firm value (such as a lump-sum tax, or EPL) or otherwise affects firm turnover (such as an entry subsidy) has that effect. The advantage of the exit subsidy is that it affects only the exit threshold and hence constitutes the cleanest instrument.

4 Benchmark Economy

To derive quantitative conclusions, the model has to be calibrated. More fundamentally, as seen in Section 3.5, the equilibrium growth rate g depends on the unknown technology parameter κ. That parameter cannot be inferred directly from evidence on the relative productivity of entrants since in empirical work, relative productivity of entrants usually is measured several years after entry and conditional on survival. κ, in contrast, represents the unconditional relative productivity of potential but unrealized projects. To solve this problem, κ is chosen such that the relative productivity of surviving entrants, measured as in empirical work, matches the data moment exactly.

Data moments used in calibration refer to the US non-farm business sector. This is a good no-firing cost benchmark since both procedural inconveniences and severance pay due upon an individual no-fault dismissal are zero in the US according to the OECD's indicators of employment protection published in Nicoletti, Scarpetta and Boylaud (2000). Other measures of employment protection are among the lowest worldwide, too.

To calibrate the model, commonly used values from the literature are used for some baseline parameters, while the remaining ones are chosen such that the distance between a set of informative model moments and corresponding data moments is minimized. Distance here is measured as the mean squared relative deviation. The fact of dealing with distributions makes the model highly non-linear and the calibration more involved. First, to obtain model moments, the whole model has to be solved for each parameter combination under consideration. Second, the distance between model and data moments is a nonlinear function of the parameters with many local minima. To find the global minimum, a genetic algorithm as laid out in Dorsey and Mayer (1995) is used.

The parameter values adopted from the literature are 0.64 for the labor share α and 0.95 for the discount factor β. The disutility of labor θ is set such that labor force participation fits the value of 66% reported by the BLS and the ILO. The productivity of entrants relative to incumbents κ is set to match the corresponding data moment exactly. Foster et al. (2001) report this to be 99%, counting as entrants firms that entered within the last ten years and are still active, so it is measured in the same way here.

The five parameters that remain to be assigned are the variance of the log productivity distribution of entrants, σ_e^2, the variance of the the idiosyncratic productivity shock hitting incumbents, σ^2; the fixed operating cost c^f, the entry cost c^e; and the breakdown probability δ. They are chosen to match three moments referring to the entire economy, and two moments related to entry and post-entry behavior: the job turnover rate, average plant size, dispersion of the productivity distribution, the four-year survival rate of entrants, and the share of aggregate productivity growth due to entry and exit. These moments are chosen because each captures a different aspect of the firm distribution and its dynamics and therefore allow a relatively full description. Average plant size and the dispersion of the productivity distribution are closely related to the mean and variance of the firm productivity distribution. The job turnover rate describes its dynamic behavior. The survival rate of entrants indicates the severity of the selection process, and the last moment fixes the importance of the entry and selection process at a realistic value. The next few paragraphs briefly discuss their definition, values, and data sources.

The job turnover rate is the sum of job creation and job destruction at continuing, entering and exiting plants in a year, divided by total employment in that year; it is a crucial dynamic feature of the plant distribution. According to the BLS, it is 28% yearly in the US. Cross-country differences in this variable are significant, as documented by Davis, Haltiwanger and Schuh (1996). The US value is on the high side among developed economies.

Average plant size (employment), a measure of the mean of the firm distribution, is 26.4 for the US business sector according to Bartelsman et al. (2004) (BHS). The dispersion of the productivity distribution helps pin down the variance of the incumbents' productivity shock. For lack of better data, we use the measure from Dwyer (1998) who finds that for the U.S. textile industries, the average ratio between the 85^{th} and the 15^{nd} percentile of the plant productivity distribution is 3. Other studies report results in the same ballpark for other countries and industries (see e.g. Roberts and Tybout 1996).

