



**UvA-DARE (Digital Academic Repository)**

**Employment protection, technology choice, and worker allocation**

Bartelsman, E.J.; Gautier, P.A.; de Wind, J.

[Link to publication](#)

*Citation for published version (APA):*

Bartelsman, E. J., Gautier, P. A., & de Wind, J. (2010). Employment protection, technology choice, and worker allocation. (IZA discussion paper; No. 4895). Bonn: IZA.

**General rights**

It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

**Disclaimer/Complaints regulations**

If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: <http://uba.uva.nl/en/contact>, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.

IZA DP No. 4895

## **Employment Protection, Technology Choice, and Worker Allocation**

Eric J. Bartelsman  
Pieter A. Gautier  
Joris de Wind

April 2010

# Employment Protection, Technology Choice, and Worker Allocation

**Eric J. Bartelsman**

*VU University Amsterdam,  
Tinbergen Institute and IZA*

**Pieter A. Gautier**

*VU University Amsterdam,  
Tinbergen Institute, CEPR and IZA*

**Joris de Wind**

*De Nederlandsche Bank  
and University of Amsterdam*

Discussion Paper No. 4895

April 2010

IZA

P.O. Box 7240  
53072 Bonn  
Germany

Phone: +49-228-3894-0

Fax: +49-228-3894-180

E-mail: [iza@iza.org](mailto:iza@iza.org)

Any opinions expressed here are those of the author(s) and not those of IZA. Research published in this series may include views on policy, but the institute itself takes no institutional policy positions.

The Institute for the Study of Labor (IZA) in Bonn is a local and virtual international research center and a place of communication between science, politics and business. IZA is an independent nonprofit organization supported by Deutsche Post Foundation. The center is associated with the University of Bonn and offers a stimulating research environment through its international network, workshops and conferences, data service, project support, research visits and doctoral program. IZA engages in (i) original and internationally competitive research in all fields of labor economics, (ii) development of policy concepts, and (iii) dissemination of research results and concepts to the interested public.

IZA Discussion Papers often represent preliminary work and are circulated to encourage discussion. Citation of such a paper should account for its provisional character. A revised version may be available directly from the author.

## ABSTRACT

### **Employment Protection, Technology Choice, and Worker Allocation\***

Using a country-industry panel dataset (EUKLEMS) we uncover a robust empirical regularity, namely that high-risk innovative sectors are relatively smaller in countries with strict employment protection legislation (EPL). To understand the mechanism, we develop a two-sector matching model where firms endogenously choose between a safe technology with known productivity and a risky technology with productivity subject to sizeable shocks. Strict EPL makes the risky technology relatively less attractive because it is more costly to shed workers upon receiving a low productivity draw. We calibrate the model using a variety of aggregate, industry and micro-level data sources. We then simulate the model to reflect both the observed differences across countries in EPL and the observed increase since the mid-1990s in the variance of firm performance associated with the adoption of information and communication technology. The simulations produce a differential response to the arrival of risky technology between low- and high-EPL countries that coincides with the findings in the data. The described mechanism can explain a considerable portion of the slowdown in productivity in the EU relative to the US since 1995.

JEL Classification: J65, O38

Keywords: employment protection legislation, exit costs, information and communications technology, heterogeneous productivity, sectoral allocation

Corresponding author:

Pieter A. Gautier  
Vrije Universiteit Amsterdam  
Dep. of Economics (2A-33)  
De Boelelaan 1105  
1081 HV Amsterdam  
The Netherlands  
E-mail: [pgautier@feweb.vu.nl](mailto:pgautier@feweb.vu.nl)

---

\* We would like to thank Wouter den Haan, Egbert Jongen, Roland Luttens and Marcel Jansen for useful comments and suggestions. We also would like to thank participants of CAED, Tokyo and ECB/CEPR Labour Market Workshop, Frankfurt as well as seminar participants at the University of Copenhagen, CPB, Tinbergen Institute, VU University Amsterdam, University of Maastricht and De Nederlandsche Bank.

# 1 Introduction

In this paper we argue that a change in the nature of technological opportunities in the mid 1990s interacted with cross region differences in employment protection to become a prominent cause of the observed divergence in productivity between the US and the EU. The emergence of accelerating improvements in computing power coupled with steepening adoption rates of communication technology resulted in a large variance in realized productivity and profits for firms choosing to use these technologies. The increase in variance is good for aggregate productivity and appealing to individual firms because good news is unbounded while bad news is bounded by the option to exit or fire workers. When in the mid-nineties these technological opportunities arose, the expected net benefits of exploring this technology were higher in countries with low EPL because the option to shut down was less costly. We give robust evidence that in countries with high EPL, high-risk innovative sectors (which are associated with intensive ICT use) are relatively small. The negative relationship also holds between other exit frictions (i.e. low cost recovery of capital for exiting firms) and the relative size of risky sectors. We explain the empirical findings using a matching model with endogenous technology choice, i.e. firms can choose between a risky and a safe technology. In a calibrated version of the model, high firing or exit costs reduce the number of jobs in the risky sector, lower productivity in the risky sector, and lower aggregate productivity.

Our paper draws from and combines results from a variety of different literatures. The main question we look at is prominent in the literature on innovation, IT and productivity growth. The model we use is derived from models in the search literature that mostly have been used to study the effects of frictions (including EPL) in labor markets, but recently these models are used for studying allocation and productivity as well. Further, our use of model calibration, and comparison of model simulations with moments and parameter estimates from data draw on a rich macro literature. Finally, we follow a lengthy sequence of papers studying the effect of EPL on labor markets and macro outcomes. We discuss these points in turn.

Growth accounting exercises in the US have shown most of the acceleration of output growth to be due to ICT capital deepening and to increases in TFP associated with ICT use (for an overview of the findings, see Jorgenson, Ho and Stiroh 2008). Cross-region comparisons (van Ark, O'Mahony and

Timmer, 2008) show that ICT production and use has been much lower in the EU than in the US and that this may explain much of the relative slowdown. The growth accounting literature is not, however, capable of explaining *why* the ICT producing sector in the EU is smaller, *why* ICT investment and thus ICT-capital deepening is lower, *why* the contribution from ICT-using industries is smaller, and thus *why* aggregate productivity diverges. The link we make between technology choice and employment protection and exit costs in general depends on the special nature of information and communication technology. A nice case study of such risky innovation is given by Brynjolfsson McAfee, Sorell, and Zhu (2008), where the benefits of adopting an innovative IT system arise in conjunction with a reorganization of the production process. The success of the innovation can only be determined by experimenting with the new organization in the market. In case of failure, the configuration of the hardware, software, process, and organization structure needs to be changed again, while in case of success, the system is scaled up, for example by replicating it in other locations. This fits nicely with the findings of Bloom, Sadun, and Van Reenen (2007) that U.S. multinational firms have high returns to investment in IT in their UK subsidiaries because they only transplant the IT implementations that were adopted successfully in the US.

Consistent with this innovation strategy, Brynjolfsson, McAfee and Zhu (2009), find that the cross-sectional variance of profits in IT using firms is higher, and has been increasing steadily since 1995, relative to the cross-sectional variance of profits in firms with low IT uptake. In many cases, the IT and organizational investments do not lead to success and require either another round of attempts at getting the implementation right, or exit. Similarly, Bartelsman (2008) finds that the variance of market share changes among firms in an industry is higher in those countries and industries where firms have higher adoption rates of broadband internet. In this paper, we find that the variance of productivity across firms and the churn of jobs has become higher since 1995 in ICT intensive industries. While the direction of causality is difficult to ascertain, this evidence shows that higher rates of adoption of new technology coincide with increased cross-sectional variation in profits, productivity, market share, and employment.

Although we do not explicitly model the process of experimental innovation in detail, our model is consistent with it. To model this process, the decision to innovate not only requires a fixed entry fee but also requires some complementary factor input, say labor, with an associated flow of factor payments.

Specifically, the risky sector firms are modelled as in Mortensen and Pissarides (1994) and the safe sector firms are as in Pissarides (2000). Both sectors are connected with each other through the pool of unemployed workers from which both sectors hire and EPL reduces the risky and increases the safe sector. The Mortensen-Pissarides search model is particularly useful to study labor market policies because it is simple and simultaneously solves for the labor market stocks and flows.<sup>1</sup> Frictions are essential in our model to explain the coexistence of vacancies and unemployed workers, but they also are needed to allow for an equilibrium where both high and low productivity firms can simultaneously exist. As in Mortensen and Lentz (2008), a key factor for aggregate productivity is the allocation of workers to different firms.

We calibrate our model for the US using a variety of sources including the EUKLEMS dataset (O'Mahony, and Timmer 2009) and a novel dataset built up from firm-level sources (Bartelsman, Haltiwanger, and Scarpetta 2009, from now on called BHS). By exploring new data sources we are able to get more information on primitives that previously had to be fixed at arbitrary values. For example, we use our model to derive a relation between the underlying ex ante mean and variance of the productivity distribution in the risky sectors and the observed (truncated) mean and variances.<sup>2</sup> Further we can generate experiments such as considering the effect of changing the estimated US level of EPL (one month of production) to European levels (seven months of production).<sup>3</sup> Simulated data generated from the model in this manner shows the same relationship between sector size and EPL interacted with riskiness that we find in the actual data.

By now there exists a huge literature on the effects of EPL on labor market performance based on cross country evidence.<sup>4</sup> The main conclusions are that the effects on employment are negative but small. Participation is typically smaller in countries with strong EPL and the effects on unemployment are essentially zero. EPL reduces the flows in and out of employment and increases unemployment duration.

---

<sup>1</sup>The effects of EPL have been studied extensively in the search matching literature using a single sector model. See e.g. Brüggeman (2006), Burda (1992), Garibaldi (1998), Ljungqvist (2002) and Mortensen and Pissarides (1999). Alvarez and Veracierto (2001) study EPL in a Lucas-Prescott search model. Those papers do not consider the allocation of workers over risky and safe sectors.

<sup>2</sup>Acemoglu and Shimer (2000) show that under search frictions, technology dispersion can be an equilibrium response of firms with the same potential outcomes.

<sup>3</sup>There is a lot of variation in severance payments and procedural cost within Europe. Severance payments range from 0 in e.g. the UK and Belgium to 18 months in Italy and 20 months in Portugal for a worker who has been employed for 20 years. In many European countries, severance payments are equal to one month salary for each year worked.

<sup>4</sup>This literature includes Addison and Teixeira (2003), Bertola (1990), Blanchard (1998), Lazear (1990), Nickell and Layard (1998), Blanchard and Portugal (1998), OECD (2004).

