The regulation of entry and aggregate productivity*

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Abstract

Euro Area economies have lower total factor and labor productivity than the Unites States. I argue that differences in entry cost contribute to this pattern by affecting firms' technology choice. Introducing technology choice into a standard heterogeneous-firm model, small differences in administrative entry cost can explain around one third of differences in total factor productivity. The productivity difference arises because the reduction in competition due to higher entry costs reduces the incentive to adopt more advanced technologies. Firm heterogeneity, technology choice, and the effect of entry costs on competition all contribute to strengthening results compared to previous studies. The effects of entry costs are even larger when the labor market is not competitive.

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1 Introduction

The lag of Euro Area countries in labor and total factor productivity (TFP) relative to the Unites States is a topic of ongoing discussion in Europe, reflected in political projects (e.g. the Lisbon Agenda), commission reports (e.g. the Sapir Report), and many academic papers (e.g. Blanchard 2004, Prescott 2004). This paper shows that in a model of heterogeneous firms that adopt a technology upon entry, a small shift in administrative entry cost equivalent to those reported by Djankov, La Porta, Lopez-de-Silanes and Shleifer (2002) – corresponding to a tiny fraction of the total cost of the entry investment – can explain a substantial part of the differences

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in TFP observed between Euro Area countries and the U.S.. The main driver of this result is the effect that the reduction in competition that comes from higher entry costs reduces the incentive to adopt more advanced technologies.

These implications of entry costs for aggregate productivity have not received much attention in the literature. This paper hence complements existing accounts of the effect of entry costs and product market regulation on employment (see e.g. Fonseca, Lopez-Garcia and Pissarides 2001), on entry (Ciccone and Papaioannou 2007), on structural change and sectoral specialization (Samaniego forthcoming, Messina 2006), and on unemployment, the real wage, and distributional issues (Blanchard and Giavazzi 2003). It also provides a theoretical basis for the finding by Nicoletti and Scarpetta (2003), Loayza, Oviedo and Servén (2005), and Barseghyan (2008) of a negative relationship between product market or entry regulation and total factor productivity. In a very thorough analysis applying instrumental variables techniques to a data set of 97 countries, Barseghyan (2008) finds that an increase of administrative entry costs by 80% of income per capita (half a standard deviation in his sample) reduces TFP by 22%.

[Table 1]

Table 1 summarizes data on private sector labor productivity (measured as output per hour), capital intensity, TFP and the administrative cost of entry for the U.S. and some major Euro Area economies. The data on administrative entry costs is from Djankov et al. (2002). The remaining variables are from the new Groningen Growth and Development Centre's (GGDC) Productivity Level Database.[1] The data show that European labor productivity is below its U.S. counterpart, despite higher capital intensity in some countries.[2] As many authors have remarked, this must be due to differences in TFP, since differences in human capital are smaller than this gap (see e.g. Klenow and Rodriguez-Clare 1997, Hall and Jones 1999, Caselli 2005). It is also clear from Table 1 that the Euro Area countries feature systematically higher administrative

[1] This database provides aggregate and industry-level comparisons of output, inputs and various productivity measures, including TFP, for 30 OECD countries. Its focus is on creating measures that are comparable across countries. The methodology is described in Inklaar and Timmer (2008) and extends the work by Jorgenson and coauthors that is collected in Jorgenson (1995). The data is available at `http://www.ggdc.net/databases/levels.htm`.

[2] Blanchard (2004) and others have remarked that differences in per capita GDP between Europe and the U.S. are largely due to differences in employment rates and in hours worked. Yet, when using the GGDC's PPP for value added to compare GDP across countries, substantial differences even in GDP per hour worked remain. Using value added PPP is desirable but requires data on output and input prices. Inklaar and Timmer (2009) show that differences between value added PPP and the more commonly used final output PPP can be substantial.

entry costs than the U.S.. Matching these patterns and evaluating the impact of small changes in administrative entry costs on aggregate productivity is the objective of this paper.

To achieve this, I introduce two new features in a standard dynamic stochastic heterogeneous-firm model building on Hopenhayn (1992). The first new feature is technology choice by entering firms. In existing heterogeneous-firm models such as Jovanovic (1982), Campbell (1998), Samaniego (2006), and Restuccia and Rogerson (2008), firms receive idiosyncratic productivity shocks every period and enter and exit based on this. Their entry productivity, however, is drawn from an exogenously given distribution. This restriction effectively closes down one margin of optimization for firms.[3] Introducing technology choice reactivates this margin and allows to endogenize part of the underlying productivity process affecting firms. I model technology choice by letting entering firms irreversibly choose a parameter determining expected productivity. Subsequently, their productivity follows a Markov process that depends on this parameter. The cost of the sunk entry investment is increasing and convex in the expected productivity of the technology chosen. Stochastically evolving firm productivity, optimal choice of technology at entry, and endogenous exit of unprofitable firms then yield a stationary distribution of firms over productivity levels. So, although firms constantly enter, exit, and change position within the distribution, the distribution itself and other aggregate variables do not change.[4]

The second new feature of the model concerns the competitive environment. The firms just described produce differentiated intermediate goods under monopolistic competition. Following Blanchard and Giavazzi (2003), I then assume that the substitutability of their products increases in the number of active firms. As there are more firms, the product space gets more crowded, products more similar, and thus more substitutable. As a result, the change in the number of firms brought about by higher entry costs affects other aggregate variables.[5] Ebell and Haefke (2009) have recently used this approach to analyze the interaction of product and labor market regulation in a setting with homogeneous firms. Both this feature and technology choice by entrants distinguish the paper from Barseghyan's (2006) theoretical analysis of the impact of entry costs on productivity.

[3]An exception is Ericson and Pakes (1995), who analyze the industry-level strategic interaction among a small number of firms that can invest in productivity-enhancing innovation.

[4]This setup squares well with the rich recent empirical literature on firm dynamics that stresses the importance of firm-specific shocks, firm turnover, large heterogeneity in productivity within industries, and importance of entry and exit for productivity. For surveys of past work and recent evidence on both developed and developing countries, see Roberts and Tybout (1996), Sutton (1997), Caves (1998), Foster, Haltiwanger and Krizan (2001, 2006), Bartelsman and Doms (2000), Tybout (2000), Bartelsman, Haltiwanger and Scarpetta (2004) and references therein.

[5]This is of course a prediction of many models of imperfect competition. To preserve tractability in a model with heterogeneous firms, the setup chosen here is particularly useful.

To obtain quantitative results, the stationary equilibrium of the model is calibrated to the U.S. business sector, using static and dynamic moments of its firm distribution. Calibration allows imputing the parameters of the unobserved entry investment cost function. The effect of small differences in entry cost can then be evaluated by comparing stationary equilibria. It results that the loss in output and consumption due to higher entry cost exceeds the direct burden of the additional entry cost many times. Quantitatively, introducing administrative entry costs of 30% of per capita GDP (about the German level) explains around a third of the TFP difference between Germany and the U.S.. The performance is similar for other Euro Area countries. This corresponds to a third of the effect of entry costs on TFP found by Barseghyan (2008).

The most important effect triggered by higher entry costs goes through the competitive channel. Higher entry costs reduce the number of active firms. The products of the remaining ones then are more differentiated. This protects the market shares of low-productivity firms, reduces those of highly productive firms, and thereby diminishes the incentive to adopt advanced technologies. (Syverson (2004) provides evidence from one industry supporting this differential effect of substitutability on firms' profits.) With entrants choosing less productive technologies, TFP, output and consumption all fall.

The effects are qualitatively similar but smaller without technology choice, without heterogeneity, or when there are no competitive effects. They are larger when wages are not determined competitively but by bargaining. This echoes the argument of Blanchard and Giavazzi (2003) that product and labor market imperfections interact.

To summarize, the contribution of this paper is to trace part of the difference in aggregate productivity between similarly developed economies to differences in administrative entry cost. Already small costs can have large effects. This result is particularly relevant in the light of the current European debate about its productivity lag with respect to the U.S., and about the possible role of regulation.

The paper is structured as follows. The economy is described in Section 2. In Section 3, optimal firm behavior is characterized and a stationary competitive equilibrium is defined. The model is calibrated to the U.S. business sector in Section 4, and the effect of changes in entry cost is analyzed in Section 5. Section 6 concludes. Proofs and detailed descriptions of model extensions are provided in the Appendix.

2 The economy

The economy consists of a continuum of unit measure of identical households and of two types of firms: a competitive sector of final goods producers and a continuum of endogenous measure $\bar{\mu}$ of firms producing intermediate goods. There also is a large pool of potential entrants into the intermediate goods sector. Time is discrete and indexed by t, and the horizon is infinite.

Households have linear utility in consumption of the final good. They derive income from working and own the firms in the economy, claiming their profits.

The final good is produced by combining intermediate goods. The production function is given by the Dixit-Stiglitz aggregator

$$Q_t = \left(\int_i q_{it}^{\frac{\xi-1}{\xi}} \, \mathrm{d}i \right)^{\frac{\xi}{\xi-1}}$$

where Q_t denotes output of the final good, i indexes intermediate goods and their producers, and q_{it} denotes the quantity of intermediate good i used. As the sector is competitive, the final good is sold at marginal cost, and final goods producers do not make profits. Cost minimization by final goods producers yields demand for intermediate good i as

$$q_{it} = \left(\frac{p_{it}}{P_t} \right)^{-\xi} Q_t, \tag{1}$$

where p_i is the price of good i. P_t is the marginal cost (and, under perfect competition, also the price) of a unit of the final good and can be interpreted as a price index of intermediate goods. Equation (1) is the standard demand function faced by intermediate goods producers in monopolistically competitive settings. The elasticity of substitution among the differentiated goods is given by ξ. Following Blanchard and Giavazzi (2003) and Ebell and Haefke (2009), I assume that substitutability increases if more types of goods are produced, i.e., $\xi = \xi(\bar{\mu})$ with $\xi' > 0$ and $\xi > 1$ for all $\bar{\mu}$. One possible interpretation of this assumption is that the more differentiated products there are, the more similar, and thus substitutable, they must be.