Next, a crucial statistic describing the post-entry process is the survival rate of entrants. Matching it well is important for obtaining a good estimate of κ since the latter is calculated using the relative productivity of surviving entrants. The four-year survival rate, i.e. the proportion of entrants of a given year still active four years later, is 63% in the U.S. (BHS). This is lower than

Table 1: Calibration: Model statistics, calibration targets (U.S., all data for 1990s)

Statistic	model	U.S.
Average firm employment	26.4	26.4
Labor force participation	66.4%	66%
Relative productivity of entrants	99%	99%
Job turnover rate	28.0%	28%
Productivity dispersion	2.9	3
Four-year survival rate of entrants	61.9%	63%
Share of aggregate productivity growth due to entry and exit	27.2%	26%
not used in calibration:		
Output per capita growth	1.85%	1.80%
Employment-weighted firm turnover	7.2%	7.0%
Firm turnover rate	13.1%	22%
Seven-year growth rate of entrants	39%	40%

Sources: Bartelsman et al. (2004), Bureau of Labor Statistics (http://data.bls.gov), Foster et al. (2001), van Ark, Melka, Mulder, Timmer and Ypma (2003), Tables 1, 20.

in most other industrialized countries, but higher than in many Latin American ones, though quantitatively, cross-country differences are not very large.

Finally, we aim to match the contribution of entry and exit to aggregate productivity. This is important for giving the right importance to the process of entry and selection relative to within-firm productivity growth. FHK find its value to be 26% for the U.S. manufacturing sector, and higher in retailing. Other studies find similar estimates, BHS give an overview. Calibration targets and model values are given in Table 1. Adopted parameter values are given in Table 2. Model statistics fit all targets closely.

The calibration fits rather well even in dimensions that were not targeted. The firm turnover rate is very low, but its employment-weighted counterpart fits almost exactly. The discrepancy might arise if the model with its rather high entry cost does not capture a fringe of very small, short-lived firms. BHS show that these are numerous. This does not seem to matter too much for firm growth and aggregate growth, though, since the calibrated model matches the seven-year growth rate of surviving entrants well. Most remarkably, the aggregate growth rate is very close to that found in the data – a clear indication that the growth mechanism proposed here and its calibration are plausible.

Table 2: Calibration: Parameter values

Parameter	Value	Description
α	0.64	Labor share
β	0.95	Discount factor
θ	1.15	Disutility of working
σ_e^2	0.60	Variance of log productivity distribution of entrants
σ^2	0.1	Variance of idiosyncratic productivity shock
c^f	3.3%	Fixed operating cost, % of avg firm output
c^e	198%	Cost of entry, % of avg firm output
δ	0.0275	Probability of exogenous exit
$\exp(\kappa)$	6.04	Ratio prodty best incumbents/avg entrant

5 Firing costs and productivity growth

The focus of the paper is the analysis of the impact of firing costs on aggregate productivity growth. Since growth is endogenous in the model developed above, frictions can affect not only the level (as in previous literature), but also the growth rate of output and productivity. This section explores their effect first theoretically, then empirically.

5.1 Theoretical discussion

It is crucial to note that firing costs affect firms in two ways: they constitute a friction to the adjustment of labor, and they are a tax on exit, if charged to exiting firms. Their effects can most easily be seen in the light of the discussion of optimality in Section 3.6. Firstly, as an adjustment friction, firing costs cause firms' employment to deviate from optimal employment in the frictionless economy. This lowers firm value and the incentive to enter or to continue in operation. As a consequence, the exit threshold rises and comes closer to the socially optimal one that solves equation (19), but at the cost of distorting firms' labor demand policy. Hence, firing costs are a very "dirty" instrument for achieving stricter selection.

Secondly, if charged upon exit, firing costs are a tax on exit. They then provide an incentive towards continuing (compared to the case with the exemption), and shift the exit threshold away from its optimal value. Compared to the benchmark economy, they decrease both the expected value of continuing and the value of exit; the latter falls by more only because it implies bearing the firing cost immediately, whereas in the former, it would be borne later and is therefore discounted.[17] Only the difference between the changes to the expected value of continuing and the value of exit affects the exit threshold and selection, so they react less than with the exemption. To summarize, firing costs raise growth and firm turnover when only charged to continuing firms, and reduce both when also charged to exiting firms. The second effect is smaller in absolute size. The next paragraphs provide a more formal discussion of the effect of firing costs.

Consider first the case where firing costs are only charged to continuing firms ($F_x = 0$). Then, they do not affect the value of exit V^x compared to the benchmark economy. They do reduce the value of continuing, though. For given g, equation (9) then implies a lower equilibrium wage w. This keeps the expected value of entry equal to c^e, and the exit threshold for entrants constant. The exit threshold for firms with $n_{-1} > 0$ is higher, since firm value falls in n_{-1}, and the exit threshold rises in it. Hence, the average exit threshold in the economy with firing cost is at least as high as in the frictionless economy. As shown in Section 3.5, this implies a higher exit rate, more severe selection, and faster growth. Concerning other variables, for all equilibrium conditions to hold, w has to fall more with the higher growth rate than if g stayed constant. The lower wage and costless firing upon exit imply that average employment rises, and the number of firms falls. Just as the wage, consumption declines. The size of this fall relative to the higher growth rate determines the sign of the reaction of welfare.