Autor, Kerr, and Kugler (2008) give some evidence that EPL reduces productivity at the plant level but they cannot rule out that their results are (partly) due to confounding economic shocks. Samaniego (2006) gives evidence that EPL is negatively correlated with ICT diffusion. In a related empirical exercise, Bartelsman, Perotti, and Scarpetta (2008) show that the productivity of broadband intensive industries relative to other industries is lower in countries with high EPL. Bassanini, Nunziata and Venn (2009) give evidence that productivity in high turnover industries is relatively low if EPL is strong which is consistent with our findings. However, in our model, turnover is endogenous and depends on the choice of technology. Our paper is to our knowledge the first one that gives evidence that firing costs may harm productivity and innovation by decreasing the size of innovative sectors. We also confirm Samaniego's finding of a negative correlation between broadband use and EPL across countries. The advantage of cross country industry panel data is that an attempt can be made to identify the causal effect by controlling for the possible correlation between strong EPL and other active labor market policies. The sectoral variation can be used for identification because we can see how relative sector size within a country varies across countries. Our equilibrium search model explicitly allows for competition between firms in the innovative and firms in the safe sector and we can jointly derive relative sector sizes, equilibrium participation, unemployment and employment rates in both sectors. The mechanism that we propose is related to Saint-Paul (2002) where countries with high EPL specialize in secure goods at the end of their product cycle while countries with low EPL specialize in more innovative goods.

Finally, there exists a large literature on optimal layoff taxes, i.e. Bentolila and Bertola (1990), Hopenhayn and Rogerson (1993) and Ljungqvist. Blanchard and Tirole (2008) and Michau (2009) show that optimal layoff taxes are positive if workers are risk averse and cannot borrow against future income. The motivation for this is Pigouvian; firms do not internalize the increase in UI expenditures when they fire a worker. Since we assume risk neutral workers (or alternatively complete capital markets), those effects are absent in our model. Finally, Acemoglu and Shimer show that UI benefits can have a positive effect on firm productivity because it stimulates workers to search for high productivity jobs and stimulates firms to create those jobs.

The paper is organized as follows. Section 2 summarizes the stylized facts on the productivity divergence. Section 3 discusses our theoretical model which is calibrated in section 4. Section 5 shows our

main empirical finding that risky sectors are relatively smaller in high-EPL-countries. We conclude with some reflections on the importance of this link between EPL and productivity and with ideas for future research.

## 2 Stylized Facts

This section presents some stylized facts on productivity, risky innovation, and sectoral allocation of labor. We start with a picture that begs the important question: Why has productivity in the EU stopped converging to the US level, and has it actually been diverging since the mid-nineties? Using data from the EUKLEMS database, Figure 1 shows real value added per hour worked in the market sector in the EU-15 versus the United States.<sup>5</sup> The finding has spawned an exploration into the details, breaking the pattern down into contributions of countries and industries, and further into the contributions for each factor of production. Overall, van Ark, O'Mahony and Timmer (2008) argue that the European productivity slowdown is attributable to the slower emergence of the 'knowledge economy' in Europe compared to the United States. The findings are that the EU enjoys lower growth contributions from investment in information and communication technology and has a relatively small share of technology producing industries. The EU also has slower multifactor productivity growth than in the U.S. where the acceleration in productivity likely is associated with advances in the innovative uses of information technology.

The explanation of the *why* for these findings that we put forward in this paper has to do with the nature of innovation in both the production and use of information and communication technologies. In our model, we assume that the innovative sector also is 'high risk'. That is, a firm that invests in these technologies or sectors has a higher variance of payoffs than a firm that invests in more traditional sectors or in more traditional types of capital equipment. In a recent paper, Brynjolfsson, McAfee, Sorell, and Zhu (2008) argue that the payoff associated with ICT-related business investments comes from scaling

---

<sup>5</sup>Output of the fifteen EU countries are converted to dollars using industry-of-origin purchasing power parity data from the EUKLEMS database. The same pattern emerges if one displays relative total factor productivity (TFP) which takes into account changes in both capital and labor quality. However, for consistency with measures used in our model and because these data are more consistent across source, we will stick to indicators of ppp-adjusted real value added and hours worked.



Figure 1: Labor Productivity EU15 relative to US; source: EUKLEMS

up a successful venture after it has shown its success in smaller-scale experiments. The upshot is that investing in such experiments has a high chance of failure and a very small chance of a very high payoff. Data from Compustat, linked to the Harte-Hank indicators on firm-level ICT investments, show that the cross-sectional variance of profits of ICT-intensive firms versus non-ICT intensive firms starts diverging in the mid-nineties (Brynjolfsson, McAfee, and Zhu 2009), see Figure 2.

Similar evidence is found by analyzing a country/industry panel dataset of indicators built up from firm-level data. Using linked longitudinal data on sales and broadband use at the firm-level for 13 EU countries, Bartelsman (2008) finds that industries that have a higher percentage of workers with access to broadband internet exhibit higher variance of the distribution of firm-level sales growth.

Using the same datasource, the table below shows results for the regression of the coefficient of variation of labor productivity productivity across firms in an industry on the percentage of workers with broadband access within the industry. The data (labelled ONS, and described in the section on empirical evidence) cover the years 2001 through 2005, during which time the penetration of broadband

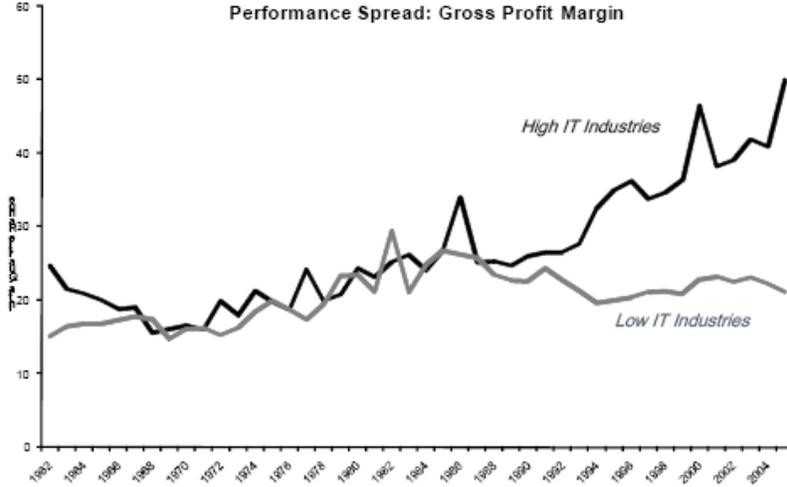


Figure 2: Variance of Gross Profit Margin, source: Brynjolfsson et al. (2009)

was growing rapidly.

$$C_{c,i,t} = \alpha + \gamma B_{c,i,t} + \sum_j \delta_j D_j + \varepsilon_{c,i,t} \quad (1)$$

Where  $C$  is the coefficient of variation of industry productivity in country  $c$ , industry  $i$ , and year  $t$ ,  $B$  is the percentage of workers in the industry with access to broadband internet, and  $D$  are dummy variable for each country, industry, and time periods. The regression is run both in levels and first differences. In both cases, the correlation is significantly positive, as shown in table 1. <sup>6</sup> This correlation does not imply causality, and needs to be interpreted with care because the ex-post observed variance in an industry may already reflect the endogenous firm-level choice of whether to invest in safe or risky innovation.

	Levels	First-differences
$\gamma$	0.97 (2.47)	2.03 (3.72)
$R^2$	0.40	0.07
D.F.	650	461
Fixed effects	ctry, ind, time	ctry, ind, time

**Table 1: Productivity variance and broadband use**

<sup>6</sup>We ran the regression without fixed effects and all combinations of country, industry, and or time dummies. In first differences, all coefficients are significant and roughly equal in size. In levels, regressions with industry but no country dummies gave an insignificant (negative) correlation. This points to the possibility of an omitted variable that boosts both the variance of productivity and the use of broadband, for example declining prices of ICT goods and services.

The data on ICT use at the firm level, linkable to other longitudinal firm-level data is not available in the U.S. However, the BHS dataset includes time series information on firm entry and exit and on job creation and destruction for detailed industries in the U.S. We use the broadband intensity of industries in Europe from the ONS dataset to rank industries by 'ICT intensity'. We use this industry ranking from Europe to split the U.S. industries into high-ICT and low-ICT groups and create indicators of employment-weighted gross firm turnover and gross job flows for the two aggregates.<sup>7</sup> Next, we average the gross job turnover (job creation plus job destruction divided by employment) and employment-weighted gross firm turnover (jobs flows of employees shed at firm exit plus hires at entering firms divided by employment) for the periods 1986-1994 and 1995-2004. The results are shown in table 2. The patterns are roughly the same as shown for the variance of profitability of firms by Brynjolfsson et al. (2009)

	Gross Job Flows		Entry-Exit Job Flows	
	1986–1994	1995–2004	1986–1994	1995–2004
High ICT Industries	17.5	23.1	6.8	10.4
Low ICT Industries	17.5	18.6	8.1	8.1

**Table 2: Gross Job Flows**

The next stylized facts portray the productivity and employment evolution of the EU and the US, split between high-risk industries and low-risk industries. First, we must make a ranking of riskiness. Based on the above, a good candidate measure of the riskiness of the industry is the fraction of workers with access to broadband. We calculate this ranking for the EU15 country with the lowest OECD-EPL indicator, namely the United Kingdom. Other indicators of riskiness related to the observed distribution of firm-level productivity, such as the variance of the productivity distribution across firms, generate the same stylized results. In section 5 we discuss this in greater detail. First, the productivity levels (ppp-adjusted real value added per hour) of the risky industries within the broad market sector are higher

<sup>7</sup>The cut-off industry for high-versus low-ICT using sectors is chosen to split employment in Europe evenly.

than the safe sector, both in the EU15 and in the U.S, see Figure 3. However, in the EU the risky sector productivity is forty percent higher than the safe sector, with a slight increase over time, while in the US, the risky sector starts sixty percent more productive, but rises rapidly over time and ends up twice as productive as the safe sector. Next, the share of employment going to the risky sector in the EU stays near fifty percent, while it is nearly at sixty percent in the U.S.<sup>8</sup>