Demand from final goods firms shapes the environment in which intermediate goods producers compete. The remainder of the paper focusses on intermediate goods producers and their choices. For brevity, I will refer to them simply as “firms” in the following.

Firms are risk-neutral and maximize the discounted value of expected profits. In every period, they go through the following sequence of events and actions. All active firms pay a fixed operating cost, and then learn their new productivity level. Based on this, they choose their price, output and employment, and the wage adjusts to clear the labor market. Firms also decide whether they will be active next period; i.e., incumbents decide whether to exit and potential entrants whether to enter. Firms that decide to enter choose a technology. They then receive a draw from the distribution of entrants' productivity at the start of the next period.

Production entails a strictly positive fixed operating cost of c^f units of the final good per period.[6] Active firms then set their price optimally, as a function of their productivity and of the demand they face. They produce according to the production function

$$q_{it} = \exp(s_{it})n_{it},$$

where s_{it} denotes firm i's time-t realization of the stochastic process driving its productivity, and n_{it} the amount of labor it employs at time t. Because firms face downward-sloping demand functions, they choose a finite level of output and employment that depends on their productivity s_{it}. As a consequence, firm size is a well-defined concept and with heterogeneity in s_{it}, a non-degenerate firm size distribution arises.

Employment n_{it} can be adjusted costlessly every period. Firms hire labor on a competitive labor market. Denote aggregate labor demand by N_t. Labor supply elasticity does not affect results very much, so assume that labor supply is inelastic at $\bar{N} = 1$. Then the wage ω_t is a function of aggregate labor demand only.

The idiosyncratic productivity shock s follows a first-order Markov process. Specifically, assume that

Assumption 1 *s_{it} follows an AR(1) process with firm-specific constant v_i:*

$$s_{it} = v_i + \rho s_{i,t-1} + \epsilon_{it}, \qquad 0 < \rho < 1, \tag{2}$$

where ϵ is distributed normally with mean zero and variance $\sigma^2 > 0$. It is independent both across firms and over time.

Here, think of $v_i \in \mathbb{R}_+$ as the technology that firm i operates; it determines expected lifetime productivity. Because $\rho < 1$, s_{it} is stationary and mean-reverting. Denote the p.d.f. of s_{it} for a given v_i conditional on $s_{i,t-1}$ by $g_{v_i}(s_t|s_{t-1})$ and its conditional distribution function by $G_{v_i}(s_t|s_{t-1})$. There is another stochastic element to a firm's life; its production facilities break down with an exogenous probability $\delta \geq 0$, forcing the firm to exit. This ingredient allows the model to fit the fact that although empirically, the exit hazard is higher for small plants, there are still some large plants that exit.

[6] A fixed cost is necessary to ensure positive exit; otherwise instead of exiting, firms could cut production to zero and wait for better times. It can also be thought of as the cost of foregoing an outside option.

Entrants that start producing in period t and have technology v_i draw their initial productivity s^0_t from a p.d.f. $h_{v_i}(s^0)$. For concreteness, suppose that

Assumption 2 $s^0 \sim N(\bar{s}^0,\, \sigma_e^2)$, *with* $\bar{s}^0 = \kappa \frac{v_i}{1-\rho}$, *and* $\kappa, \sigma_e^2 > 0$.

The constant κ serves to calibrate the productivity of entrants relative to incumbents in the aggregate, while v_i is entrants' choice variable. From period $t+1$ on, entrants follow the process (2). Among surviving firms there is a selection effect: since low-productivity firms exit to avoid the fixed operating cost, average productivity is higher than $\frac{v_i}{1-\rho}$, the asymptotic mean of (2). Hence, Assumption 2 implies that entrants expect to start with a realization of their productivity state below average productivity of incumbents, unless κ is much larger than 1. As a consequence, young firms are more likely to exit, and the hazard rate declines in age. So, by Assumptions 1 and 2, the structure of the productivity process captures the features of persistence and mean reversion of productivity, learning/selection, lower relative productivity of entrants, and declining hazard rates found in the data (see e.g. the surveys by Caves 1998, Bartelsman and Doms 2000).

The part of the model that extends Hopenhayn (1992) and that is crucial for the results obtained in the following is entrants' technology choice. Due to Assumptions 1 and 2, technology v_i determines expected productivity over a firm's lifetime. Concretely, for any v' and v with $v' > v$, the unconditional distribution functions $g_{v'}(s)$ and $h_{v'}(s^0)$ first-order stochastically dominate $g_v(s)$ and $h_v(s^0)$, respectively.

Technology v_i is irreversibly chosen upon entry at a cost given by the entry investment cost function $c^e(v_i)$. This function gives the investment c^e (in units of the final good) that a firm has to make to enter the market with technology v_i. Ruling out a scrap value of the firm on exit, this investment is irreversible and sunk. Moreover, the menu of technologies available and the associated costs do not change over time.[7]

The shape of $c^e(v_i)$ is governed by the following assumption.

Assumption 3 *The entry investment cost function* $c^e(v)$ *is positive for all* v *and strictly increasing and convex in* v.

In the numerical analysis, an exponential specification is chosen for tractability; it is simple enough to identify its parameters just from calibration. Also assume that very advanced technologies are prohibitively costly (Assumption 3′). This implies that the equilibrium technology

[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).

is finite. "Very advanced" here need not be defined too precisely, the point being that only finite productivity has been observed in reality.

Assumption 3 allows for several economic interpretations. The production technology is embodied in a fixed factor that firms acquire upon entry. It could be that there are information costs about this factor that increase in its efficiency; or the life cycle of the technology could matter, with less competition in more advanced, younger products; or there could be decreasing returns in the production of the technology. Optimal choice of technology also means that the technological frontier is endogenous in this model. While a little more advanced technologies are available, adopting them is not optimal, whereas the prohibitive cost of much more advanced technologies can be seen as economically equivalent to non-availability.

The final element missing from the description of the economy is the firm distribution. To track firms' cross-sectional distribution, define $\mu_t(v, s)$ as the measure of firms that have technology v and productivity state s in period t. Denote the set of all v with V, that of all s with S, and the $V \times S$ state space with Σ. Then $\bar{\mu}_t \equiv \mu_t(\Sigma)$ is the measure of all firms. The distribution $\mu_t(\cdot)$ is common knowledge.

Since all units with the same v are independently affected by the same stochastic process, this number of units is large, and there is no aggregate uncertainty, the evolution of the cross-sectional distribution can be characterized by the underlying probability distribution, and aggregate variables are deterministic given an initial distribution of firms.[8] With respect to the firm distribution $\mu_t(\cdot)$ this means that although the identity of firms with any s is random, their measure is deterministic. In a stationary equilibrium as focussed on here, aggregate variables are constant, so the time subscript can be dropped.

3 Competitive equilibrium

The interesting optimizing agents in this economy are intermediate goods producers ("firms"). In this section, their optimal behavior is characterized, and a stationary competitive equilibrium is defined. This is followed by a brief discussion of the relationship between key objects and a short description of the algorithm used for calculating the equilibrium allocation.

[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).

3.1 Firm behavior

Firms' individual state variables are v and s; they have a static control p (or, equivalently, q or n) and dynamic controls that consist of the entry and exit decisions and choice of technology. They take three types of decisions: Potential firms decide whether to enter, incumbents decide whether to exit, and active firms maximize current profits.

The incumbent's problem: The problem for an active firm is to maximize current profits. As usual in setups with monopolistic competition, it is optimal to set the price as a constant markup over marginal cost: $p_i = \frac{\xi}{\xi-1}\frac{\omega}{\exp(s_i)}$. This implies that a firm's price falls in its productivity s and in the substitution elasticity ξ and increases with the wage ω. The resulting firm-level labor demand function $n(s_i, \omega, \xi)$ is continuous, increasing in s, and decreasing in ω. A firm's output and profits also are continuous, increasing in s and decreasing in ω.

The reaction of employment, output and profits to changes in ξ depends on a firm's relative productivity. When goods are closer substitutes, a highly productive firm can leverage its productivity more and can gain a large market share. Higher differentiability, in contrast, protects low-productivity firms. As a consequence, employment, output and profits increase in ξ for firms with high productivity, and fall in ξ for low-productivity firms. (See the first part of the proof of Lemma 8 for the derivation.)

Discounting profits by a common discount factor $\beta \in (0, 1)$, the value of an incumbent is

$$W(v_i, s_i, \omega, \xi; \mu) = \pi(s_i, \omega, \xi) + \beta \max\left\{W_x,\ (1-\delta)\, E[W(v_i, s_i', \omega, \xi; \mu')|s_i] + \delta W_x\right\}, \quad (3)$$

where primes denote next-period values. The max operator indicates a firm's option to exit, obtaining the value of exit W_x, if this exceeds the expected value of continuing. A firm that decides to continue can still suffer exogenous breakdown with probability δ, also yielding the exit value W_x. By standard arguments, a unique value function W exists, is strictly increasing in v and s, strictly decreasing in ω, and continuously differentiable in v. (See Lemma 1, Corollary 2, and Lemma 5 in the Appendix.) Anticipating a stationary equilibrium where $\mu' = \mu$, the productivity distribution μ can be dropped as an argument. For an individual firm, this distribution only matters through its effect on the wage ω and on the substitution elasticity ξ. When μ is stationary, these are constant, and it is not necessary to keep track of μ to project their future evolution. In the following, for brevity, decisions of the firm can then be written as functions of ω and ξ only.