Charging the firing cost also to exiting firms ($F_x = 1$) complicates the picture. First of all, in this case, too, for the free entry condition to hold the stationarized equilibrium wage has to be lower than in the benchmark for given g. Then, as discussed above, the exit threshold and firm turnover fall only slightly, resulting in slightly lower g. Because of the fall in the growth rate, the wage need not fall as much as for constant g. With the lower wage, average firm size rises, though less than when firing upon exit is costless. With less and larger firms, the production structure is less efficient than in the benchmark economy because of decreasing returns, and stationarized output declines. Combined with lower g, this implies that welfare is unambiguously lower in this case.

5.2 Quantitative evaluation

This section reports quantitative results on the effect of altering the benchmark economy by introducing firing costs of c^n times the equilibrium wage for each worker fired. c^n is set to one,

[17] A similar point is already present in Bentolila and Bertola's (1990) discussion of optimal firing of a marginal worker and its consequences for average employment.

Table 3: Results: Introducing firing costs (always: $F_x = 1$, exit exemption: $F_x = 0$)

Statistic	Benchmark	$F_x = 1$	$F_x = 0$
Firm turnover rate	13.3%	13.2%	15.0%
Job turnover rate	28.0%	12.1%	12.3%
Average firm size	26.4	29.4	30.7
Productivity dispersion	2.9	2.9	2.9
Four-year survival rate of entrants	61.9%	58.7%	57.9%
Relative productivity of entrants	99%	98.7%	95.9%
Labor force participation	66.4%	65.3%	66.5%
Relative size exiting firms	3.4%	2.5%	9.6%
Output per capita growth	1.848%	1.763%	1.851%
Consumption (bm = 100)	100	94.8	96.2
Welfare change		-5.4%	-3.8%
(equivalent variation, % of c)			

i.e. a year's wages. This is close to the average over continental European countries according to the OECD's employment protection indicators.

Results are reported in Table 3 and fit the qualitative patterns described above. Note that consumption is a stationarized value that cannot be compared directly across columns. To properly evaluate welfare, the welfare loss using the equivalent variation is given. The number indicates what percentage of consumption would have to be taken away from consumers in the no-firing-cost case to make their welfare equivalent to that of consumers in each of the other two economies.

The most salient result are the changes in growth rates. Introducing firing costs decreases the growth rate by around 1 tenth of a percentage point when firing costs are always charged. When exiting firms are exempt, the growth rate rises marginally. For the rest, results fit the qualitative results outlined above. Welfare clearly drops with firing costs. For $F_x = 0$, the distortion in the allocation of labor outweighs the higher growth rate, implying a welfare loss of 3.8%. For $F_x = 1$, the growth rate actually drops, so the welfare loss is even larger at 5.4%. Note also that charging firing costs also to exiting firms has only a marginal effect on the job turnover rate.

It is well-established that the variance of idiosyncratic shocks is larger in the service sector. For instance, the coefficient of variation of firm size is up to three times as high as in manufacturing sectors (see BHS), job turnover is higher (see e.g. Davis, Faberman and Haltiwanger 2006),

Table 4: Results: Service sector (always: $F_x = 1$, exit exemption: $F_x = 0$)

Statistic	Benchmark	$F_x = 1$	$F_x = 0$
Firm turnover rate	18.9%	16.2%	22.2%
Job turnover rate	39.6%	16.6%	17.8%
Average firm size	21.4	21.3	25.4
Productivity dispersion	3.3	3.2	3.3
Four-year survival rate of entrants	57.2%	56.9%	54.1%
Relative productivity of entrants	99%	101%	95.4%
Labor force participation	66.4%	64.2%	67.0%
Output per capita growth	3.9%	3.6%	4.1%
Consumption (bm = 100)	100	95.1	91.4
Welfare change (equivalent variation, % of c)		-8.1%	-5.4%

and firm turnover is higher (BSS). In such a setting, employment protection legislation constrains firms more strongly. And indeed, recent growth differences between Europe and the US were largest in a large subsector of the service sector, namely in IT-using services (van Ark et al. 2003, Blanchard 2004). Table 4 shows the effect of firing costs of a year's wages in an economy where σ^2, the variance of the idiosyncratic shock, is raised from 0.1 to 0.15 to mimic the service sector. First note that this sector has a higher growth rate than the benchmark economy – this is the positive effect of σ^2 on the growth rate established in Section 3.5. Turnover rates and productivity dispersion are higher, too. Now firing costs have a stronger effect on the growth rate and on welfare for both settings of F_x. If firing costs are only charged to continuing firms ($F_x = 0$), there is stricter selection, and the growth rate rises by 0.2%. If they are also charged to exiting firms ($F_x = 1$), the growth rate drops by 0.3%. Welfare falls in both cases.