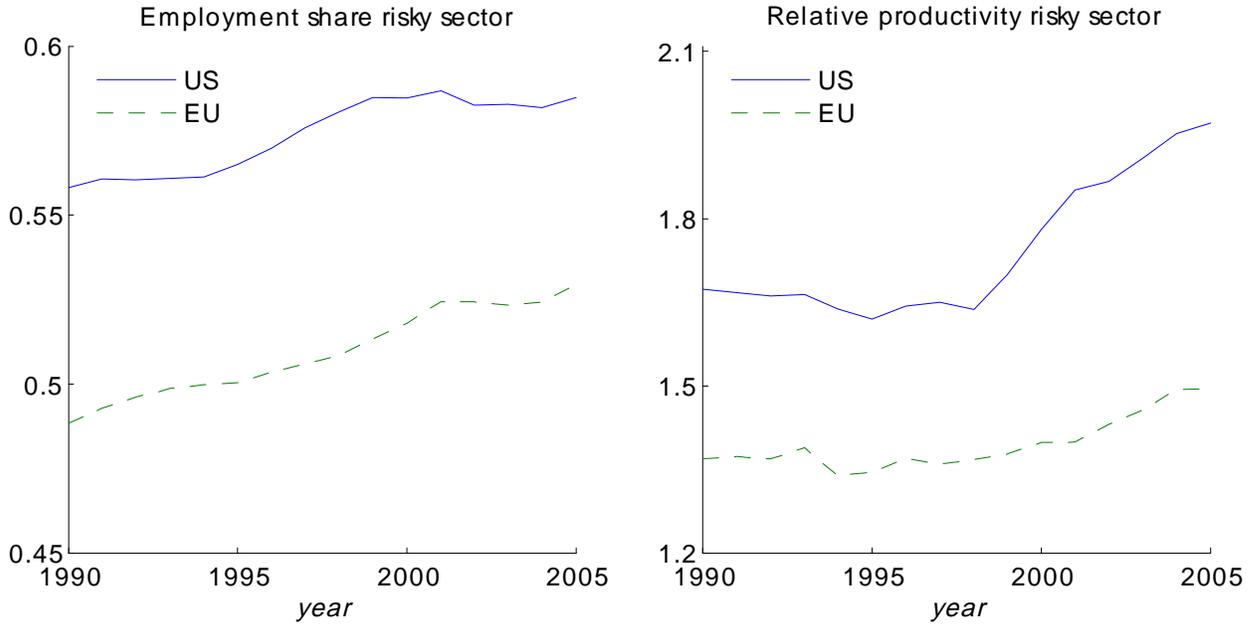


Figure 3: Risky Sector vs Safe Sector: US and EU

A nearly identical picture emerges when we split the EU15 into countries with high EPL and low EPL (see figure 4). During the late 1990s high-EPL countries in the EU did not see an acceleration in productivity or employment share in the risky sector. These are the main stylized facts to be explained by our model and explored further in detail in section 6. The distribution of EPL across countries does not change appreciably over time (see Nicoletti, Scarpetta, and Boylaud, 2000), thus changes in EPL alone cannot explain the productivity divergence. The core of our explanation is that employment protection makes firing more costly and makes the risky sector less attractive to open jobs. Moreover it shifts the

<sup>8</sup>In our model, risky sector productivity is lower in high-EPL countries because low-productive jobs do not shut down. In the actual industry data, it is likely that firms choose between riskier and safer activities within each industry and that more safe activities lower average industry productivity in 'risky sectors' in high EPL countries.

firing threshold productivity level (below which a worker is fired) to the left and reduces the average productivity in the risky sector. The EPL distribution has not changed much in the nineties so this by itself cannot explain the US-Europe divergence but our story is that the US was able to better explore the benefits from the new risky ICT technologies that became available during the nineties.

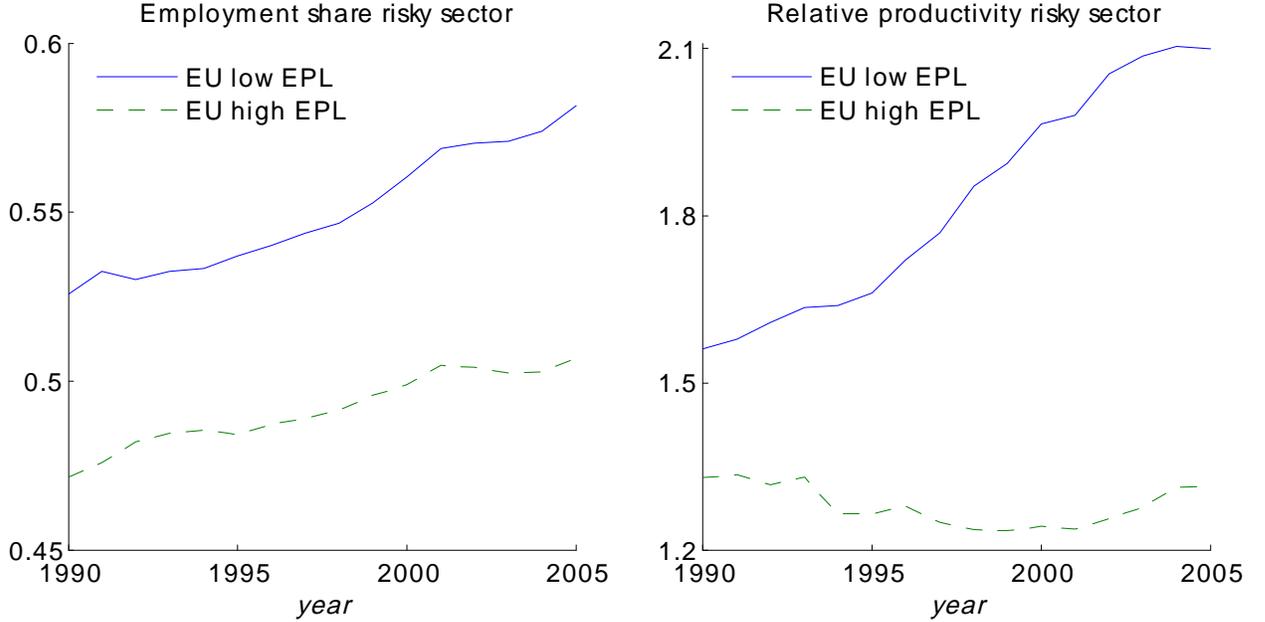


Figure 4: Risky Sector vs Safe Sector: High and Low EPL EU Countries

### 3 The model

Consider a labor market of size  $l \in [0,1]$  with search frictions and free entry of vacancies where risk neutral firms can invest in one of two technologies; a risky one or a safe one. In the safe technology sector (0), all matches are equally productive as in Pissarides (2000) while in the risky technology sector (1), firms are hit by shocks that can increase or decrease productivity as in Mortensen and Pissarides (1994). Those shocks can be interpreted as demand and or supply shocks. All risk neutral workers are identical. A matched worker-firm pair in sector 1 produces  $y + x$  where  $x$  is a draw from  $F(x)$  with mean  $\mu$  and a variance of  $\sigma^2$ .  $F(x)$  has no mass points and at this stage we do not have to make assumptions on the support of  $F(x)$ . The shocks in the risky sector arrive at a (Poisson) rate  $\lambda$ . When such a shock occurs,

firms must draw a new value of  $x$  from  $F(x)$ . In sector 0,  $\lambda = 0$  and consequently all firms produce  $y$ . We assume that new firms start at  $y + \mu$  rather than at a finite upper support as Mortensen and Pissarides (1994) assume. So in the absence of shocks ( $\lambda = 0$ ) and for  $\mu = 0$ , sector 0 and 1 would be identical and the model reduces to the Pissarides (2000) model.

Wages in sector  $i$ ,  $w_i$  are determined from the generalized Nash bargaining solution with continuous renegotiation (so the wage changes after a shock occurs) and workers cannot search on the job. When opening a vacancy, the firm can choose which sector to enter. Vacancy creation cost for sector 0 and 1 are respectively given by  $c_0$  and  $c_1$ . Both sectors are hit by exogenous job destruction shocks,  $\delta$ . After such a shock, the match ends and no exit cost has to be paid (as in Brügemann (2007)). This is without loss of generality; we could alternatively assume that when exogenous job destruction occurs that firms also have to pay an exit cost but this is equivalent to a decrease in  $y$ . Besides exogenous job destruction the firms in sector 1 choose a unique productivity threshold,  $x_d$ , below which a job is destroyed. So, in sector 1, both exogenous and endogenous (at rate  $\lambda F(x_d)$ ) job destruction occurs. When a firm decides to fire a worker it must pay an exit cost  $k$ . We are interested in how this firing tax distorts the sorting of firms into safe and risky sectors and the participation decision of workers.<sup>9</sup> In the absence of frictions, firms prefer the risky technology because there is no bound on positive shocks while firms have the option to close the job if a sufficiently large negative shock arrives.

Denote the total stock of vacancies by  $v$  and the stock of unemployment by  $u$  and define labor market tightness  $\theta = v/u$ . We can also define labor market tightness in each of the sectors as:  $\theta_0 = v_0/u, \theta_1 = v_1/u$ . The total number of matches in each sector is determined by a constant returns to scale matching function,  $M_0(u, v_0)$  and  $M_1(u, v_1)$  for respectively the safe and the risky sector. The matching functions are differentiable and strictly concave in each of their arguments. Define the total matching rate for workers in sector  $i$  as  $m_i = M_i/u$ . The rate at which vacancies are filled in each sector is then:  $m_i/\theta_i$ . In this set up, workers always impose negative congestion externalities on each other and positive ones on vacancies while vacancies only cause negative congestion externalities on other vacancies in the same sector. We can think of this matching process as one where vacancies for sector 0 are posted on one page

---

<sup>9</sup>In our model, the only productive input is labor, and firing costs thus coincide with the more generic concept of exit costs. We will use the terms interchangeably. In the empirical section we use different indicators relating to employment protection, firing costs, and capital losses at exit.

of the newspaper and vacancies for sector 1 on another page and workers pick a page at random and then a job at random from that page. Alternatively, we can think of sector 0 being located in one area and sector 1 in another area. We believe this is a reasonable assumption, i.e. posting an ICT vacancy will typically not decrease the rate at which workers meet vacancies in the financial sector. If unemployment increases, the matching rate for all workers goes down and for vacancies it goes up while if the number of vacancies in sector 1 increases, the matching rate for workers goes up and the matching rate for vacancies in sector 1 goes down. The matching rates in sector 0 are only indirectly affected. Since unemployment goes down, the matching rate for firms in sector 0 goes down but less so than in sector 1 because the congestion externality of type 0 vacancies on type 1 vacancies is absent.