Exit: A firm exits when the expected value from continuing is smaller than the value of exiting: $E[W(v_i, s_i', \omega, \xi)|s_i] < W_x$. With W strictly increasing in s, for given v_i, ω and ξ, this is the case for s strictly smaller than some unique exit threshold $s_x(v_i, \omega, \xi)$ given by

$$E[W(v_i, s_i', \omega, \xi)|s_x] = W_x \tag{4}$$

that is strictly decreasing in v_i and increasing in ω and ξ. Firms with more productive technologies can endure lower levels of the productivity shock before being forced to exit. A higher wage reduces the value of all firms and a higher substitution elasticity that of low-productivity firms, raising the exit threshold. From Assumption 1, $G_v(s_x|s) > 0$ for all v and s, so there always is a strictly positive measure of firms that exit.

Entry and Technology Choice: Entrants compare costs and benefits of entry, and choose v_i to maximize the expected net present value of entry. Benefits correspond to the expected value of a firm with technology v_i, costs are given by the entry investment $c^e(v_i)$. The net value of entry W^e at the optimal choice then is

$$W^e(\omega, \xi) = \max_{v_i}\{E[W(v_i, s_i^0, \omega, \xi)|v_i] - c^e(v_i)\},$$

where the expectation is over the initial draw of s^0 conditional on the choice of v. Denote the measure of entrants using technology v by $M(v)$. Optimal choice of technology v_i^* requires[9]

$$\partial E[W(v_i^*, s_i^0, \omega, \xi)|v_i^*]/\partial v_i = c^{e\prime}(v_i^*). \tag{5}$$

Since the solution v_i^* to (5) is a function of aggregate variables only, all entrants in a given period adopt the same technology, so the i subscript on $v^*(\omega, \xi)$ can be dropped.

At the same time, under free entry, entry occurs ($M(v^*) > 0$) until

$$E[W(v^*, s_i^0, \omega, \xi)|v^*] = c^e(v^*) \tag{6}$$

in equilibrium. This also implies that the value of exit W_x is zero – starting a new firm after exiting yields zero expected net value. Since a strictly positive measure of firms exits every period, $M(v^*)$ also must be strictly positive for the firm productivity distribution to be stationary, as considered in the following. Equation (6) hence holds with equality. The wage and the measure of firms adjust to ensure this.

[9] Lemma 5 in the Appendix shows that the expected value of entry is differentiable in v and that the problem is concave, so the first order condition is sufficient for an optimum.

Cross-sectional distribution: Firms' choices determine the evolution of the cross-sectional distribution of firms over v and s. In a stationary state, $\mu(v,s)$ evolves according to

$$\mu'(v,s) = \int_{s_x(v,\omega,\xi)}^{\infty} (1-\delta)\mu(v,u)\, g_v(s|u)\, \mathrm{d}u + M(v)\, h_v(s) \quad \text{for any } (v,s). \tag{7}$$

The integral captures the evolution of continuing firms, while the last term accounts for entry.

The model is closed by labor market clearing. Aggregating over firms yields aggregate labor demand

$$N(\mu(\cdot),\omega,\xi) = \int_{\Sigma} n(s,\omega,\xi)\, \mathrm{d}\mu(v,s). \tag{8}$$

Equating this to labor supply $\bar{N}$ implicitly determines the equilibrium measure of firms $\bar{\mu}^*$. The solution to the system of (5), (6), (7) and the labor market clearing condition then is a triple $(v^*,\omega^*,\bar{\mu}^*) \in \mathbb{R}^3_+$ and a firm productivity distribution μ^*.

3.2 Equilibrium definition

In this section, a stationary equilibrium is defined, its determination is sketched, and an algorithm for finding it is given.

Define a *stationary competitive equilibrium* as real numbers $v^*,\omega^*,\xi^*,M^*,s_x^*,N^*$, and functions $\mu^*(v,s), W(v,s,\omega,\xi)$ such that:

(i) entry is optimal: v^* and ω^* satisfy (5) and (6) if $M^*>0$, and $E[W(v,s_i^0,\omega,\xi)|v] < c^e(v)$ for all v otherwise;

(ii) exit is optimal: s_x^* satisfies (4);

(iii) firm value $W(v,s,\omega,\xi)$ is given by (3) for all v, s, ω, ξ;

(iv) markets clear: $N(\mu^*,\omega^*,\xi^*) = N^* = 1$;

(v) the firm distribution evolves according to (7), and it is stationary: given s_x^* and v^*, M^* is such that $\mu' = \mu = \mu^*$; and

(vi) the substitution elasticity ξ^* is the one generated by the equilibrium measure of firms $\bar{\mu}^*$: $\xi^* = \xi(\bar{\mu}^*) = \xi(\mu^*(\Sigma))$.

The restriction to stationary equilibria does not allow considering dynamic changes of the distribution. However, it does allow the analysis of processes within the distribution and the comparison of stationary equilibria (as in the comparative dynamics exercise to follow), which is sufficient for obtaining interesting results.

Existence of a competitive equilibrium intuitively follows from the following argument.[10] It has been shown in several contexts, starting with Lucas and Prescott (1971), that equilibria in similar models of industry evolution maximize industry discounted consumer surplus net of production costs. This objective is continuous. Under Assumption $3'$, it is bounded above, and equilibrium v^* is finite. Then, without loss of generality, the domain of (v^*, M^*) can be restricted to a compact subset X of $\mathbb{R}^2$. The feasible set then is the set of all (v^*, M^*) such that equilibrium conditions (i) to (vi) hold. Finding a competitive equilibrium then corresponds to maximizing a bounded and continuous objective on the compact set X. By Weierstrass's Theorem, an allocation that maximizes net discounted surplus, and hence a competitive equilibrium, exists.

Figure 1 shows the cost and value of entry around the equilibrium as functions of v. By entrants' optimality condition (5), the slopes of the two curves have to be equal in equilibrium. Under the assumptions on $c^e(v)$, this occurs for a finite v^*. Proposition 6 in the Appendix shows that it is also unique. Combining this optimality condition with the free entry condition (equation 6) pins down v^* and ω^* for a given measure of firms. Intuitively, if the value of entry exceeds the cost of entry at any v, there is excess demand for entry, driving up the wage until the net value of entry is zero. If on the other hand the cost of entry exceeds its value at all v, and there is exit, then the wage needs to drop to clear the labor market, and there is net exit, reducing the measure of firms. At the equilibrium v and ω, the value of entry schedule is tangent to the entry cost curve at v^* and lies below it for all other v. Finally, the equilibrium measure of firms $\bar{\mu}^*$ is implicitly determined by the labor market clearing condition.

For illustration, Figure 2 shows the benchmark firm distribution resulting from the calibration in the next section, with productivity relative to average productivity on the x-axis. The mode lies at 0.87 and the median at 0.83; the distribution is heavily skewed to the right because of exit.

A crucial intermediate result to be used for evaluating the impact of exogenous shifts in entry cost is that W_v, the derivative of the value of entry with respect to the technology v, declines in ω and rises in ξ. This is shown in Lemmas 7 and 8 in the Appendix. Intuitively, while firm value rises in v, an increase in the wage shortens expected firm lifetime and thereby the benefits from a higher v, reducing W_v. A higher substitution elasticity, in contrast, implies that more productive firms obtain a larger market share, and thus increases the marginal value of a higher v. (Conversely, stronger differentiation preserves the market share of low-productivity firms.)

Using the equilibrium conditions, a stationary equilibrium can be found by applying an

[10] This argument has been outlined by Hopenhayn (1992) in a very similar context.

algorithm that consists of the following steps. First, guess v, ω and $\bar{\mu}$. Using these guesses, obtain expressions for firm value $W(v, s, \omega, \xi)$ and for the exit trigger $s_x(v, \omega, \xi)$ (equilibrium condition (ii)). In the numerical implementation, this is done by value function iteration, discretizing the state space S into a grid of 1000 points. The boundaries of the grid influence results if set too narrowly. Therefore, they are expanded until results are not affected anymore. The process for s combined with the exit trigger imply a firm productivity transition matrix P_x incorporating exit. The stationary firm distribution (equilibrium condition (v)) then is given up to a multiplicative constant corresponding to $\bar{\mu}$ by the ergodic distribution $\mu = (I - P_x^T)^{-1}\mu^0$ of a stochastic process with transition matrix P_x and initial state μ^0, where μ^0 is a vector capturing the distribution of entrants over S, I is the identity matrix, and the superscript T denotes the transpose of a matrix. Using μ, W and the guesses for ω and $\bar{\mu}$, evaluate the labor market clearing condition and the free entry condition. Solving the system consisting of these two conditions for the ω and $\bar{\mu}$ consistent with the guess of v is very fast. Finally, compute $\partial E[W(v, s^0, \omega, \xi|v)]/\partial v$ at the guess for v and evaluate (5). Adjust v and iterate on this process until (5) also holds, and v^*, ω^* and $\bar{\mu}^*$ are obtained.

4 Calibration

Since the calibration matters for the size of the effects obtained in the numerical analysis in the next section, it is described in detail in this section. Functional forms and parameters are chosen to fit the U.S. business sector. Given these choices, model quantities resulting from calibration uniquely determine the parameters of the entry cost function via the optimal v condition (5) and the free entry condition (6).

To ensure comparability with statistics from firm-level data, the time period is set to one year. The objects that are most difficult to calibrate are the entry cost function $c^e(v)$ and the function relating the elasticity of substitution to the measure of firms, $\xi(\bar{\mu})$. For the entry investment, only one value is observed in a stationary equilibrium because all firms choose the same technology v^*, as shown before. However, an entry investment cost function needs to be specified for evaluating the impact of an increase in administrative entry cost. This problem can be solved in a simple way. It is sufficient to calibrate only one value $c^e \equiv c^e(v^*)$ of the entry investment function. v^* can be normalized for the benchmark economy because it just scales the level of productivity and output of the economy, but does not influence the shape of the productivity distribution or any ratios. Then choosing the simple functional form $c^e(v) = k_1 e^{k_2 v}$, $k_1 > 0$, $k_2 > 1$ for the entry investment cost function implies that the parameters k_1 and k_2 are pinned down by the equilibrium conditions (5) and (6) as $k_2 = W_v(v^*, \omega^*)/W(v^*, \omega^*)$ and $k_1 = W(v^*, \omega^*)e^{-k_2 v^*}$.[11] For the substitution elasticity, we adopt the functional form $\xi(\bar{\mu}) = \bar{\xi}\bar{\mu}$, following Ebell and Haefke (2009).[12] The model can then be solved for a value of ξ taken from the data, and $\bar{\xi}$ backed out using the endogenous equilibrium measure of firms.