Hence, firing costs can have potentially large growth rate effects, particularly in sectors where firms face a very volatile environment, such as in services. This fits very well with the pattern of recent growth rate differences between the US and Continental Europe. It also results that details of EPL regimes matter, and that dealing with exit efficiently is an important policy concern in its own right. In fact, charging firing costs to exiting firms does not reduce job turnover by much, but has potentially large additional welfare costs compared to charging them only to continuing firms.

This is important in settings where job turnover is thought to be costly. Indeed, an additional but nontrivial step in the analysis would consist in incorporating a motive for the existence of firing costs, such as search frictions. In a setting with exogenous growth, Alvarez and Veracierto (2001) find that then, severance payments are welfare-improving because agents become unemployed less often, and less search costs are incurred. This more than compensates the static distortions they induce. However, this result relies on an analysis where firing costs do not affect growth. Combining results obtained here with those by Alvarez and Veracierto allows the conjecture that in a model with growth and search frictions, firing costs would probably be harmful when always charged, since they would decrease growth on top of the static distortions, but might still be welfare-improving if not charged upon exit.

6 Some indicative empirical evidence

Selection is a crucial driver of growth in the model presented here. This section provides some indicative empirical evidence on the effect of labor market regulation on the selection process.

In the model, selection is governed by equation (8) that states that firms exit when their productivity falls below a threshold at which the expected value of maintaining the firm active equals the value of exiting the market. Firing costs charged to continuing firms reduce firm value and thereby raise this threshold. Firing costs charged upon exit reduce the value of exiting and thereby lower the threshold. These two predictions can be tested empirically using industry-level data for different countries. (It would be interesting to perform it with firm-level data.)

Most of the existing literature studies the impact of some general employment protection legislation (EPL) measure or indicator on gross job flows. For instance, Micco and Pagès (2004) use cross-sectoral differences to apply a difference-in-difference approach and find that more stringent regulation strongly reduces industry-level job flows, particularly in sectors requiring higher flexibility. Autor, Kerr and Kugler (2006) use variation in the adoption of EPL across U.S. states and find lower employment flows, less firm entry, capital deepening, and a decline in the level of TFP following introduction of wrongful-discharge protections. These results fit with the level effects of EPL as analyzed already in Hopenhayn and Rogerson (1993) and also present here. To our knowledge, the only paper studying the impact of EPL on growth is Scarpetta et al. (2002). They find a small negative effect of EPL on productivity growth, and a negative effect on entry, particularly of small firms. Causality could be reverse here, however: it might be that low-growth countries impose stricter EPL "to protect workers," resulting in the negative coefficient. The difference-in-difference approach of the other studies quoted here serves exactly to overcome this problem. As detailed when presenting the results, the approach chosen here also deals with this issue.

Industry-level data used is from the OECD Firm Level Data Project.[18] International comparability is ensured because the data is gathered using a common analytical framework and harmonized definitions of key concepts such as entry, exit, and the unit of measurement. The data set contains annual observations on total employment and the number of continuing, entering, and exiting firms for 34 private sector industries in 10 OECD economies.[19] It does not allow inference about productivity. However, it gives the average size of exiting firms in an industry (total employment of exiting firms divided by their number). Since a firm's employment is a non-decreasing function of its productivity, the model predictions carry over to the exit size (instead of productivity) threshold. This yields an unbalanced panel with 2178 observations over the years 1977 to 2000 and varying country coverage; or a balanced panel for all countries for 1989 to 1993 with 1021 observations. Results reported below are for the unbalanced panel; they are both qualitatively and quantitatively similar for the balanced panel.