Let  $V_i$  be the asset value of a vacancy and let  $J_i(x)$  be the asset value of a filled job in sector  $i$ . Free entry of vacancies implies:

$$rV_0 = -c_0 + \frac{m_0}{\theta_0} [J_0 - V_0] = 0 \quad (2)$$

$$rV_1 = -c_1 + \frac{m_1}{\theta_1} [J_1(0) - V_1] = 0 \quad (3)$$

Firms pay creation cost,  $c_0$  or  $c_1$  and at rate  $\frac{m_i}{\theta_i}$  their vacancies switch to filled jobs. Under free entry, all profit opportunities are explored in equilibrium so the value of opening a vacancy must be equal to zero in expectation. Let  $U$  be the asset value of an unemployed worker and let  $E_i(x)$  be the asset value for workers employed in sector  $i$ . Let  $S_0$  be the value of the surplus of a match in sector 0 and  $S_1(x)$  be the value of the surplus of a type  $x$  match in sector 1.

$$S_0 = J_0 + E_0 - U \quad (4)$$

$$S_1(x) = J_1(x) + E_1(x) - U \quad (5)$$

By our assumption that wages are determined by a generalized Nash bargaining solution with bargaining power  $\beta$ , wages in sectors 0 and 1 are implicitly determined by respectively:

$$E_0 - U = \beta S_0 \quad (6)$$

$$E_1(x) - U = \max[0, \beta S_1(x)] \quad (7)$$

$$J_1(x) = \min[(1 - \beta)S_1(x), S_1(x)]$$

Note that  $S_1(x)$  can be negative for certain realizations of  $x$ . The asset value for a filled vacancy in sector 0 is given by :

$$rJ_0 = y - w_0 - \delta J_0. \quad (8)$$

In the safe sector matches only end if they are hit by a job destruction shock which occurs at rate  $\delta$ . In sector 1 endogenous job destruction is also possible but then firms must pay an exit cost  $k$ . As mentioned before, if the job is hit by an exogenous shock  $\delta$  those cost do not have to be paid. For any realization  $x$ ,  $J_1(x)$  solves:

$$rJ_1(x) = y + x - w_1(x) - \delta J_1(x) + \lambda \left( \int_{x_d}^{x_u} [J_1(z) - J_1(x)] dF(z) - F(x_d) (J_1(x) + k) \right). \quad (9)$$

A firm with realization,  $x$ , receives during the match:  $y + x - w_1(x)$ . If the job is destroyed exogenously this value becomes zero, if a technology shock arrives (at rate  $\lambda$ ), the firm can close the job and fire the worker if the shock is below an endogenous threshold  $x_d$  which occurs with probability  $F(x_d)$  and this results in a loss of  $k$ . The firm can also decide to continue producing at the new technology if ( $x \geq x^d$ ) and the wealth gain or loss for a realization  $z$  is then equal to  $[J_1(z) - J_1(x)]$ , the upper support of  $F(x)$  can be arbitrary large. The threshold value for  $x$  below which the job is destroyed,  $x_d$ , follows from the following reservation value property:

$$J_1(x_d) = -k, \quad (10)$$

As long as the job is more valuable than the exit cost, it is optimal to remain operational. So the higher  $k$ , the lower the exit threshold. Similarly, the participation constraint for employed workers is that they should be at least as well off as when they are unemployed. This implies,

$$E_1(x_d) = U,$$

and that the match surplus at the least productive job is negative:

$$S_1(x_d) = -k, \quad (11)$$

The asset value of being unemployed is:

$$rU = b + m_0 [E_0 - U] + m_1 [E_1(0) - U]. \quad (12)$$

Unemployed workers receive unemployed benefits  $b$  (for positive analysis this can also be interpreted as home production) and they find jobs in the safe and risky sector at rates  $m_0$  and  $m_1$  they respectively. Non participants enjoy home production and are not available for the labor market. Let the distribution of home production be given by  $H$ , then the labor force consists of those workers who receive a higher payoff from working than from home production:

$$l = H(rU). \quad (13)$$

The value of having a job in the safe sector is simply equal to:

$$rE_0 = w_0 - \delta [E_0 - U] \quad (14)$$

while the asset value of being employed in the risky sector is given by:

$$rE_1(x) = w_1(x) - (\delta + \lambda F(x_d)) [E_1(x) - U] + \lambda \int_{x_d}^{x_u} [E_1(z) - E_1(x)] dF(z) \quad (15)$$

Workers receive a wage  $w_1(x)$ , at rate  $(\delta + \lambda F(x_d))$  their job is destroyed for exogenous reasons or because the lower bound threshold productivity is crossed. In that case, the worker becomes unemployed. At rate  $\lambda(1 - F(x_d))$ , a match is hit by a technology shock above the threshold and the wealth change for realization  $z$  is given by:  $[E_1(z) - E_1(x)]$ . From the Bellman equations above we can derive a job destruction equation for sector 1 and job creation conditions for sector 0 and sector 1. Together they jointly determine  $\theta_1, \theta_1$  and  $x_d$ . Unemployment and vacancies follow from two steady state flow equations. Details are delegated to the appendix.

## 4 Calibration

We calibrate the structural parameters of our model in three steps. In the first step, we fix some exogenous parameters according to standard values in the literature. In the second step, we set some other exogenous parameters at values that match the US labor market stocks and flows. In the third step, which is the key step of our calibration strategy, we set the productivity shock parameters—the arrival rate  $\lambda$ , the mean  $\mu$ , and the standard deviation  $\sigma$ —together with the firing costs parameter  $k$  in order to match the observed truncated cross-sectional distribution of US productivity. The right shape comes from the productivity shock parameters and the right truncation comes from the firing costs parameter. This third step is most important for us because we are mainly interested in long-run productivity effects. Since we explore several new data sources we are able to identify the productivity shock parameters including the arrival rate, which is set to an arbitrary value in previous literature.

### 4.1 Parameters from other studies

In this step, we fix several parameters according to what is common in the literature and we also normalize two parameters. The parameter values set in this step can be found in Table 3.

Without loss of generality, we normalize the productivity of the safe sector to  $y = 1$ . Following Pissarides (2009), and similar to Shimer (2005) and Hall and Milgrom (2008), we set the monthly interest rate to  $r = 0.004$ . Following Shimer (2005), we abstain from market inefficiencies due to search externalities by assuming that the Hosios condition  $\beta = 1 - \eta$  is satisfied and we set unemployment benefits to  $b = 0.4$ . This lies at the upper end of the range, if interpreted entirely as unemployment benefits. It is, however, too low, if interpretation includes leisure. Hall and Milgrom (2008), for example, think of 0.71 as a reasonable estimate for the flow value of unemployment and think of 0.25 as a reasonable estimate for unemployment benefits. In our model, we distinguish between non-participation and unemployment and think only non-participants can fully enjoy leisure. Note that our calibration is different from the calibration of Hagedorn and Manovskii (2008)—high  $b$  and low  $\beta$ —and hence we will not be able to explain the cyclical properties of labor market tightness. It is worthwhile noting that our key results on long-run productivity effects and the sectoral allocation of workers are robust to changes along this

dimension.

We do not have appropriate industry-level vacancy data. Having such data is not crucial though; we can calibrate the matching function parameters  $\eta$  and  $\xi$  using aggregate data. We take the matching elasticity from Pissarides (2009), that is  $\eta = 0.5$  which is similar to Hall and Milgrom (2008) and consistent with the evidence provided in Petrongolo and Pissarides (2001). Without loss of generality, we normalize the matching efficiency parameter to  $\xi = 0.3$ .<sup>10</sup>

Parameter	Value	Description	Motivation
$y$	1	productivity safe sector	normalization
$r$	0.004	monthly interest rate	Pissarides (2009)
$\beta$	$1 - \eta$	Nash bargaining share worker	Hosios condition
$b$	0.4	unemployment benefits	Shimer (2005)
$\eta$	0.5	matching elasticity	Pissarides (2009)
$\xi$	0.3	matching efficiency	normalization

**Table 3: Calibration according to the literature**

## 4.2 Matching the US labor market stocks and flows

In this step, we set several parameters in order to match the US labor market stocks and flows. We combine aggregate data from the OECD LFS (stocks) and the JOLTS (flows) with industry-level data from the EUKLEMS. The parameter values set in this step can be found in Table 4.

We set labor market participation  $l$  to match the labor market stocks data from the OECD LFS. That is, we set labor market participation to  $l = 0.77$ . We do not back out the underlying distribution of home production, because it is not identified using only US data. We carry out various robustness checks and find that endogenizing labor market participation would strengthen our key results, see section 5.3.

Our safe-risky classification is based on the ONS database. We rank industries in the UK—having the lowest OECD-EPL of the EU15 and hence being the closest related to the US—by their broadband intensity. We split the industry ranking according to EU15 employment and call the top half risky and the bottom half safe. This ranking is consistent with the stylized facts presented in Figure 3. We have

<sup>10</sup>As is well known from the literature, the matching technology parameter  $\xi$  and the vacancy creation cost  $c_0$  and  $c_1$  are not separately identified.

also experimented with ranking by variance in productivity and with calling the top quartile risky and the bottom quartile safe, with similar calibration results.

We set the exogenous job destruction rate  $\delta$  to match the labor market flows data from the JOLTS. Distinguishing between the safe and risky sector is not easy. First, the JOLTS data is based on two-digit industry codes, while our safe-risky classification is based on three-digit industry codes. This makes it difficult to use industry-level data from the JOLTS. We set the total separation rate of the safe as well as the risky sector equal to the total separation rate of the manufacturing sector, that is  $s^{safe} = s^{risky} = 0.029$ . Secondly, the safe and risky sector differ in our model only in terms of riskiness, while in the real world they also differ in other dimensions. There is, for example, a big difference in skill composition. That is, the safe sector consists of 14% high-skilled, 68% medium-skilled and 18% low-skilled, while the risky sector consists of 37% high-skilled, 57% medium-skilled and 6% low-skilled, based on the EUKLEMS. It is important to take this into account, because low-skilled workers face a much higher separation rate than high-skilled workers. This can easily be a factor five, see for example Moscarini (2003). Our aim is therefore to match the model for medium-skilled separation rates, which we construct from the data. For this purpose, we assume that within-sector differences are the same for the safe and risky sector, that is

$$\frac{s_{high}^{safe}}{s_{medium}^{safe}} = \frac{s_{high}^{risky}}{s_{medium}^{risky}} = \omega_h^s < 1$$

$$\frac{s_{low}^{safe}}{s_{medium}^{safe}} = \frac{s_{low}^{risky}}{s_{medium}^{risky}} = \omega_l^s > 1.$$

We set  $\omega_h^s = 0.4$  and  $\omega_l^s = 2$ , implying a factor five difference between high-skilled and low-skilled and medium-skilled a bid closer related to low-skilled than to high-skilled. From the skill decomposed separation rates

$$s^{safe} = p_{high}^{safe} s_{high}^{safe} + p_{medium}^{safe} s_{medium}^{safe} + p_{low}^{safe} s_{low}^{safe}$$

$$s^{risky} = p_{high}^{risky} s_{high}^{risky} + p_{medium}^{risky} s_{medium}^{risky} + p_{low}^{risky} s_{low}^{risky}$$

implying that the medium-skilled separation rates are

$$s_{medium}^{safe} = \frac{s^{safe}}{p_{high} \omega_h^s + p_{medium}^{safe} + p_{low} \omega_l^s} = 0.026$$

$$s_{medium}^{risky} = \frac{s^{risky}}{p_{high} \omega_h^s + p_{medium}^{risky} + p_{low} \omega_l^s} = 0.035.$$

This gives us  $s_{medium}^{safe} = 0.026$  and  $s_{medium}^{risky} = 0.035$ . In the safe sector of our model, there is only exogenous separation and hence we set the exogenous job destruction rate to  $\delta = 0.026$ . Now the endogenous job destruction rate must be  $\lambda F(x_d) = s_{medium}^{risky} - \delta = 0.008$ . This serves as target in the next step of our calibration strategy.