The parameters to calibrate then are c^e, c^f, ξ, ρ, σ, δ, κ, σ_e and β. As far as possible, they are set using information from the literature. For the remaining ones, moments of the stationary equilibrium of the model are matched to data models. Four parameters can be set using information from the literature. To match a real annual interest rate of 4%, β is set to 0.96. Using information from Broda and Weinstein (2006, Table 4), ξ is set to 3. This is close to the median substitution elasticity they find in U.S. data at different levels of aggregation. It also generates a labor share of two thirds, very close to its empirical value. (The remaining income remunerates the fixed factor and corresponds to the sum of the capital share and profits in the data.) Lee and Mukoyama (2008) provide estimates on the stochastic process for firms' employment that can be used to calibrate ρ and σ, the parameters governing the evolution of the productivity of incumbents. In a regression of employment on its lag, they obtain a coefficient on the lag of 0.97 and a standard deviation of the error term of 0.4. This implies values of 0.97 for ρ and $0.4/(\xi - 1)$ for σ. Davis, Haltiwanger, Jarmin and Miranda (2006) report a similar number for firm-level employment volatility. The very high persistence of firm-level productivity also is a general result in the empirical literature (see e.g. Baily, Hulten and Campbell 1992, Bartelsman and Doms 2000).

For c^e, c^f, δ, κ and σ_e no direct evidence is available. However, because these parameters determine the shape, location and truncation point of the firm productivity distribution, information on the empirical distributions of entrants and incumbents can be used to set them. Since these parameters have interacting effects, they cannot be calibrated individually. Instead, they are calibrated jointly to fit a set of data moments of equal size. This fit is very nonlinear in the parameters; so a genetic algorithm following Dorsey and Mayer (1995) is used to find the best fit. It turns out to be useful to calibrate c^e and c^f as the ratio c^e/c^f and the level c^f. Given all other parameters, the level c^f then only matters for the average size of firms. It is thus fixed

[11] There is little empirical evidence on the shape of the entry cost function. The specification chosen here is conservative in the sense that it tracks the value function very closely. (Much more closely than apparent in Figure 1, which is stylized for readability.) As a consequence, the quantitative effect of the empirical exercise will be relatively small and can be considered a lower bound; a more convex entry cost function would yield larger effects.

[12] This functional form of the substitution elasticity also arises in a model where $\bar{\mu}$ firms compete à la Cournot in each differentiated product category.

to match the average establishment size of 15.8 in data reported by the U.S. Small Business Administration (SBA).[13]

To fit the remaining four parameters, the following static and dynamic characteristics of the firm distribution are chosen as targets: the employment-weighted firm turnover rate, the productivity of firms that entered within the last 10 years relative to the average firm, the productivity of exiting relative to continuing firms, and the investment/output ratio. The measure of the relative productivity of entrants allows anchoring the mean of entrants' productivity distribution. The weighted turnover rate is informative about the variance of that distribution. The relative productivity of exiting firms is informative about δ, the parameter that controls how much exit comes from the the bottom vs the rest of the distribution. Finally, the investment/output ratio contains information about the size of the entry investment. To evaluate the calibration, other static and dynamic moments of the firm productivity and size distributions can be used, such as the job turnover rate, survival rates, the age-size profile, and measures of productivity dispersion.

Bartelsman, Haltiwanger and Scarpetta (2004, Table 5) report average yearly employment-weighted firm turnover of 7% for the US for the 1990s. They report similar numbers for other industrialized economies, including continental European ones, with the exception of Germany, where the rate is under 4%. Estimates of entrants' relative productivity agree that both in Census of Manufactures data (Foster, Haltiwanger and Krizan 2001) and in the Census Longitudinal Research Database (Haltiwanger 1997), the mean of the distribution of entrants' productivity is on average slightly below that for incumbents. Employing a variety of measures, Foster et al. (2001) settle on a value of around 99% for average productivity of firms that entered over the last 10 years relative to that of incumbents. They also report that exiting firms that were active for more than a single year are slightly less productive than continuing firms. Finally, in OECD data, the investment/output ratio (average non-residential capital formation relative to output) is 14.4% for the period 1998 to 2003.

[Tables 2 and 3]

Finally adopted parameters are shown in Table 2. Table 3 shows target statistics in the left column and resulting statistics for the model economy in the right column. The calibration fits

[13] This data is available at `http://www.sba.gov/advo/research/data.html`.

target moments very closely. Only the productivity of exiting firms relative to continuing ones is slightly on the high side.

The adopted parameter values are reasonable. Entrants are on average 10% less productive than incumbents. (While $\kappa > 1$, this just means that entrants' average log productivity is larger than $v/(1-\rho)$, the asymptotic mean of the productivity process for incumbents. The population mean turns out to be 38% higher than this asymptotic mean, so entrants are less productive than the average incumbent.) The variance of the productivity distribution of entrants is not very large. Combined with the substantial entry investment and a rather small fixed operating cost, this allows the model to fit the employment-weighted turnover rate from the data very closely. This target moment puts little weight on entry and exit of very small firms. A consequence of this is the somewhat high survival rate of entrants generated by the model, indicating that the calibration misses some very short-lived firms. Entrants in the model are likely to survive. For the purpose of the exercise conducted in this paper, this is desirable. Small and short-lived firms do not matter much for aggregate outcomes. For instance, SBA data show that while in 1992, 49% of all establishments with employees had less than 5 employees, they accounted for less than 6% of employment. While the calibration may thus not allow us to infer the full effect of administrative entry costs on firm turnover, because we miss part of the effect on very small firms, it is very well suited for measuring the effect on aggregate variables.

The bottom part of Table 3 shows that the calibration also fits well for dimensions that have not been targeted. The job turnover rate of 37.8% is quite close to the annual data value of 32% (Davis, Faberman, Haltiwanger and Jarmin 2008). The productivity spread between the 9$^{\text{th}}$ and the 2$^{\text{nd}}$ decile, although possibly a bit high at 3.4, fits well with reported values of around 3 (see e.g. Dhrymes 1991, Dwyer 1998). Not only the variance, but also the skewness of the distribution is well-captured. In the model, 63.3% of establishments have employment below the average. This is close to the value of around two thirds reported in SBA data. Finally, as indicated above, the calibration fits the bulk of the distribution well at the cost of missing some turnover of young and small firms, as indicated by entrants' survival rates, which are somewhat too high in the calibration. The growth rate of surviving entrants, however, is close to its value in the data (Bartelsman et al. 2004, Table 8), indicating that the calibration does a good job at capturing the entrants that matter most: the ones that stay around and grow. Hence, the calibration fits well in both the targeted dimensions and in supplementary ones.

To summarize, given that the model is very parsimonious, the calibration fits rather well. The next section explores the effect of administrative entry costs on aggregate productivity.

5 The effect of administrative entry costs

As illustrated in the introduction (see Table 1), the U.S. has higher labor productivity (output per hour worked) than other OECD members. Differences in capital intensity and in the skill composition of the labor force can account for only part of the difference. Several European countries actually use more capital-intensive production methods. As a consequence, most of the labor productivity gap is "explained" by higher TFP in the U.S.. This section explores how the present model can generate part of this difference. To fix ideas, think in terms of a comparison of the U.S. and Germany, using the 1997 data from the Groningen Growth and Development Centre's Productivity Level Database shown in Table 1. For that year, and similarly in other periods, German capital intensity is slightly (6%) above that of the US, while output per worker is 10% lower. The skill composition of the labor force is inferior, but this explains only part of the gap. Using a Cobb-Douglas production function with a capital share of 0.3, a simple accounting exercise implies that German TFP is 7% lower than that of the U.S.. While many explanations could be used to chip away at this difference, the scope of this section is to illustrate how the present model can resolve some of it.

In an influential article, Djankov, La Porta, Lopez-de-Silanes and Shleifer (2002) publish meticulously gathered data on administrative entry barriers in 85 countries. They describe the minimum cost needed to meet official requirements to legally operate a small industrial or commercial firm. This fits with the characteristics of entrants in the benchmark economy. The cost corresponds to 47% of per capita output in the average country, close to zero (0.5%) in the country with the lowest cost (United States), and 463% in the country with the highest cost (Dominican Republic). In Germany, it is 32.5%, close to the values for other Euro Area economies. Djankov et al. also relate these costs to other variables such as measures of corruption and the quality of public goods, and conclude in favor of the public choice view that entry regulation benefits politicians and bureaucrats without necessarily increasing welfare. Yet more can be said. The consequences of entry regulation do not stop at its direct cost; through its effect on entry, technology choice, and aggregate productivity, the cost in terms of lost output can be many times the direct cost.

The exercise conducted in this section consists in imposing an additional entry cost of 30% of per capita output of the benchmark economy on entrants, regardless of the v they choose. This value is close to the value for Germany and to the Euro Area average. It amounts to an upward shift of $c^e(v)$ by 1.9% (4.3%) of the output of the average (median) firm, or by 0.6% of the entry investment in the benchmark economy. Since this change is small, the parameters of the entry investment cost function and of $\xi(\bar{\mu})$ imputed in the calibration can be used to find the new stationary equilibrium with this additional cost.

The next section reports results from this experiment in the benchmark model and briefly evaluates its performance. Subsequently, I show that heterogeneity matters and that results are even stronger in an extension of the model with a non-competitive labor market.