The model predicts that the reaction of this exit size threshold to firing costs depends on whether they are charged only to continuing firms or also to exiting ones. OECD EPL indices published in Nicoletti et al. (2000) allow to distinguish this roughly. They report separately indicators on the "procedural inconveniences" and on the "direct cost" of dismissals. Both are indices ranging from 0 to 6 (least to most restrictive). For ease of reference, call them "firing difficulty" (FD) and "firing cost" (FC), respectively. The firing cost indicator mainly consists of the cost of severance payments due when dismissing a redundant worker. (Requirements regarding collective dismissals are usually at least as onerous.) The firing difficulty index measures the administrative and legal burden of firing, in particular whether a written statement to a third party is required, whether its approval is needed, and how long the delay up to the start of the notice period is.

These procedural difficulties apply mainly to continuing firms; exit directly creates facts.[20] Firing costs, in contrast, should in principle affect all firms, including exiting ones. In practice, workers may not receive severance payments in full, depending on the rank of their entitlements relative to other creditors; however, some drain on the firm's exit value remains. So while firing difficulty should only affect the expected value of continuing, and thereby raise the exit threshold, firing costs should also reduce the value of exit, and reduce the exit threshold. Hence,

[18] This data is available on the OECD's web site at `http://www.oecd.org/document/4/0,2340,en_2649_34117_1962948_1_1_1_1,00.html`.

[19] These countries are Canada, Denmark, Finland, France, Germany, Italy, the Netherlands, Portugal, the United Kingdom, and the United States. Industries are mainly 2-digit ISIC (Rev. 3) industries; in a few cases, such as "Textiles, textile products, leather and footwear", some of these are aggregated.

[20] However, in general, more evidence on the implementation of EPL upon bankruptcy would be desirable.

in a regression of the average size of exiting firms on both firing difficulty and firing costs, the coefficient on the former should be positive and the one on the latter negative.

Table 5 shows results of a regression of the (log) average size of exiting firms on measures of firing cost and firing difficulty. The coefficients on both firing costs and firing difficulty are significant, and their signs conform with the predictions of the model, i.e. higher firing difficulty is related to higher size of exiting firms, and higher firing costs to lower size (column A). Subsequent columns show that this result is robust to controlling for industry fixed effects (columns B and D to G), year effects (column G), and other variables that could affect the size of exiting firms, for instance the (log) average size of all firms (logn), product market regulation (PMR), the costs of bankruptcy procedures (BKC), and (log) costs of exporting (EXPC). The signs on these controls are in line with what the literature suggests.[21] Results are also robust to using just the time averages for each industry (columns C and H), or to excluding industries where selection processes are possibly weaker due to public intervention, such as agriculture, mining, utilities, telecoms, and construction, or to limiting the regression to the manufacturing or the service sector.

Due to lack of time variation in the policy variables, the difference-in-difference framework that Micco and Pagès (2004) and Autor et al. (2006) employ to reduce problems of omitted variable bias and endogeneity cannot be used here. However, at least the latter problem is likely to be less severe here due to the distinction of the two components of EPL and because of the nature of the dependent variable. For instance, in regressions of job turnover on EPL, it is imaginable that there is some unobserved factor contributing to high job turnover, and eliciting political pressure for stricter EPL, obscuring the effect of EPL on job turnover. In the present context, results are much more nuanced because we are considering the effects of two different policy variables. Moreover, it is more difficult to make up an additional channel linking the size of exiting firms to EPL.[22]

[21] The product market regulation indicator is from Nicoletti et al. (2000). The negative sign is an indication that product market regulation protects incumbent firms: it drives down the exit threshold. The indicator of the cost of bankruptcy procedures is from the World Bank's Doing Business database (http://www.doingbusiness.org), following a methodology developed by Djankov, Hart, McLiesh and Shleifer (2006). These are official costs going off the remaining asset value of exiting firms. This can explain the positive coefficient – higher costs prompt creditors to be more active, and cause firms to exit earlier. Costs of exporting come from the same source. Their negative impact on the exit threshold fits with predictions of recent heterogeneous-firm theories of trade in the spirit of Melitz (2003).

[22] As a thought experiment, imagine that in some country/industry, for some reason, the average size of exiting firms was very high, and that this triggered demands for stricter EPL. This would raise the estimate of the EPL coefficient in question. Concerning the one on FC, this means biasing it towards zero; the true coefficient would then be even more negative than the estimate presented here. Concerning the other coefficient, the estimate presented here might then be too high; however the channel from large firm exit only to stricter procedural

7 Conclusion

This paper has analyzed the effect of firing costs on productivity growth, a topic that is currently receiving much attention in policy circles, notably in Europe, but has not been subject of much study in the theoretical literature. To perform the analysis, a model of growth through selection and experimentation has been developed, taking into account recent evidence on firm dynamics, particularly on the importance of job turnover, firm heterogeneity, and the contribution of entry and exit to aggregate productivity growth. In the model, firms receive idiosyncratic productivity shocks and therefore differ in productivity and employment. Growth occurs endogenously due to selection among incumbents, and due to imitation by entrants. In a nutshell, selection eliminates the worst active firms, so that entrants direct their imitation efforts towards the remaining, better ones. Modeling mean productivity of entrants as a constant fraction of the productivity frontier, the model economy grows through rightward shifts of the firm productivity distribution. The more variable the fate of firms in the economy, the stronger the selection mechanism, and the faster growth.