Finally, we take the labor market stocks from the OECD LFS and the relative sector sizes from the EUKLEMS. Together with our safe-risky classification, this gives us  $u = 0.04$ ,  $e_0 = 0.32$  and  $e_1 = 0.41$ . We combine these stocks with the above flows to solve for the implied labor market tightness via the safe and risky sector flow equations (26) and (27). We set the vacancy costs  $c_0$  and  $c_1$  in order to match labor market tightness. Vacancy costs are defined relative to productivity which is with Hall and Milgrom (2008) and Hagedorn and Monovskii (2008). Since we do not have appropriate industry-level vacancy data, we could not distinguish between safe and risky sector vacancy costs. It seems reasonable, however, that risky sector vacancy costs are larger than safe sector vacancy costs, since vacancy costs also include capital installment costs and the risky sector has for example a much larger broadband penetration. We assume that  $c_1 = 2c_0$ . Using the job creation condition of the safe sector (19) we find that  $c_0 = 0.2092$ .

Parameter	Value	Description	Motivation
$l$	0.77	size labor force	size labor force (OECD LFS)
$\delta$	0.026	Poisson rate ex. job destr.	ex. job destr. (JOLTS, EUKLEMS)
$c_0$	0.2092	vacancy costs safe sector	stocks, flows (OECD LFS, JOLTS, EUKLEMS)

**Table 4: Calibration in order to match the US labor market stocks and flows**

### 4.3 Matching the cross-sectional distribution of US productivity

In this step, we set the ex ante productivity shock parameters—the arrival rate  $\lambda$ , the mean  $\mu$ , and the standard deviation  $\sigma$ —together with the firing costs parameter  $k$  in order to match the ex post observed

truncated cross-sectional distribution of US productivity. More specifically, we match the cross-sectional mean and variance of risky sector productivity and we require risky sector in- and outflow to be consistent with the data. The parameter values set in this step can be found in Table 5.

### Cross-sectional mean and variance in the model

Let  $\hat{y}$  be the average output per worker in the risky sector. Workers who have not yet received a shock, a fraction  $1 - s$ , produce  $y$ . Workers who have already received at least one shock greater than  $x_d$ , a fraction  $s$ , produce on average  $y + \frac{1}{1-F(x_d)} \int_{x_d}^{x_u} z dF(z)$ . We can solve for the fraction  $s$  using the steady state flow equation  $\lambda(1 - F(x_d))(1 - s)e_1 = (\delta + \lambda F(x_d))se_1$  with the flow into  $s$  on the left-hand side and the flow out of  $s$  on the right-hand side, giving us  $s = \frac{\lambda}{\delta + \lambda}(1 - F(x_d))$ . The average output per worker in the risky sector is

$$\hat{y} = y + s \frac{1}{1 - F(x_d)} \int_{x_d}^{x_u} z dF(z) = y + \frac{\lambda}{\delta + \lambda} \int_{x_d}^{x_u} z dF(z).$$

The variance of output per worker in the risky sector is

$$\begin{aligned} \hat{\sigma} &= s \frac{1}{1 - F(x_d)} \int_{x_d}^{x_u} (y + z - \hat{y})^2 dF(z) + (1 - s)(y - \hat{y})^2 \\ &= \frac{\lambda}{\delta + \lambda} \left( \int_{x_d}^{x_u} z^2 dF(z) - \frac{\lambda}{\delta + \lambda} \left( \int_{x_d}^{x_u} z dF(z) \right)^2 \right). \end{aligned}$$

Productivity shocks are assumed to follow a normal distribution with mean  $\mu$  and standard deviation  $\sigma$ .

Using the analytic expressions for the truncated normal distribution, we can simplify the expressions for

$\hat{y}$  and  $\hat{\sigma}$ , giving us

$$\begin{aligned} \hat{y} &= y + \frac{\lambda}{\delta + \lambda} \left( \left( 1 - \Phi \left( \frac{x_d - \mu}{\sigma} \right) \right) \mu + \varphi \left( \frac{x_d - \mu}{\sigma} \right) \sigma \right) \\ \hat{\sigma} &= \frac{\lambda}{\delta + \lambda} \left( \left( 1 - \Phi \left( \frac{x_d - \mu}{\sigma} \right) \right) (\mu^2 + \sigma^2) + \varphi \left( \frac{x_d - \mu}{\sigma} \right) (x_d + \mu) \sigma \right) - (y - \hat{y})^2 \end{aligned}$$

where  $\varphi(\cdot)$  is the probability density function of the standard normal distribution and  $\Phi(\cdot)$  is its cumulative density function.

### Cross-sectional mean and variance in the data

Again, it is important to take the difference in skill decomposition into account, because high-skilled

are much more productive than low-skilled. This can easily be a factor three, based on evidence from the EUKLEMS. We assume that within-sector differences are the same for the safe and risky sector, that is

$$\frac{\pi_{high}^{safe}}{\pi_{medium}^{safe}} = \frac{\pi_{high}^{risky}}{\pi_{medium}^{risky}} = \omega_h^\pi > 1$$

$$\frac{\pi_{low}^{safe}}{\pi_{medium}^{safe}} = \frac{\pi_{low}^{risky}}{\pi_{medium}^{risky}} = \omega_l^\pi < 1.$$

We set  $\omega_h^\pi = 2.4$  and  $\omega_l^\pi = 0.8$ , implying a factor three difference between high-skilled and low-skilled, and medium-skilled much closer related to low-skilled than to high-skilled. From the skill decomposed productivities

$$\pi^{safe} = p_{high}^{safe} \pi_{high}^{safe} + p_{medium}^{safe} \pi_{medium}^{safe} + p_{low}^{safe} \pi_{low}^{safe}$$

$$\pi^{risky} = p_{high}^{risky} \pi_{high}^{risky} + p_{medium}^{risky} \pi_{medium}^{risky} + p_{low}^{risky} \pi_{low}^{risky}$$

we can now solve for the medium-skilled productivities

$$\pi_{medium}^{safe} = \frac{\pi^{safe}}{p_{high}^{safe} \omega_h^\pi + p_{medium}^{safe} + p_{low}^{safe} \omega_l^\pi}$$

$$\pi_{medium}^{risky} = \frac{\pi^{risky}}{p_{high}^{risky} \omega_h^\pi + p_{medium}^{risky} + p_{low}^{risky} \omega_l^\pi}.$$

In our model, only the ratio  $\frac{\pi_{medium}^{risky}}{\pi_{medium}^{safe}}$  is identified (because we have normalized safe sector productivity to  $y = 1$ ) which is equal to  $\hat{y}$ , that is

$$\hat{y} = \frac{\pi^{risky}}{\pi^{safe}} \frac{p_{high}^{safe} \omega_h^\pi + p_{medium}^{safe} + p_{low}^{safe} \omega_l^\pi}{p_{high}^{risky} \omega_h^\pi + p_{medium}^{risky} + p_{low}^{risky} \omega_l^\pi}.$$

We take  $\frac{\pi_{medium}^{risky}}{\pi_{medium}^{safe}} = 1.62$  from the EUKLEMS. This would imply  $\hat{y} = 1.24$ ; however, we do not feel comfortable in matching such a high number since there may also be other mechanisms that make the risky sector more productive than the safe sector. Examples are sorting by unobservable characteristics (see Gautier and Teulings 2006) and risk premia. Therefore, we match a somewhat lower number, namely  $\hat{y} = 1.1$ . Next, we set our target for the standard deviation of the productivity shocks,  $\hat{\sigma} = 0.16$ , while the BHS dataset would suggest a cross-sectional standard deviation in the range of 0.2 to 0.3. We also

want to match a somewhat lower variance because we want to capture the difference between risky sector variance and safe sector variance. In the BHS data the safe sector productivity also varies across firms, while it is zero in the model.

**Combining the cross-sectional mean and variance with risky sector in- and outflow**

In addition to the targets for the cross-sectional mean and variance, we obtain two additional targets via the risky sector in- and outflow. In the previous step of our calibration strategy we already determined the implied labor market tightness based on the stocks and flows observed in the data and we also determined the endogenous separation rate. We combine information from several new data sources on the cross-sectional distribution of productivity to identify the productivity shocks parameters including the arrival rate, which had to be set to arbitrary values in previous literature. In addition to the targets for the cross-sectional mean and variance, we obtain two additional targets via the risky sector in- and outflow. Appending the targets on the cross-sectional mean and variance with the risky sector in- and outflow and with the job destruction margin, gives us five equations in five unknowns. We solve this system of equation and get  $\lambda = 0.1410$ ,  $\mu = 0.0653$ ,  $\sigma = 0.4989$  and  $k = 1.2227$ , see the appendix for the details.

Parameter	Value	Description
$\lambda$	0.1410	Poisson rate productivity shock
$\mu$	0.0653	mean productivity shock
$\sigma$	0.4989	std. deviation productivity shock
$k$	1.2227	firing costs
<b>Motivation</b>	endog.	job destruction (JOLTS, EUKLEMS), cross-sectional mean (EUKLEMS), cross-sectional variance (BHS), stocks and flows (OECD LFS, JOLTS, EUKLEMS)

**Table 5: Calibration in order to match the cross-sectional distribution of US productivity**

## 5 Simulations

### 5.1 The effects of EPL and rising riskiness

The calibrated model allows simulation of steady-state employment shares and relative productivity by varying any of the model parameters. Of interest for this paper is the effect of differences across economies

in exit costs,  $k$ . Further, our stylized facts point towards an increase over time in the standard deviation of productivity shocks,  $\sigma$ , in the risky sector. The simulations thus consist of computing steady state employment and productivity outcomes for a wide range of  $k$  and  $\sigma$ .

We allow the exit costs to vary from the calibrated value of the US ( $k = 1.2$ ), comparable to roughly one month of output. The low EU values ( $k = 3$ ) through the high EU values ( $k = 7$ ) are comparable to 7 months of production or about 1 year of wages.<sup>11</sup> The standard deviation of productivity is varied from 0.4 to 0.8. This range is consistent with the increase in riskiness that has been observed with rising ICT use.

The results are presented in Table 6 and in figure 5. The table shows steady state outcomes for a list of variables for (i) the benchmark  $\sigma = 0.5$  and (ii) a higher  $\sigma = 0.75$  to capture the introduction of the new ICT technology. Across the columns, as firing cost increase, we see that in the risky sector there will be less firing (more labor hoarding), and because of that risky-sector productivity falls and the match surplus decreases. Consequently, labor market tightness goes down in the risky sector. Despite the lower productivity, wages go up in the risky sector because the (employed) worker's bargaining position improves in the risky sector. The match surplus in the safe sector goes up because essentially the other sector is being taxed. The safe sector becomes larger except when risk is low and firing costs are high. In this case, employment is fairly flat, as increases in the risky sector resulting from the decrease in outflow balances the decrease in inflow and unemployment drops. The drop in unemployment causes the safe sector to shrink despite the fact that  $\theta_0$  increases. Since unemployed workers are less likely to get hired in the high productivity risky sector their bargaining position with safe-sector employers goes down. Next, consider what happens if  $\sigma$  increases (i.e. after the ICT revolution). A higher level of firing cost decreases employment in the risky sector, increases employment in the safe sector, increases wages in the risky sector, decreases wages in the safe sector and the total employment effect is positive. As firing costs rise, both the allocation shift towards the safe sector and the increase in labor hoarding will contribute to lower overall productivity,  $\pi \equiv \frac{e_0 y + e_1 \hat{y}}{e_0 + e_1}$ . Finally, total output net of vacancy costs, labelled  $\Omega$  in the table, unambiguously decreases as firing cost increase, irrespective of  $\sigma$ .