5.1 Results in the benchmark model

Quantitative results of the exercise are presented in Table 4. The table shows aggregate quantities for the stationary equilibrium of the economy with the additional entry cost, expressed relative to their counterparts in an economy without the additional cost. The three columns present results for three scenarios, each incorporating an additional channel. Column 1 presents results for the elementary case where entry costs rise, but firms cannot adjust their technology and there are no effects on competition. Column 2 then shows results for the case where firms can adjust their technology choice in response to the different entry cost. The last column shows results for the case where all channels are active, i.e., firms can adjust their technology and the change in the number of firms affects how substitutable the differentiated goods produced by the firms are.

[Table 4]

No technology choice. In the first case of a fixed technology v as in the original Hopenhayn (1992) model, an increase in administrative entry cost can only have a direct effect on entry and the number of firms, and no indirect effects through changes in firms' entry investment choice. With higher entry costs, entry is not profitable for any v at the old wage. Exit, however, would continue, reducing labor demand and putting downward pressure on the wage. Hence, the wage must be lower for the free entry condition to hold in an equilibrium with the higher entry cost. Output and consumption fall in proportion with the wage. The consumption loss exceeds the direct burden of the administrative cost by a moderate amount. Aggregate productivity falls a little. The capital-output ratio falls slightly because the number of firms declines more than output. The firm productivity distribution does not change much.

This case is the classic, and simplest, case demonstrating the effect of entry barriers. They reduce the number of firms active in equilibrium while increasing their average size. With decreasing returns to scale or differentiated inputs in final goods production, this leads to a loss in productivity and output that goes beyond the direct additional cost. This basic effect is present in all scenarios considered here.

Barseghyan (2006) quantifies the effect of entry cost on TFP in such a model with heterogeneity but without technology choice. His results are stronger; he finds a response of TFP to entry regulation equivalent to a reduction of TFP by 2.2% in the exercise conducted here. The reason for the difference is that in his setting, firms rent capital every period and do not need to acquire it upon entry. Then the regulatory cost is the only entry cost. As a result, small changes in the entry cost have larger effects than here, where they have to be put in perspective relative to the entry investment firms make. The assumption made here thus is very conservative. Allowing firms to make some of their investment later in life, and not all of it at entry, would amplify the effect of entry costs. In this sense, results obtained in this paper with all investment at entry put a lower bound on the effect of entry costs.

Technology choice. Next, consider the case where firms can adjust their technology v in response to the higher administrative entry cost. Results for this case are shown in column 2. They are also illustrated in Figure 3. Again, the equilibrium wage must be lower for there to be entry. The lower wage raises the marginal value of higher v due to higher survival probability (Lemma 7), so the value of entry schedule becomes steeper at every v. This implies that the new equilibrium technology v^* has to lie to the right of the old one. Intuitively, the marginal cost of adopting a better technology has remained constant, while the fall in the wage increases the marginal benefits of doing so, implying a higher v^* in the new equilibrium. Hence, the new equilibrium features a higher entry investment (net of the administrative cost, it increases by 8%), and a lower wage. However, because of the higher equilibrium entry investment, the measure of active firms is almost 8% lower. Overall output falls because the smaller number of firms matters more than the larger entry investment. Because output declines more than the capital stock, the capital-output ratio rises slightly. With lower output and a higher capital stock, it is also clear that TFP must be lower.

Apart from an increase in average firm size due to the lower wage, the firm size and productivity distributions are not affected much. Relative to the average, the marginal firm in the economy with higher entry cost is less productive, as the lower wage reduces the exit threshold.

The higher entry cost thus shelters inefficient incumbents. This is amplified endogenously by the choice of higher entry investment. The general equilibrium interactions thus make the effect of the administrative entry cost more severe. At the level of the individual firm, the ability to adjust v allows better adjustment and reduces the harm from the administrative entry cost. In general equilibrium however, individual firms' reactions have repercussions and effectively lead to higher entry barriers and lower output.[14,15]

Technology choice and competitive effects. Column 3 shows the effect of an increase in administrative entry cost when there are also competitive effects. Results are quite different in this case. The reason is that in the presence of firm heterogeneity, changes in the substitution elasticity have a novel effect. The "standard" effect is that a fall in the number of firms reduces effective substitution elasticity and thereby raises firms' markups and profits. In this case, the reduction in the number of firms that occurs as higher entry costs discourage entry should directly promote firm value, and results in columns 2 and 3 should look similar. However, lower substitutability does not affect all firms in the same way. Markups rise in the same way for all firms, but the market share of highly productive firms falls as goods become more differentiated, while differentiation helps low-productivity firms survive. The fall in the effective substitution elasticity that comes with a reduction in the number of firms hence benefits low-productivity firms more than high-productivity ones. As a result, the value of entry becomes less steep in v, as it becomes less valuable to have higher productivity (Lemma 8). This effect turns out to be stronger than that of the fall in the wage. As a result, W is flatter than $c^e(v)$ at the old equilibrium v, implying that the new equilibrium v must be smaller.

This result is a new (anti-)competitive effect of entry barriers on productivity. Not only do they allow less productive firms to survive, but they also reduce firms' incentives to invest in more productive technologies, as low substitutability among goods erodes the advantage derived from higher productivity.

Quantitatively, the technology choice and capital/output ratio stray less far from the bench-

[14] The reasoning is similar when comparing sectors with different levels of entry cost within an economy. Imagine a two-sector economy with the same entry investment cost schedule for both sectors. Now shift one of them up, say $c_1^e(v)$. To make the marginal entrant indifferent between the two sectors requires the price of the good produced in sector 1 to be higher. As a result, firms in that sector make larger entry investments, fitting the correlation between capital intensity and entry cost found across industries.

[15] Allowing firms to raise v after entry by making further irreversible investments would lead to similar results. While firms would then prefer to enter small and expand only if things go well, administrative entry cost would still reduce the wage and increase the optimal investment. If due on each investment, as is plausible, it would also make investment lumpier, making firms spend more time away from their desired capital stock.

mark economy in this case than in the previous one. Output and consumption, however, drop much more. To understand the source of that drop, write aggregate output as $Q = \bar{s}^{\frac{1}{\xi-1}} N$ using the goods and labor market clearing conditions. Here, $\bar{s} = \int \mu(s) \exp(s)^{\xi-1} \mathrm{d}s$ is a measure of aggregate productivity analogous to that used in Melitz (2003). The total change in output can then be decomposed into the effects of changes in $\bar{s}$ and in ξ. Doing this reveals that essentially the entire change in Q is due to the change in $\bar{s}$ induced by the lower choice of v. Changes in the substitution elasticity essentially only matter through their effect on the choice of v. The negative welfare effect is large; the total effect on consumption is much larger than just the consumption loss due to the administrative cost itself. It is also much larger than in the case without competitive effects.

Just as in the other exercises, the firm productivity distribution is not affected very much. While one would expect the firm turnover rates to be one of the primary variables to react to changes in entry cost, it does not change much. This is because the calibration fits the bulk of the firm productivity distribution well, at the cost of fitting the experience of small, short-lived firms. As it is the turnover of those firms that is most likely to be affected by the change in entry cost, turnover does not change much.

Adding technology choice and a variable elasticity of substitution to the Hopenhayn (1992) model thus incorporates important new channels, and leads to much stronger estimates of the welfare cost of entry barriers. In all scenarios, the presence of administrative entry costs reduces wages, as otherwise no entry would occur in equilibrium. In the simplest case, the effects are limited to a reduction in wages and the number of firms. When firms choose their technology optimally, lower wages and expected longer firm lifetimes lead to larger entry investments. These endogenously amplify the effect of the exogenous increase in entry cost, severely reduce the number of firms, and protect low-productivity incumbents. If a lower number of firms also means that those firms' products become less close substitutes in their use as intermediate inputs, then this reduces the relative profitability of being at the top of the productivity distribution. As a result, firms make smaller entry investments, strongly reducing aggregate productivity, with large negative consequences for output and consumption.

Compared to evidence from cross-country data, the model performs well. Using data from 97 countries, Barseghyan (2008) finds that an increase in entry costs by 80% of income per capita (half a standard deviation in his sample) reduces TFP by 22%. In the model, introducing administrative entry costs of 80% of per capita income reduces TFP by 6.6%, 30% of the reduction found in the data. Returning to the comparison of Germany and the U.S., the model does similarly well. The predicted change in TFP amounts to more than a third of the TFP difference between Germany and the U.S.. The success is even larger for the Netherlands. Even in the case of France and Italy, the model can account for more than one sixth of the observed TFP difference. Evaluating these cases shows that the TFP loss is linear in the administrative entry cost. Additional costs of 10% of GDP per capita imply a TFP drop of 0.8%.

The change in the capital-output ratio qualitatively fits the pattern between the U.S. and Germany, but it is tiny. This is in line with the results of Barseghyan (2008, Table 3C), who does not find a statistically significant effect of entry costs on the capital-output ratio in his cross-country sample. The only prediction that does not fit the evidence well is the increase in average firm size. This however has to be seen in the light of the fact that average firm size in the U.S. is far higher than in most other countries (even with similar entry regulation), probably due to effects of market size and geography that are not captured here. Hence, the model helps explain a large portion of TFP differences by taking into account the effect of a small, but well-measured difference between the two countries.

5.2 Extensions

The model used here has three particular features that distinguish it from a standard model with monopolistic competition: firm heterogeneity, technology choice, and a relationship between the measure of firms in the industry and the substitutability of their products. The effect of the last two features has already been shown in Table 4 above. This section explores the effects of remaining one, firm heterogeneity. Before concluding, I then present results for an extension of the model with non-competitive labor markets. Findings there echo the argument of Blanchard and Giavazzi (2003) that product and labor market frictions interact.

Heterogeneity matters. To evaluate the importance of firm heterogeneity for the results obtained in Section 5.1, Table 5 shows the results of the same exercise in an analogous model where firms' productivity is constant at a level chosen upon entry. For details on the model, see Appendix B. All effects are qualitatively similar to the model with heterogeneity, just smaller. In particular, the consumption loss relative to the direct burden of the administrative cost is more than 50% larger when firms are heterogeneous. With homogeneous firms, TFP barely reacts, and the capital-output ratio does not rise.