In this setting, firing costs do not only induce a misallocation of labor, reduce firm value, and discourage entry, as in other models, but also discourage exit of low-productivity firms. This congests the selection process and slows down growth. Their effect is stronger the more variable firms' productivity is. Through this mechanism, the model can match the fact that in recent years, productivity growth differences between the EU and the US were largest in the high-turbulence IT-using service sector. Modeling aggregate productivity growth in close accordance with the evidence on firm dynamics and matching this fact is the first contribution of the paper.

The second one lies in the analysis of the treatment of exiting firms. Exempting exiting firms from firing cost speeds up the exit of inefficient firms and thereby growth. Since job turnover is not much higher than without the exemption, it is likely that the growth cost of charging firing costs to exiting firms exceeds any (here unmodeled) benefits of slightly reducing job turnover. A more detailed investigation of this problem would be worthwhile.

Calibrating the model to the US economy allows for a quantitative evaluation. It turns out that firing costs always reduce welfare, even if only charged to continuing firms, as the misallocation of labor they induce outweighs the positive effect on growth. These results imply that EPL matters for productivity growth. Moreover, it is crucial how labor market policies affect

inconveniences seems far-fetched.

efficient firm exit. Charging firing costs to exiting firms implies small reductions in job turnover, but large costs in terms of lower growth. Interfering with the market selection mechanism comes at a cost.

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Table 5: Regression of log average size of exiting firms on firing costs and firing difficulty, 10 OECD countries

	A	B	C	D	E	F	G	H
estimator	OLS	FE	BE	FE	FE	FE	FE	BE
FD	0.122 ***	0.108 ***	0.040	0.153 ***	0.268 ***	0.266 ***	0.268 ***	0.247 ***
	(0.016)	(0.013)	(0.036)	(0.012)	(0.014)	(0.014)	(0.014)	(0.035)
FC	-0.079 ***	-0.069 ***	-0.058	-0.092 ***	-0.217 ***	-0.237 ***	-0.245 ***	-0.228 ***
	(0.014)	(0.012)	(0.034)	(0.011)	(0.013)	(0.014)	(0.015)	(0.034)
logn				0.536 ***	0.540 ***	0.527 ***	0.525 ***	0.494 ***
				(0.021)	(0.020)	(0.021)	(0.021)	(0.030)
PMR					-0.324 ***	-0.266 ***	-0.273 ***	-0.332 **
					(0.050)	(0.052)	(0.052)	(0.118)
BKC					0.070 ***	0.078 ***	0.082 ***	0.075 ***
					(0.004)	(0.005)	(0.005)	(0.013)
EXPC						-0.272 ***	-0.309 ***	-0.211
						(0.066)	(0.070)	(0.136)
constant	2.027 ***	2.033 ***	2.188 ***	0.245 **	0.234 *	1.932 ***	1.985 ***	1.767 *
	(0.033)	(0.028)	(0.093)	(0.075)	(0.095)	(0.425)	(0.457)	(0.871)
industry effects	No	Yes	No	Yes	Yes	Yes	Yes	No
year dummies	No	No	No	No	No	No	Yes	No
R^2 (adj.)	0.026	0.014	0.004	0.240	0.320	0.325	0.325	0.561
observations	2178	2178	2178	2165	2165	2165	2165	2165

Standard errors in parentheses; stars indicate significance at 10 (*), 5 (**), and 1 (***) percent levels, respectively. Sources: OECD Firm Level Data Project, Nicoletti et al. (2000), World Bank Doing Business Database. FE: fixed effects estimation (industry effects), BE: between estimation (industry × country as observation). Regressors: FD: firing difficulty; FC: firing cost; logn: log average size of all firms in the country-industry; PMR: product market regulation; BKC: bankruptcy cost; EXPC: export cost.