---

<sup>11</sup>Examples of European countries with low EPL are Denmark and the UK; examples of European countries with high EPL are Portugal and Italy. See the appendix table.

To summarize, productivity drops with increased firing costs, both from a selection effect (less truncation in the risky sector) and from a reduction in the size of the risky sector. The effect of rising firing costs increases with  $\sigma$ . The allocation of workers to the risky sector is not very sensitive to firing costs when  $\sigma$  is low and when firing costs are high, because essentially all jobs are 'hoarded'. Once  $\sigma$  rises, the allocation of labor to the risky sector falls with firing costs. Further, the effect of firing cost on risky sector allocation becomes stronger (more negative) as  $\sigma$  increases.

	Benchmark $\sigma = 0.50$			High $\sigma = 0.75$		
	$k = 1.25$	$k = 3$	$k = 7$	$k = 1.25$	$k = 3$	$k = 7$
$x_d$	-0.7289	-1.0098	-1.6879	-0.7806	-1.0475	-1.6930
$\lambda F(x_d)$	0.0079	0.0022	0.0000	0.0183	0.0097	0.0013
$\hat{y}$	1.0997	1.0709	1.0554	1.1817	1.1353	1.0708
$S_1(0)$	3.0123	2.9052	2.8705	3.3146	3.1254	2.9002
$\theta_1$	1.1666	1.0851	1.0594	1.4126	1.2559	1.0814
$e_1$	0.4100	0.4127	0.4191	0.5860	0.4455	0.4175
$w_1(0)$	0.9790	0.9722	0.9701	0.9829	0.9616	0.9447
$S_0$	0.8903	1.0341	1.0760	0.1830	0.7050	1.0403
$\theta_0$	0.4076	0.5500	0.5955	0.0172	0.2556	0.5565
$e_0$	0.3161	0.3190	0.3146	0.1102	0.2761	0.3150
$w_0$	0.9866	0.9845	0.9839	0.9973	0.9894	0.9844
$u$	0.0429	0.0373	0.0353	0.0728	0.0473	0.0366
$e_1/(e_0 + e_1)$	0.5657	0.5651	0.5712	0.8417	0.6174	0.5700
$\pi$	1.0563	1.0400	1.0317	1.1529	1.0836	1.0403
$\Omega$	0.9654	0.9620	0.9582	0.9875	0.9812	0.9638

**Table 6: Model Simulation**

The left panel of figure 5 illustrates the effects of changing  $k$  and  $\sigma$  on employment. If the firing costs are low enough, employment in the risky sector increases with  $\sigma$  because more vacancies are opened in the risky sector which implies that fewer unemployed workers are available for the safe sector. For higher firing costs,  $\sigma$  needs to be higher before risky sector employment 'escapes' from full labor hoarding and can benefit from the increased risk by truncating the bad draws. For a given level of riskiness, employment in the risky sector decreases with  $k$ , although the effect is small with low levels of  $\sigma$  or high firing costs. The reduced effect of firing costs on employment share with low  $\sigma$  occurs because the amount of firing becomes very small as the firing threshold shifts to the left.

The right panel of figure 5 shows that the relative productivity decreases in  $k$  and increases in  $\sigma$ . The relative productivity of the safe sector decreases with  $k$  because high exit costs shift the threshold of

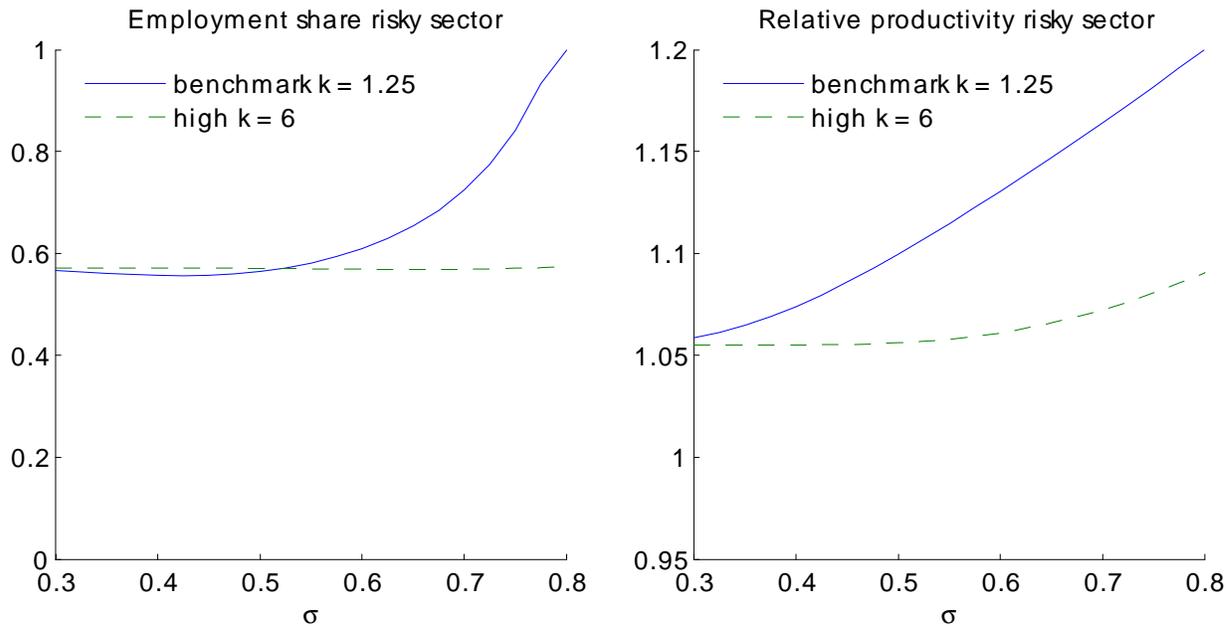


Figure 5: Simulation  $\sigma$  and  $k$

firing to a lower level of productivity. Aggregate productivity decreases rapidly when  $k$  increases, both because the relative productivity declines and because the share of resources allocated to the risky sector declines. As the variance of the productivity shock increases, the risky sector becomes more attractive so it grows while the safe sector shrinks. Further, because of the firing threshold, average productivity of jobs in the risky sector increases in  $\sigma$ . The model can also explain that in countries with high firing cost the risky sector does not increase in response to an increase in  $\sigma$  and consequently productivity also remains almost constant. To the contrary in countries with low firing cost, the employment share of the risky sector and aggregate productivity strongly increases in response to a new technology with a higher  $\sigma$  as occurred at the end of the nineties.

## 5.2 The effect of an increase in the cost of risky investments

What happens if the cost for risky activities increases? This is in particular relevant in the aftermath of the credit crisis where in the terminology of Bernanke, Gertler, and Gilchrist (1996), a flight to quality

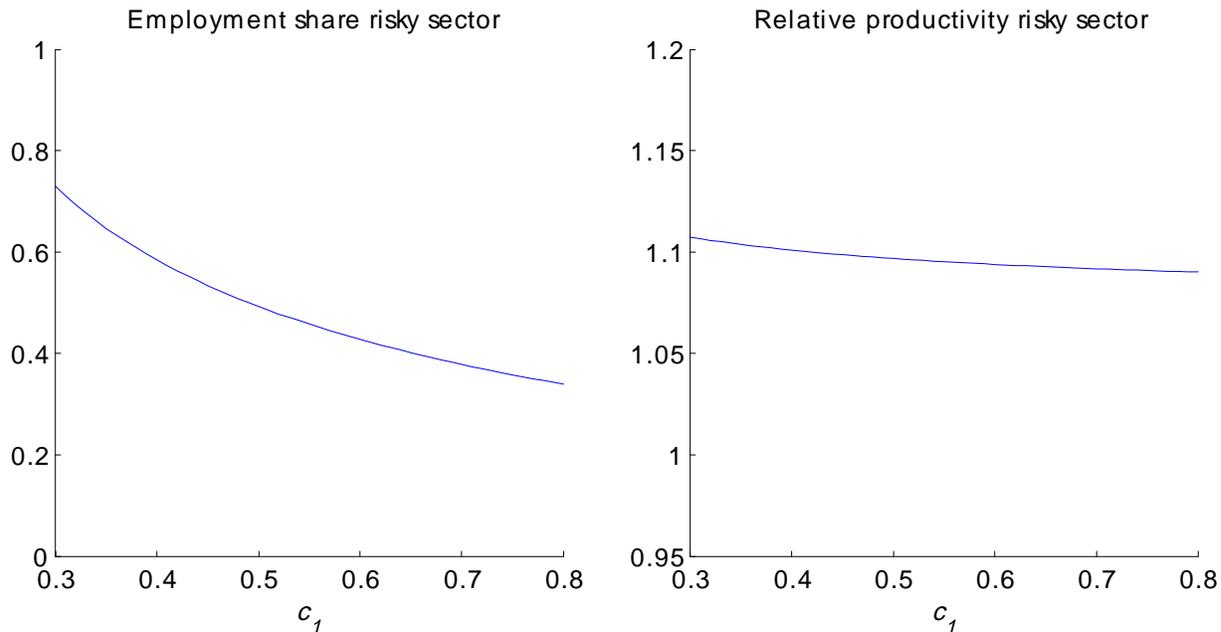


Figure 6: An increase in the cost of creating risky jobs

took place.<sup>12</sup> Although our model has no financial sector, we can take a shortcut and model this by an increase in the vacancy creation cost,  $c_1$ , for the risky sector. This captures the idea that banks become reluctant to lent to firms with a high probability to go bankrupt. Figure 6 shows that this can have substantial effects on productivity because the risky sector becomes smaller. This is one potential mechanism that can generate long term growth effects of the crisis.

### 5.3 Endogenous participation

So far we have assumed that labor force participation was exogenous. If we endogenize the participation rate  $l$  according to (13), employment protection has more negative wealth effects because it decreases the asset value of unemployment and consequently labor force participation.

---

<sup>12</sup>Lucas (2008) describes this as: "Everyone wants to get into government-issued and government-insured assets, for reasons of both liquidity and safety". Caballero and Kurlat (2008) point out that while the US as a whole is regarded to be save (and this still leads to net capital inflows), all other forms of funding dried up. Flight to quality is not specific for the current crisis but has been reported to take place in many cyclical downturns. Reinhart and Rogoff (2008) give evidence that the current crisis shows a lot of similarities with past crises around the entire world.