[Table 5]

More importantly, technology choice reacts far less to the rise in entry cost. The reason for this is that, as firm value is convex in s, uncertainty about future productivity actually enhances firm value due to Jensen's inequality ($E[W(v, s^0)|v] > W(v, E[s^0|v])$). The upside potential dominates because of the ability to adjust inputs according to productivity and to close shop in case of utter failure. Firms are then prepared to pay higher entry costs when productivity is stochastic. This also means that they react more to changes in entry cost. In economic terms: Even if the average entrant has below-average productivity and a large initial exit hazard, there is a small probability that the firm will become very efficient and make large profits. This warrants paying even a large entry cost. This effect is absent in homogeneous-firm models, causing them to underestimate willingness to pay for entry. It is also understated when exit occurs at an exogenous rate (as even in much of the heterogeneous-firm literature), because then the longer expected life associated to high productivity is not taken into account. So a heterogeneous-firm model shows much better why firms enter even if entry cost is high and probability of success low, as often observed in the literature on entry (see e.g. Geroski 1995). As these channels are absent in the homogeneous firm model, aggregate productivity (TFP) falls less there.

Workers' bargaining power. Blanchard and Giavazzi (2003), among others, argue that goods and labor market regulation interact. This is also relevant here. Due to the presence of fixed operating costs and the irreversible entry investment, there are rents. Labor market institutions matter for their distribution. To model this while departing as little as possible from the basic model, suppose that the labor market is not competitive, but that the distribution of rents is determined by bargaining. Specifically, assume that every period, the firm and a firm-level union set the wage to maximize

$$\left[\pi(\omega, s) + c^f\right]^{1-\gamma} \ [(\omega - b)\ n(\omega, s)]^\gamma$$

where γ represents workers' bargaining power and b their outside option. The firm has to pay its fixed operating cost independently of the outcome of the bargaining process, so its outside option is $-c^f$. Once wages are determined, the firm chooses employment. This setup corresponds to Nickell and Andrews's (1983) widely-used "right-to-manage" model. Appendix C describes the model in more detail.

To obtain quantitative results in the extended model, the two new parameters γ and b need to be set. For workers' bargaining power γ, I adopt the value of 0.5 that is commonly used in the literature. As to the workers' outside option, I assume that it amounts to a fraction $\phi \in (0, 1)$

of per capita output and set ϕ to match the average U.S. civilian unemployment rate of 6%.[16] To focus on the effect of bargaining, assume that any unemployment insurance component of b is financed by lump-sum taxes.

Table 6 presents results from an increase in administrative entry costs by 30% of per capita output, considering again the same three cases as in Table 4. The pattern of results is very similar to that obtained in the main model. The main difference occurs in column 3: The drops in output and consumption are around 20% larger than in the setting without bargaining power. The multiplier effect from the increase in entry costs to consumption thus is much larger when there is bargaining.

The main driver of the consumption decline is again a lower optimal choice of v. The fall again occurs because with a smaller number of firms, firms face a lower demand elasticity. While raising markups, this reduces the market share of the most productive firms, implying a smaller optimal choice of v. This effect is stronger when there is bargaining, and rents are shared. The reason for this is that the increase in rents positively affects wages, muting their fall. As wage changes affect high-productivity firms most strongly, this makes the value of entry flatter in v and thus reduces the optimal v further. The fall in v implies that despite benefiting from increased rents, the wage still falls more when labor markets are not competitive. Entry costs thus have even larger effects when the labor market is not competitive.

6 Conclusion

Differences in total factor productivity are a puzzle, particularly between similarly developed countries. This paper has analyzed the effect of small shifts in entry cost in a dynamic stochastic model of heterogeneous firms with technology choice. Results explain around a third of observed productivity differences. Given that differences in entry costs by themselves are small relative to entry investments made by firms, this effect is very large. In fact, the consumption loss caused by increasing administrative entry cost amounts to many times the direct burden of the regulation.

The central mechanism is the following: Higher administrative entry costs reduce wages and the number of firms. With fewer intermediate goods being produced, these products become more differentiated. While this tends to raise rents overall, it reduces the market share of highly productive firms. As a consequence, the incentive to adopt more advanced technologies is reduced, and aggregate TFP falls. The combination for firm heterogeneity, technology choice,

[16] BLS data, average for 1985 to 1999. The figure is similar for longer periods.

and the competitive channel imply that this effect is strong, and can account for a substantial part of the TFP difference between some Euro Area economies and the U.S.. It is even stronger when labor markets are not competitive. The results give strong support to the idea that product market frictions matter for productivity.

Appendix

A Formal Statements of Results and Proofs

For any point of the state space, a firm's labor demand, output and profits, and aggregate labor demand and output can be obtained by static optimization. Firm value then is given by the functional equation

$$W(v,s,\omega,\xi) = \sup_{x\in\{0,1\}} \left\{\pi(s,\omega,\xi) + \beta(x+(1-x)\delta)\, W_x + \beta(1-x)(1-\delta)\, E[W(v,s',\omega,\xi)|s]\right\}, \tag{9}$$

where x is the value taken on by the exit policy function $X(v,s,\omega,\xi)$ ($x=1$ means exit), and $\pi(\cdot)$ is the profit function resulting from static optimization.

Lemma 1 *There is a unique firm value function $W(\cdot)$ that satisfies (9). The exit policy function $X(\cdot)$ is single-valued and lets firms attain the supremum in (9).*

Proof. Proof is by applying Theorem 9.12 from Stokey and Lucas (1989). Assumption 9.1 trivially holds. Since the expectation of s is finite and v^* is finite by Assumption $3'$, total returns are bounded, and Assumption 9.2 holds. Conditions (a) and (b) of Theorem 9.12 are also fulfilled if v^* is finite. ■

Corollary 2 *The firm value function $W(\cdot)$ is continuous, strictly increasing in v and in s, and strictly decreasing in ω. For given v, it is bounded.*

This follows from the properties of the profit function; by Theorems 9.7 and 9.11 in Stokey and Lucas (1989) they carry over to the value function. Boundedness then follows from the fact that $E(s'|s)$ is well-defined and finite for all s.

Corollary 3 *For $c^f > 0$ and under Assumption 1, there is a unique exit trigger $s_x(v,\omega,\xi) \equiv \{s \text{ s.t. } E[W(v,s',\omega,\xi)|s] = W_x\}$. Hence, the exit policy function X is single-valued; it takes value 1 (exit) for $s < s_x$ and value 0 for $s \geq s_x$. The exit trigger $s_x(\cdot)$ is strictly decreasing in v, strictly increasing in ω, and continuous in both.*

Proof. Firms exit whenever the expected value of continuing is smaller than the value of exiting:

$$E[W(v,s',\omega,\xi)|s] < W_x = 0, \tag{10}$$

where the value of exit W_x is zero due to the zero net value of entry condition (6). Since $E(s'|s)$ increases in s by Assumption 1, and because firm value increases in s by Corollary 2, the left-hand side (LHS) of (10) is strictly increasing in s. Moreover, given any $c^f > 0$, there is an s so low that expected value of continuing is negative, and an s so high that it is positive. Then there is a unique s_x such that an equality replaces the inequality in (10). Firms exit whenever $s < s_x$. The properties of s_x follow from the properties of the value function. ■

To ensure that the condition for optimal technology choice (5) is well-defined, it is necessary to show that the value function is differentiable with respect to v. For this, it first has to be shown that expected firm life is finite. This is also crucial for a stationary equilibrium. Moreover, the result highlights that it is not necessary that the exogenous breakdown rate δ be strictly positive for the results to go through.

Lemma 4 *Given the specification of the stochastic process for s in (2), the lifetime T of a firm is finite for all v with probability* 1. *It has a well-defined pre-entry expectation $\bar{T}$ that is the same for all firms.*

Proof. Proof is easiest by reasoning in terms of the properties of Markov processes. Define the set $S_x = \{s \in S : s < s_x\}$. Once a firm draws an $s \in S_x$, it exits, so S_x is an ergodic set. Because the firm's productivity innovation ϵ has positive variance, there are $s \geq s_x$ such that $G_v(s_x|s) > 0$, i.e. with a positive probability of exiting in the next period. Hence, the set $\{s \in S : s \geq s_x\}$ is transient. Then, by Theorem 5.6 in Doob (1953), s can remain outside S_x for a finite time only with probability 1. Moreover, the probability of remaining in the transient set decreases at a geometric rate. As a consequence, expected firm life is finite with probability 1. This implies that it has a well-defined expectation $\bar{T}$. As all firms choose the same v, it is the same for all firms from a pre-entry perspective. ■

Lemma 5 *If Assumptions 3 and 3′ hold, the expected value of entry W^e is continuously differentiable in v in a neighborhood D of v^*, with $W^e_v > 0$ for all $v \in D$.*

Proof. Gross firm value can be expressed as a sum of current and future profits, weighted by their conditional probabilities. Since firm lifetime is finite with probability 1 and has a well-defined pre-entry expectation (Lemma 4), this sum is finite. All the summands are convex, so their sum is convex. Just as gross firm value, the entry investment function is also continuous, monotonically increasing, and convex in v. So net entry value is also continuous in v. To infer its shape, consider first its limits. Both are negative: the net value of entry goes to minus infinity as v goes to plus infinity by Assumption $3'$, and it goes to a negative number as v goes to minus infinity because $\lim_{v\to-\infty} c^e(v) \geq 0 > -c^f = \lim_{v\to-\infty} W(v)$ by Assumption 3 and by optimal exit. Disregard the case where net entry value is always smaller than at the limit where v goes to minus infinity, since then there would be no v with positive entry, hence no entry in equilibrium. Instead focus on the case where there is some v with higher net entry value than in the limits. In that case, there is some v^* that yields the maximum net entry value. Since net entry value is a continuous function of v, it must be concave around v^*. As v is a control variable and constant over a firm's life, its domain can be limited to that concave part. Call its domain D. So the (relevant part of) the net entry value function is concave. Hence, it can be written as a weighted sum of concave net period return functions. Having obtained this, it follows from Theorem 9.10 in Stokey and Lucas (1989) that the expected net value of entry W^e is differentiable with respect to v. The derivative is positive by Corollary 2. Moreover, the firm's technology choice problem is concave, and the first order condition (5) is sufficient. ■

The central result for a unique equilibrium then is:

Proposition 6 *Under the assumptions made, equilibrium condition (i) is fulfilled by a unique finite pair* (v^*, ω^*) *for a given* ξ.