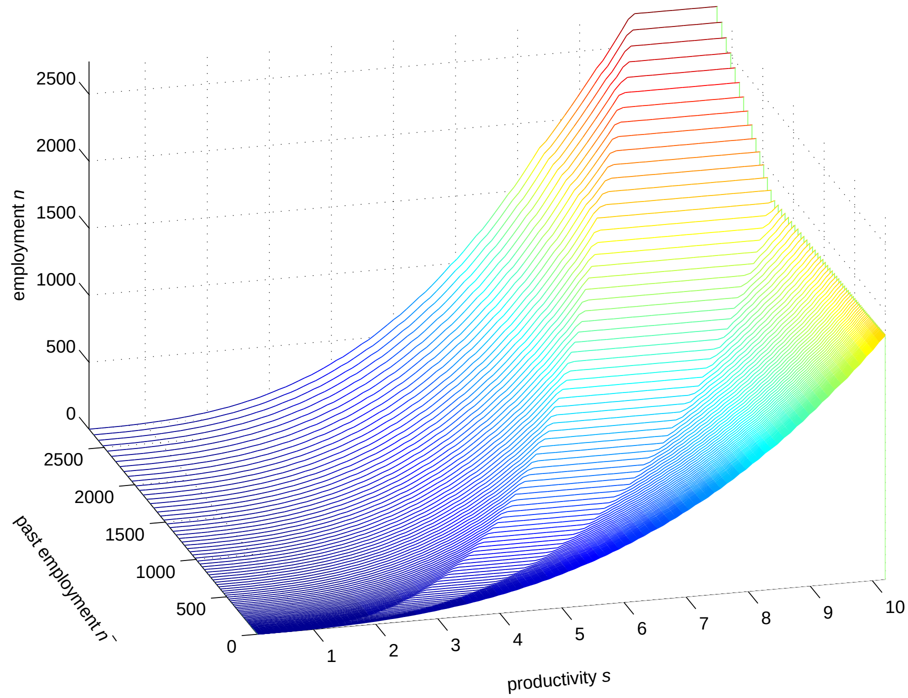

Figure 1: The employment policy function when firing costs are always charged ($F_x = 1$)

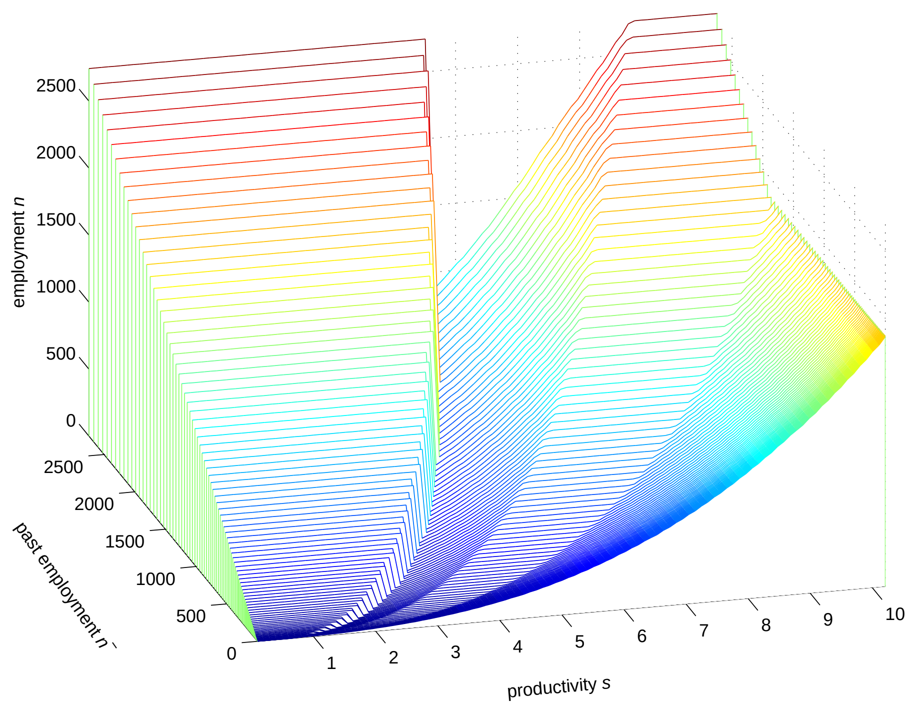

Figure 2: The employment policy function with firing cost exemption upon exit ($F_x = 0$)