## 6 Data and empirical results

In this section we explore the empirical relationship between EPL and the allocation of resources to risky sectors. We assess whether risky industries have relatively higher levels of employment in countries with low firing costs versus countries with high firing costs. Table 7 provides an overview of the data used for this exercise. The EUKLEMS database (O’Mahony and Timmer 2009) provides measures of output, hours worked, other factor inputs, prices, and industry purchasing power parities for EU countries and for US, for disaggregated industries covering the whole economy from 1970 through 2004. We use the share of hours worked in an industry relative to total hours worked in all industries in each country and time period as the variable to be explained.<sup>13</sup>

The firing cost indicators are available from two sources. First, a country-time panel dataset collected at the OECD (Nicolletti, et al. 2000), provides indicators of the stringency of employment protection (EPL).<sup>14</sup> The time dimension of this dataset may contain interpolations between actual component level information collected from OECD member countries in specific years, and thus has less reliability than the cross-country dimension. A complementary dataset of indicators of ‘Costs of doing business’ (CDB), including entry and exit costs has been compiled by the World Bank (see Djankov, La Porta, Lopez de Silanes, and Schleifer 2002). Current indicators on, for example, hiring and firing costs, or time to start a business, are available for many countries from 2004 to the present.

Finally, as a source of information on the riskiness of a sector, we make use of two datasets collected using the method of ‘distributed micro data research’ (Bartelsman, Haltiwanger and Scarpetta, 2009). These datasets include moments computed from the underlying distributions in confidential firm-level datasets available at national statistical offices, aggregated to the country, industry, and year level. First, for the 1990s data has been collected for a selection of OECD countries, mostly for firms in manufacturing. Next, a project, coordinated by the UK Office of National Statistics (ONS 2008), and funded by Eurostat, compiled information from linked longitudinal business registers, production surveys, and e-commerce

---

<sup>13</sup>We limit our study to industries in the Market Sector, defined similarly to that in the EUKLEMS dataset. The market sector includes industries in manufacturing, trade, finance and business services, but excludes agriculture, government and services. We also exclude utilities and nuclear fuel production.

<sup>14</sup>The OECD index is based on 18 factors of employment protection of regular workers against individual dismissal, specific requirements for collective dismissals and regulation of temporary employment.

surveys for 13 EU countries for firms in all sectors of the economy for the years 2001 to 2005.

Source	Periods	Countries	Industries	Variables
EUKLEMS	1970-2005	EU+US	30, market sector	Output, factor inputs, prices, PPPs
OECD-EPL	1985-2005*	OECD	No info	EPL indicators
WB-CDB	2004-2007	World	No info	Entry/ firing costs, rigidities
BHS	1990s	OECD, Asia, Lat Am	16, manufacturing.	Moments from firm surveys
ONS/Eurostat	2001-2005	13 EU countries	30, market	Moments from firm surveys

**Table 7: Data sources**

In the available data, we have no direct measure of the variance of shocks faced by firms choosing the ‘risky’ sector. Instead, we have the variance of the cross sectional distribution of productivity observed across firms in each industry in the national datasets. As our model shows, for firms choosing risky strategies the observed variance is truncated with respect to the underlying distribution of shocks, and the point of truncation depends on firing costs. However, in the model the observed productivity variance moves monotonically with the variance of the underlying shocks for any level of firing costs. For our baseline empirical results we therefore use as the sectoral-riskiness indicator the observed variance of labor productivity within an industry averaged across countries. For robustness, we also use other proxies for industry riskiness from the ONS and BHS datasets.

To rank industries according to riskiness, the above indicators from the BHS or the ONS dataset are averaged over time (and across countries where noted) and are turned into an ordinal index of industry-specific ‘riskiness.’ This ordinal ranking is then normalized into a uniform index ranging from -0.5 for the lowest risk to 0.5 for the highest risk sector.

The first results are presented for a regression equation of the following general form:

$$e_{c,i,t} = \alpha + \beta Cf_{c,t} + \gamma Cf_{c,t}R(\sigma)_i + FE + \varepsilon_{c,i,t} \quad (16)$$

where  $e_{c,i,t}$  is the ratio of hours worked in industry  $i$ , country  $c$  and year  $t$  relative to total hours in that country and year. The exogenous variable  $Cf_{c,t}$  is the firing cost or exit cost indicator, and  $R(\sigma)_i$  is the rank of the industry risk, with a higher rank being more risky. The parameter  $\gamma$  measures the effect

of the regulatory environment interacted with the indicator of industry risk on the share of employment in the industry. Depending on specification, industry fixed effects  $FE$  (mean levels, including the level effect of  $R_i$  or mean levels and trends) are swept out with appropriate dummy variables.<sup>15</sup> This type of specification has become widespread in evaluation of the impact of policy or environment on performance, e.g. Rajan and Zingales (1998). Essentially, the equation uses difference-in-differences to identify how changes in the policy, here  $Cf_{c,t}$ , differentially impact different sectors, based on the expected sensitivity of the sector to the policy change. To our knowledge, we are the first in this literature to explicitly model the interaction between the ranking and the policy instead of relying on reasoned assumption about the sensitivity.<sup>16</sup>

Table 8 presents the baseline results for the full sample of all countries with available data for the period 1995-2005. In this and in all other Figures, t-statistics are in parenthesis, the risk indicator is based on the variance of productivity in the entire sample, industry fixed effects and a time trend is included.

The firing cost variable used is the OECD indicator for stringency of employment protection for regular workers, and the riskiness indicator is based on the observed variance of labor productivity within an industry in each of the countries in the ONS dataset. Column (1) shows results when fixed effects control for industry means and fixed time effects, and column (2) shows the results with industry mean and an industry specific time trend removed. The dependent variable is the share of hours worked for that industry as a percentage of total hours for that country and year. The interpretation of the coefficient,  $\gamma$ , is as follows: A movement of the EPL index by 1 point, (say from the German value of 2.7 to the Belgium value of 1.7), will increase the share of employment in the riskiest industry (rank=.5) by 0.5 percentage point, while reducing the share of employment in the safest sector by the same amount.<sup>17</sup>

---

<sup>15</sup>Country fixed effects are insignificant and numerically very close to zero because the dependent variable is a share and the level effect of  $Cf$  is included.

<sup>16</sup>Because the employment share variable is bounded between zero and one, we have replicated all our results with a logistic transformation of the dependent variable. The qualitative results, equation fit, and p-level of all estimates are roughly equivalent, but the parameter value is less easily interpreted. In all our specifications we correct for heteroskedasticity in errors that likely occur in each industry cluster.

<sup>17</sup>The level effect of the exit costs,  $\beta$ , is not shown. Because of the specification of the dependent variable as a share, and the inclusion of industry fixed effects, the coefficient captures small interactions between means of EPL and means of shares over time and countries. The coefficient is always very insignificant and close to zero in magnitude.

	(1)	(2)
$\gamma$	-1.01 (12.75)	-1.01 (12.98)
$R^2$	0.84	0.85
D.F.	5508	5494
Fixed effects	industry mean	industry mean and trend

**Table 8: Regression results**

t-statistic in parenthesis. Period: 1995-2005; Industry rank: productivity variance; ExitCost: EPLRegular. See appendix for country and industry listing.

The next three tables provide some robustness checks concerning the country sample used, the time periods, the indicators for industry riskiness, and the variables related to layoff and exit costs.

In Table 9, the time periods are varied, as are the country samples. Appendix Table 1 shows a list of countries, and the specified sub-samples. Generally, samples vary by including or excluding non-EU OECD members, or including/excluding transition economies. For ease of comparison, only the parameter  $\gamma$  and the t-statistic are presented. Overall, the general pattern is consistent: higher firing costs are associated with lower employment shares in high risk industries and higher shares in low risk industries. The effect is never lower in the latter part of the sample period, consistent with the outcome of the model simulation with rising risk. The effect varies a bit across country sample, and it seems that inclusion of the transition economies weakens the effect.

Sample	sub-period		
	1995-2000	2000-2005	1995-2005
EU	-.71 (5.04)	-.84 (5.49)	-.77 (7.15)
EUN	-0.87 (6.72)	-.94 (6.89)	-0.91 (9.27)
EURO	-.63 (3.32)	-.63 (7.15)	-.62 (4.62)
OECD	-0.85 (7.85)	-0.94 (8.09)	-0.89 (10.81)
ALL	-0.98 (9.52)	-1.04 (9.57)	-1.01 (12.98)

**Table 9: Country/Period sub-samples**

t-statistic in parenthesis. Industry rank: productivity variance; ExitCost: EPLRegular; Fixed Eff: industry means & trends. See appendix for country listing.

Table 10 shows the result after splitting the sample in countries with high versus low firing costs,

and industries into high risk and low risk sets. In the last column, we see the results for the full set of industries, split by the level of layoff and exit costs and in the last row we see the results for all countries split into columns by riskiness. For all of the permutations, the qualitative effect is the same. Looking across each row, the differential impact of firing costs is higher in the high-risk industry sub-sample, consistent with the outcome of the model simulation. In the model, firing costs become particularly onerous when riskiness is high. Looking down the columns, the differential impact of firing costs is higher with low firing costs, also consistent with the model. When firing costs already are high, there is less scope for an effect of further increasing these costs because the amount of firing already is minimal.

Country sub-sample	Industry sub-sample		
	Low risk	High risk	All
Low firing cost	-2.67 (6.26)	-3.31 (7.84)	-1.65 (9.92)
High firing cost	-1.35 (3.32)	-2.97 (6.52)	-1.07 (6.17)
All	-1.03 (5.36)	-1.99 (9.91)	-1.01 (12.98)

**Table 10: Country/Industry sub-samples**

t-statistic in parenthesis. Period: 1995-2005; Industry Rank: productivity variance; ExitCost: EPLRegular; Fixed Eff: industry means & trends. See appendix for country and industry listing.

Finally, Table 11 varies the indicators used for exit costs and for ranking of riskiness of industry. The first alternate indicator of riskiness captures the adoption and intensity of the use of broadband internet by firms in each industry, from the ONS dataset and is measured as the percentage of workers with access to broadband internet (DSL pct). The next measure is the ratio of productivity of the top quartile of firms to the mean in an industry, (P4/P). Because firing costs truncate from below, this indicator may be less affected by firing costs than the overall variance of productivity<sup>18</sup>. The last column shows our base measure, the variance of productivity. All industry riskiness rankings are averaged across countries in the ONS dataset. The exit cost indicators are described and the values for each country are given in the Appendix. For each exit cost indicator, the effect is largest when the riskiness ranking is based

<sup>18</sup>We also use riskiness indicators drawn from firm-level distributions in the UK which has the lowest level of exit costs in the EU. The US has even lower firing costs than the UK, but the US productivity variance is only available for manufacturing industries. We test all our results for all industries with the UK-based riskiness indicator or for manufacturing sectors only, with US or EU-based riskiness indicators, with very similar results as presented in our main tables.

upon broadband penetration, slightly lower for the width of the top of the productivity distribution and smallest for the overall variance measure of industry riskiness.