Proof. Equilibrium existence has been shown in the main text. Finiteness of v^* follows from Assumption $3'$. Uniqueness of the equilibrium pair (v^*, w^*) follows from the following reasoning. Both expected gross value of entry and the entry investment cost function are convex in v. The two do not coincide (their limits differ). By equations (5) and (6), equilibrium occurs at a tangency. Since two convex univariate functions can have at most one tangency, the equilibrium is unique. ■

With an expression for the exit trigger, and v^* and ω^* consistent with positive entry in hand, it remains to determine a firm distribution μ and a measure of firms $\bar{\mu}$ consistent with a stationary equilibrium. For obtaining the distribution, there are two crucial ingredients. First, as shown in the main text, all entrants in a given period adopt the same technology. For a stationary equilibrium, clearly, this is constant over time so that we can fix v at v^* and consider $\mu(s)$. Second, there is a one-to-one mapping from the exit trigger s_x to entry mass M. This follows from the fact that given a stationary $\mu(s)$, the total measure of firms has to be constant, and hence the measure of exiting firms $\mu(s < s_x)$ has to equal the measure of entering firms M. Since expected firm life is finite (Lemma 4), this can be achieved. The firm distribution in a stationary equilibrium then is a fixed point of the operator T defined by

$$(T\mu)(s) = \int_{s_x(\mu)}^{\infty} (1-\delta)\mu(u)\, g_{v^*}(s|u)\, \mathrm{d}u + M\, h_{v^*}(s), \tag{11}$$

i.e. a μ such that $(T\mu)(s') = \mu(s')$. Fixed-point arguments as given in Stokey and Lucas (1989) do not apply easily in this case because, due to entry and exit, the transition function for $\mu(s)$ is not monotone: Every period, low-productivity firms perish and are replaced by more productive ones, with only the remaining firms' productivity following a monotone process. However, the conditions for the existence of a unique stationary equilibrium with positive entry and exit derived in Hopenhayn (1992, equation 12) carry over exactly to the present case. The result that v^* is finite and the fact that the profit function is multiplicatively separable in productivity and the wage are sufficient for this.

For comparative statics, it is necessary to know how W_v^e interacts with ω and ξ. Unfortunately, general statements about second derivatives of value functions are hard to make, but the next two results establish that W_v^e falls in the wage and rises in ξ.

Lemma 7 *W_v^e is strictly decreasing in ω.*

Proof. Write expected gross value of entry as

$$W^e(v, \omega, \xi) = \int_S h_v(s^0)\, W(v, s^0, \omega, \xi)\, \mathrm{d}s^0.$$

Its derivative with respect to v is

$$\frac{\partial W^e(v, \omega, \xi)}{\partial v} = \int_S h_v(s^0)\, \frac{\partial W(v, s^0, \omega, \xi)}{\partial v}\, \mathrm{d}s^0 + \int_S \frac{\partial h_v(s^0)}{\partial v} W(v, s^0, \omega, \xi)\, \mathrm{d}s^0.$$

Now consider an $\omega' > \omega$. The second integral becomes smaller because W decreases in ω. The first integral is a weighted average of W_v for $s^0 \geq s_x(v, \omega, \xi)$ (continue), which is positive, and for $s^0 < s_x(v, \omega, \xi)$, which is zero. Increasing the wage raises s_x and thereby puts more weight on the second term, hence the first integral decreases in ω, too. As a result, W_v^e falls in ω. ■

Lemma 8 *W_v^e is strictly increasing in ξ.*

Proof. First, show that increases in ξ raise profits for high s and reduce them for low s. The derivative of log profits with respect to ξ is

$$\frac{\partial \ln \pi(s, \omega, \xi)}{\partial \xi} = \ln \exp(s) - \ln \frac{\xi \omega}{\xi - 1} = \ln \exp(s) - \ln \bar{s}^{\frac{1}{\xi - 1}}$$

using $Q = \frac{\xi}{\xi-1} wN = \bar{s}^{\frac{1}{\xi-1}} N$, where $\bar{s} = \int \mu(s) \exp(s)^{\xi-1} \mathrm{d}s$. As this has the same sign as $\partial\pi/\partial\xi$, it implies that for firms with productivity above aggregate productivity $\bar{s}^{\frac{1}{\xi-1}}$, increases in ξ raise profits, while they lower them for firms with $\exp(s)$ below aggregate productivity. As a consequence, π is steeper in s for higher ξ, i.e., $\partial\pi/\partial s$ strictly increases in ξ. (The same relationships hold for output and employment.)

As choosing a higher v implies higher expected s, and W^e is differentiable with respect to v, higher ξ then also implies strictly higher W^e_v. ■

B Homogeneous firm model

The production function is

$$y_i = e^{s_i} n,$$

where s_i is constant over time for a given firm. The optimal choice of p then is $\frac{\xi}{\xi-1}\frac{\omega}{\exp(s_i)}$, implying output

$$q(s_i) = \left(\frac{\xi}{\xi-1}\frac{\omega}{\exp(s_i)}\right)^{-\xi} P^{\xi} Q,$$

labor demand

$$n(s_i) = \left(\frac{\xi\omega}{\xi-1}\right)^{-\xi} \exp(s_i)^{\xi-1} P^{\xi} Q$$

and profits

$$\pi(s_i) = \frac{1}{\xi-1}\left(\frac{\xi}{\xi-1}\right)^{-\xi} \exp(s_i)^{\xi-1} \omega^{1-\xi} P^{\xi} Q - c^f$$

for all firms. With an exogenous exit probability of δ for each firm each period, firm value then is

$$V(s_i) = \frac{\pi(s_i)}{\rho},$$

where $\rho = 1 - \beta(1-\delta)$. Firms choose s upon entry, at cost $c^e(s) = k_1 e^{k_2 s} + k_3$. As that choice depends on aggregate variables only, and those are constant over time, all entrants at all t choose the same s, so the i subscript can be dropped. Entrants' optimal choice of s involves setting

$$V'(s) = \frac{\pi'(s)}{\rho} = c^{e\prime}(s).$$

Denote this condition by FOC. At the same time, with free entry, net value of entry must be zero in equilibrium, i.e.,

$$V(s) = c^e(s).$$

Denote this condition by NEC. Combining these conditions yields

$$e^s = \left[\frac{c^f/\rho + k_3}{k_1}\frac{\xi - 1}{k_2 - (\xi - 1)}\right]^{\frac{1}{k_2}}$$

as the optimal choice of s.

There are two additional conditions. Normalizing the price index

$$P = \left(\int_i p_i^{1-\xi}\right)^{\frac{1}{1-\xi}}$$

to unity implies

$$\omega = \frac{\xi - 1}{\xi}\exp(s)B^{\frac{1}{\xi-1}},$$

where B denotes the number of firms. At the same time, from labor market clearing ($N = Bn$),

$$B = \left(\frac{\xi}{\xi - 1}\omega\right)^{\xi}\frac{1}{\exp(s)^{\xi-1}Q}$$

where $N \equiv 1$ is labor supply. Combining this with the expression for ω yields aggregate output

$$Q = \frac{\xi}{\xi - 1}\omega.$$

Substituting this into the profit function eliminates the dependency on Q and allows solving NEC for the wage at the optimal choice of s. This yields

$$\omega = \left[e^{s\xi-1}\frac{\tilde{\xi}}{c^f + \rho c^e}\right]^{\frac{1}{\xi-2}},$$

where $\tilde{\xi} = \frac{1}{\xi-1}\left(\frac{\xi}{\xi-1}\right)^{1-\xi}$. From this follow n, aggregate labor demand, and the number of firms B.

To calibrate the model, set ξ, β and δ to 3, 0.96 and 4.5%, respectively, set c^e/c^f as in the heterogeneous firm model, and set c^f to match the average establishment size of 15.8. As in the main text, k_1 and k_2 can then be backed out from FOC and NEC. Also set $\xi(B)$ as in the main text. For results, see Table 5.

C Model with bargaining

Differences with respect to the benchmark model are as follows. The labor market is not competitive, but the distribution of rents is determined by bargaining. Concretely, assume every period, the firm and a firm-level union set the wage to maximize

$$(1-\gamma)\ln(\pi(\omega, s) + c^f) + \gamma\ln(\omega - b) + \gamma\ln n(\omega, s),$$

where γ represents workers' bargaining power and b their outside option, and the firm's outside option at zero employment is $-c^f$. The firm then chooses employment as a function of the bargained wage. This corresponds to Nickell and Andrews's (1983) "right-to-manage" model.

The firm's labor demand and profit functions are as in the benchmark model. Solving the bargaining problem yields a wage

$$w = \frac{\sigma + \gamma - 1}{\sigma - 1} b$$

Instead of being competitively determined, it increases in the outside option b and in the union's bargaining power and decreases as the demand elasticity increases.[17] Goods market clearing implies

$$N = \left(\frac{\sigma}{\sigma - 1} w \right)^{\sigma - 1} \bar{s}^{-1} = \left(\frac{\sigma}{\sigma - 1} \frac{\sigma + \gamma - 1}{\sigma - 1} b \right)^{\sigma - 1} \bar{s}^{-1}.$$

Employment is determined by labor demand and implies

$$1 - u = N \int \mu(s) \left(\frac{\sigma w}{\sigma - 1} \right)^{-\sigma} \exp(s)^{\sigma - 1} Q \, \mathrm{d}s = N \bar{s} \left(\frac{\sigma w}{\sigma - 1} \right)^{-\sigma} Q = \frac{\sigma - 1}{\sigma} \frac{Q}{w}.$$

Imposing $b = \phi Q$,

$$1 - u = \frac{\sigma - 1}{\sigma \phi} \frac{\sigma - 1}{\sigma + \gamma - 1}.$$

Unemployment rises in ϕ and in γ. This expression allows setting ϕ to fit u, given γ.