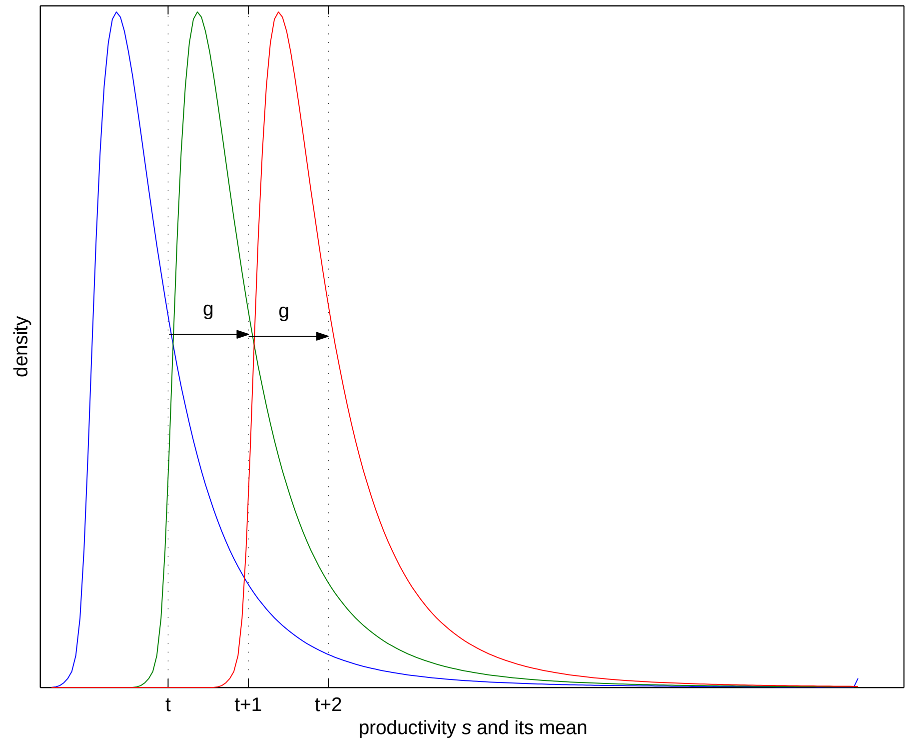

Figure 3: Growth through right-shifts of the firm productivity distribution

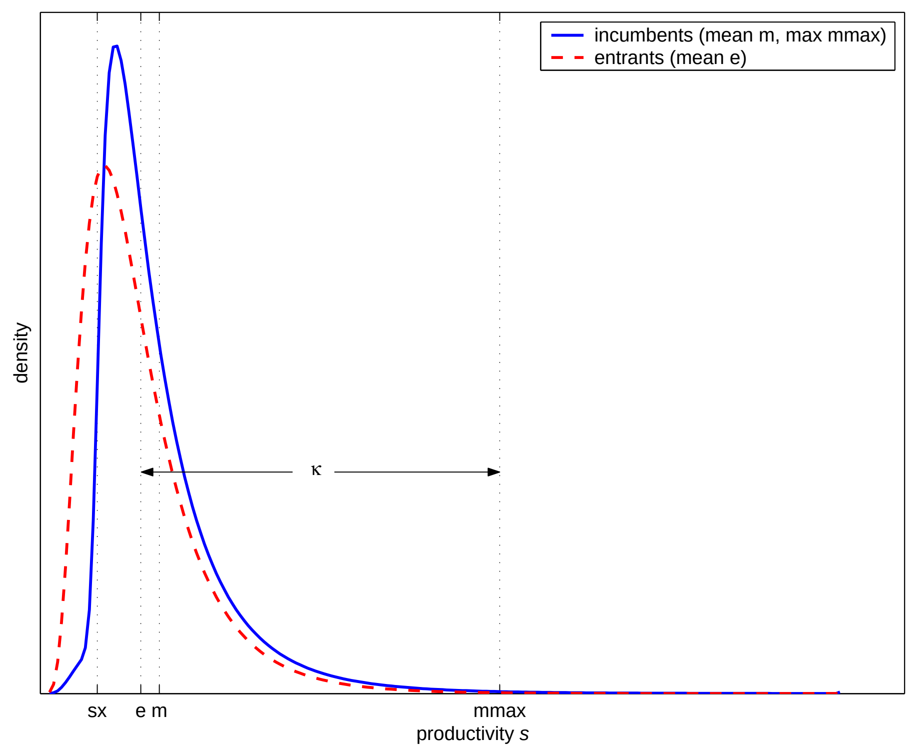

Figure 4: Productivity distribution of entrants and incumbents, difference: κ