Finally, the firm's value function and exit decision, the free entry condition, optimal technology choice and the evolution of the firm productivity distribution are analogous to the main text.

[17] The fact that the wage does not depend on the firm's productivity is due to the constant elasticity of profits with respect to the wage. Bruno and Sachs (1985) use this property to explain real wage rigidity in the face of changes in aggregate productivity.

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Table 1: Country statistics, 4 large Euro Area economies and US

	Administrative entry cost	Y/L	K intensity	TFP
		(all relative to U.S.)		
Germany	0.325	0.90	1.06	0.93
France	0.355	0.79	0.90	0.84
Italy	0.448	0.71	1.06	0.78
Netherlands	0.308	0.90	1.03	0.94
United States	0.017	1.00	1.00	1.00

Data sources: Labor productivity (output per hour), capital intensity (capital services flows per hour worked) and TFP are from the Groningen Growth and Development Centre's productivity level database (Inklaar and Timmer 2008). They are for the private sector in 1997 and are expressed in PPP terms, relative to the U.S. values. The administrative cost of entry is the sum of direct payments and the cost of time spent on the procedure needed to establish a small business. It is expressed as a fraction of the country's per capita output and is from Djankov et al. (2002, Table III).

Table 2: Parameter assignments

from the literature	
ξ	3
β	0.96
ρ	0.97
σ	0.2
firm dynamics	
κ	1.12
σ_e^2	0.22
δ	0.045
parameters of $c^e(v)$	
k_1	2.38
k_2	77.52
Costs in benchmark economy (% of avg firm output)	
Fixed cost	2%
Entry cost	319%

Table 3: Benchmark economy versus target statistics

	data (U.S.)	model
Employment-weighted turnover rate	7%	7.0%
TFP entrants/incumbents	99%	99.0%
TFP exiting/continuing firms	96%	99.9%
Investment-output ratio	14.4%	14.4%
Average employment	15.8	15.8
other statistics:		
Job turnover rate	32%	37.8%
Productivity spread	ca. 3	3.40
Fraction establishments below average employment	67.8%	63.3%
Capital-output ratio	2.9	3.19
Entrants:		
Four-year survival rate	63%	83.2%
Seven-year growth rate	39.9%	41.3%

Data sources: Employment-weighted turnover rate, entrants' survival and growth rates: Bartelsman et al. (2004); relative TFP measures: Foster et al. (2001); investment-output ratio: OECD; average employment and firms below average employment: U.S. Small Business Administration; capital-output ratio: BEA; productivity spread: Dhrymes (1991), Bartelsman and Dhrymes (1998); job turnover: Davis et al. (2008).

Table 4: Effects of introducing administrative entry cost of 30% of per capita output, 3 specifications (benchmark economy = 100)

	fixed v fixed ξ	optimal v fixed ξ	optimal v $\xi(\bar{\mu})$
	(1)	(2)	(3)
Equilibrium technology v^*	fixed	101.98	99.48
Entry investment $c^e(v^*)$	fixed	107.99	97.99
Measure of firms $\bar{\mu}^*$	98.90	92.28	99.51
Wage ω^*	99.45	99.47	97.25
Aggregate output	99.45	99.39	97.41
Consumption	99.45	99.43	97.24
Consumption loss/ /exogenous cost increase	-5.37	-6.00	-27.07
Capital/output ratio	99.45	100.26	100.10
TFP	99.45	99.47	97.49
ξ (=3 in benchmark)	fixed	fixed	99.50

Table 5: Effects of introducing administrative entry cost of 30% of per capita output, homogeneous firm model (benchmark economy = 100)

	fixed ξ	$\xi(B)$
Equilibrium technology v^*	101.39	99.68
Entry investment $c^e(v^*)$	107.30	99.00
Number of firms $\bar{\mu}^*$	93.21	99.61
Wage ω^*	99.54	98.10
Aggregate output	99.54	98.30
Consumption	99.63	98.19
Consumption loss/ /exogenous cost increase	-3.79	-17.12
Capital/output ratio	100.00	99.80
TFP	99.77	99.18
ξ (=3 in benchmark)	fixed	99.60

Table 6: Effects of introducing administrative entry cost of 30% of per capita output when workers have bargaining power (benchmark economy = 100)

	fixed v fixed ξ	optimal v fixed ξ	optimal v $\xi(\bar{\mu})$
	(1)	(2)	(3)
Equilibrium technology v^*	fixed	101.72	99.28
Entry investment $c^e(v^*)$	fixed	106.89	97.24
Number of firms $\bar{\mu}$	99.03	93.25	99.53
Wage ω^*	99.51	99.53	96.94
Aggregate output	99.51	99.53	96.80
Consumption	99.52	99.58	96.65
Consumption loss/ /exogenous cost increase	-5.38	-5.02	-37.24
Capital/output ratio	100.04	100.15	99.98
TFP	99.51	99.53	97.17
ξ (=3 in benchmark)	fixed	fixed	99.53

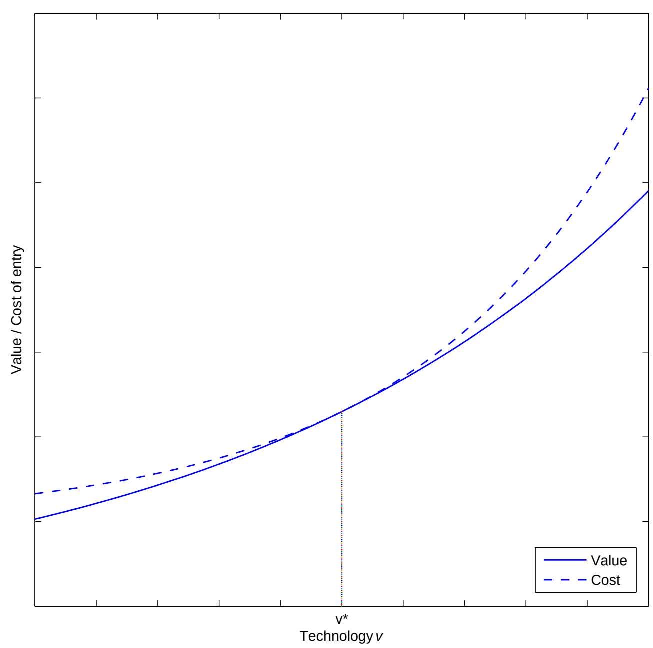

Figure 1: The value of entry and the entry cost function around the optimum

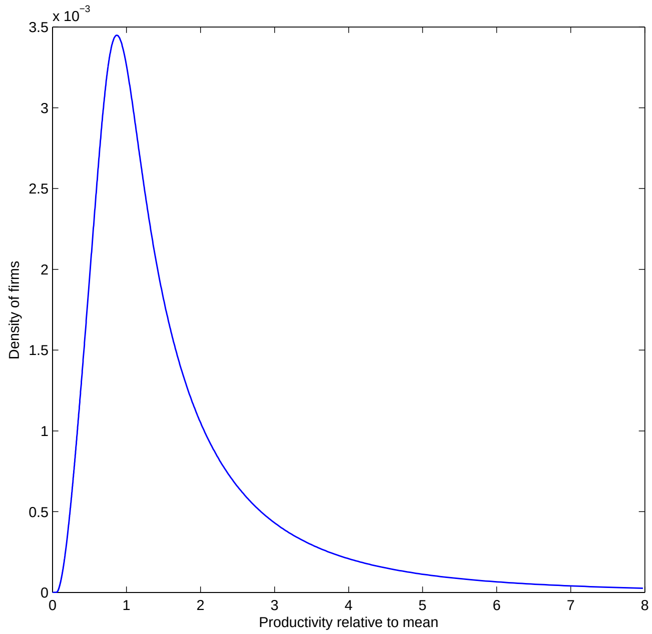

Figure 2: The firm distribution in the benchmark economy

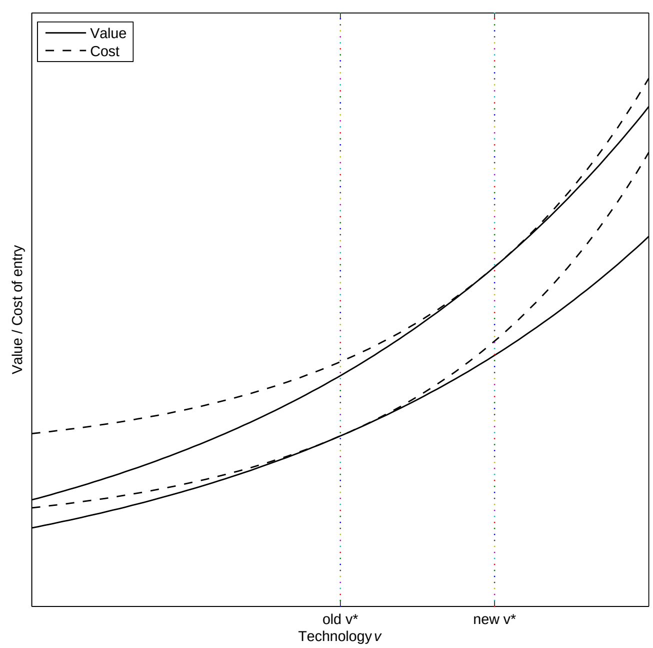

Figure 3: Upward shift in entry cost: old equilibrium (lower two lines) and new equilibrium (upper two lines)