Exit Cost	Riskiness indicator		
	DSLpct	P4/P	Variance
Exitloss%	-5.08 (13.49)	-4.04 (10.66)	-3.52 (9.24)
Exitcost%	-24.70 (17.01)	-19.38 (13.17)	-15.42 (10.40)
Firerule	-0.68 (7.40)	-0.52 (5.64)	-0.45 (4.92)
Firecost	-4.66 (15.26)	-4.18 (13.61)	-3.10 (9.99)
EPLoverall	-1.04 (13.08)	-0.80 (9.86)	-0.64 (7.91)
EPLregular	-1.21 (15.65)	-1.04 (13.46)	-1.01 (12.98)

**Table 11: Alternate exit cost and riskiness indicators**

t-statistic in parenthesis. Period: 1995-2005; Fixed Eff: industry means & trends. See appendix for indicator definitions and country and industry listing.

The first four exit cost indicators are sourced from the World Bank Cost of Doing Business Database and the last two from the OECD. The first two exit cost indicators are not directly associated with costs of shedding workers, but relate to the percentage of annual revenue that is spent on exit (Exitcost%), and the percentage of capital investment that may be reclaimed upon exit (Exitloss%). The other indicators are related to costs of employment protection (an indicator of difficulty of firing, Firerule, and an indicator of cost, Firecost%). Table 3 in the Appendix shows the values of these indicators for each country in our sample in 2004.

As an additional robustness check, we randomly select 1200 industry rankings from all possible ordinal rankings of our 26 industries and run our baselines regression to estimate the parameter  $\gamma$  for each ranking. The regressions are based on 'all countries', for the period 1995-2000, use EPL Regular as exit cost indicator, and include industry fixed effects and industry time trends. Figure 7 shows the point estimates for  $\gamma$  with confidence bounds. All the estimates of  $\gamma$  reported in this paper, as well as the estimates of  $\gamma$  for all the permutations of firing costs, rankings, and samples we have explored, fall well within the 5 percent largest negative estimates. Our preferred estimate with the productivity variance as industry and EPL Regular as firing cost lies among the 1 percent largest (absolute) effects of firing costs.

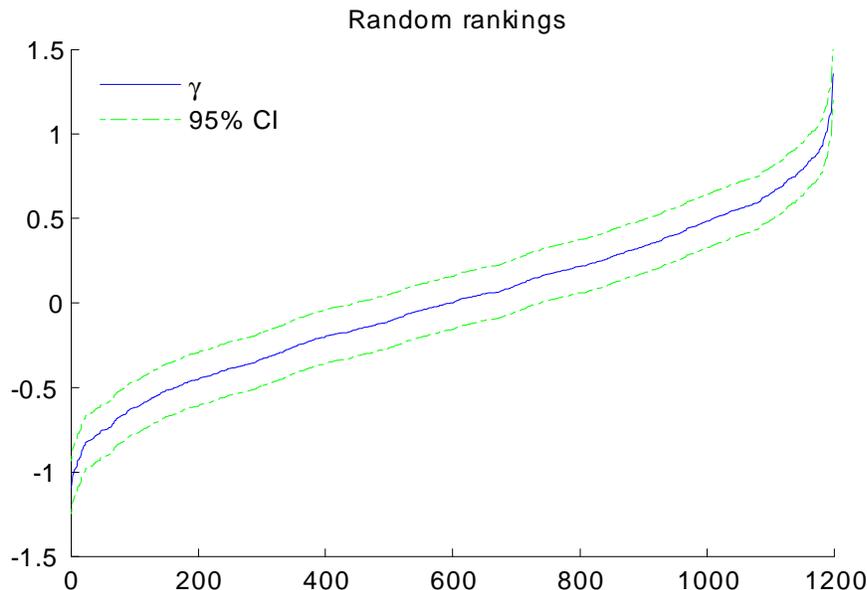


Figure 7: Estimates of  $\gamma$  with random  $R(\sigma)$

Finally, we address the issue whether entry costs rather than firing costs are causing the small employment share of risky sectors. Our first thoughts are that firms in both the safe and risky sector must pay the entry fee, so that the first order effect of higher entry costs would not discriminate between them. However, given the shorter expected life of a job in high risk sectors, more entry fees must be made to maintain employment there compared to the safe sector, reducing its size in equilibrium. In terms of the search model, fewer vacancies are needed to maintain the necessary flows into the safe sector, so that its relative size may increase with increase in entry costs. In a simulation of the model, high entry fees (keeping the ratio of  $c_0/c_1$  constant) decrease the relative size of the risky sector. However, if firing costs are increased from the calibrated value, the effect of higher entry fees on relative size is much smaller.

Our empirical findings likewise are mixed, but always retain the negative effect of firing costs. When we run our basic specification of employment share in an industry regressed on the entry fee indicator, and the indicator interacted with the industry riskiness ranking, we mostly find significantly negative effects on the interacted term, similar to the result for the employment protection index. When we included both entry and exit costs, table 12 shows that the coefficient on interacted employment protection variable remains significant when the entry costs variables are included, but that the size of the coefficient is

reduced. For some of the entry cost indicators, the interacted effect is significantly negative, but for others it is insignificant or even positive.

Entry Cost Indicator	$\gamma_{entry}$	$\gamma_{exit}$
Starting a Business - # of procedures	-.04 (4.03)	-.52 (3.65)
Starting a Business - time (days)	-.03 (5.17)	-.58 (5.17)
Starting a Business - cost (pct of capital)	-.01 (1.21)	-.95 (11.14)
Difficulty of hiring (index)	-.00 (.44)	-.97 (9.74)
Barriers to entrepreneurship	-.11 (1.48)	-.81 (5.38)
Barriers to entrp. license and permits	.05 (3.12)	-1.03 (13.09)
none. (only exit cost: EPLRegular)		-1.01 (12.98)

**Table 12: Labor share regressed on exit and entry costs**

t-statistic in parenthesis. Period: 1995-2005; Industry rank: productivity variance; Exit Cost: EPLRegular; Fixed Eff: industry means & trends.

## 7 Final remarks

In this paper we argue that the extent to which a country can benefit from the advantages of risky technologies depends on the institutional arrangements on firing and bankruptcy. The more employment protection there is, the more costly it is to exercise the job destruction or firm exit option. This mechanism can explain why the US was better able to explore the benefits of the new information technology starting in the mid 1990s. We construct a matching model with endogenous technology choice (risky or safe) and find that if we calibrate the model to the US that firing cost are in the order of about one month of production. If we increase this level to European levels (7 months of production), this reduces aggregate productivity by about 10 percent, partly through a direct reduction of average productivity in the risky sector, and partly through a significant reduction of activity (employment) in the risky sector.

One of our simplifying assumptions was that workers are risk neutral. A natural question to ask is wheter EPL is more desirable if workers are risk averse? This is not obvious since EPL makes the unemployment state less attractive because it increases unemployment duration and risk averse workers

prefer the differences between the good and bad state to be small. In other words, it puts the burden of unemployment on a smaller group. In richer models where optimal UI benefits and EPL are determined jointly, optimal EPL may well be positive.

In future work we want to further explore the role of risky technologies on long term productivity and growth. Simple simulations show that if the price of financing risky projects increases and it becomes more costly to open risky vacancies, this can have substantial effects on productivity.

## References

- ACEMOGLU, D., P. AGHION, AND F. ZILIBOTTI (2006): “Distance to Frontier, Selection, and Economic Growth,” *Journal of the European Economic Association*, 4(1), 37–74.
- ACEMOGLU, D., AND R. SHIMER (2000): “Productivity gains from unemployment insurance,” *European Economic Review*, 44(7), 1195–1224.
- ADDISON, J. T., AND P. TEIXEIRA (2003): “The Economics of Employment Protection,” *Journal of Labor Research*, 24(1), 85–129.
- ALVAREZ, F., AND M. VERACIERTO (1999): “Labor-Market Policies in an Equilibrium Search Model,” *NBER Macroeconomics Annual*, 14, 265–304.
- AUTOR, D. H., W. R. KERR, AND A. D. KUGLER (2008): “Does Employment Protection Reduce Productivity? Evidence From US States,” *The Economic Journal*, 117(521), F189–F217.
- BARTELSMAN, E. J. (2008): “From Micro to Macro,” in *Information Society: ICT Impact Assessment by linking data from different sources*, chap. 14, pp. 255–271. Eurostat.
- BARTELSMAN, E. J., J. HALTIWANGER, AND S. SCARPETTA (2009): “Measuring and Analyzing Cross-Country Differences in Firm Dynamics,” in *Producer Dynamics: New Evidence from Micro Data*, ed. by T. Dunne, J. B. Jensen, and M. J. Roberts, vol. 68 of *Studies in Income and Wealth*, chap. 1, pp. 15–79. NBER/Chicago.
- BARTELSMAN, E. J., E. C. PEROTTI, AND S. SCARPETTA (2008): “Barriers to Exit, Experimentation and Productivity,” mimeo.
- BASSANINI, A., L. NUNZIATA, AND D. VENN (2009): “Job protection legislation and productivity growth in OECD countries,” *Economic Policy*, 24, 349–402.
- BENTOLILA, S., AND G. BERTOLA (1990): “Firing Costs and Labour Demand: How Bad is Euroclerosis?,” *The Review of Economic Studies*, 57(3), 381–402.

- BERNANKE, B., M. GERTLER, AND S. GILCHRIST (1996): “The Financial Accelerator and the Flight to Quality,” *The Review of Economics and Statistics*, 78(1), 1–15.
- BERTOLA, G. (1990): “Job security, employment and wages,” *European Economic Review*, 34(4), 851–879.
- BLANCHARD, O. (2006): “European Unemployment: The Evolution of Facts and Ideas,” *Economic Policy*, 21(45), 5–59.
- BLANCHARD, O., AND P. PORTUGAL (2001): “What Hides behind an Unemployment Rate: Comparing Portuguese and U.S. Labor Markets,” *American Economic Review*, 91(1), 187–207.
- BLANCHARD, O. J., AND J. TIROLE (2008): “The Joint Design of Unemployment Insurance and Employment Protection: A First Pass,” *Journal of the European Economic Association*, 6(1), 45–77.
- BLOOM, N., R. SADUN, AND J. V. REENEN (2007): “Americans Do I.T. Better: US Multinationals and the Productivity Miracle,” *National Bureau of Economic Research Working Paper Series*, w13085.
- BRÜGEMANN, B. (2006): “The Joint Effect of Firing Costs on Employment and Productivity in Search and Matching Models,” mimeo.
- (2007): “Employment protection: Tough to scrap or tough to get?,” *The Economic Journal*, 117(521), F386–F415.
- BRYNJOLFSSON, E., A. MCAFEE, AND F. ZHU (2009): “Leaders and Laggards: IT and the Growth of Performance Differences Between Firms,” mimeo.
- BRYNJOLFSSON, E., A. MCAFEE, F. ZHU, AND M. SORELL (2008): “Scale Without Mass: Business Process Replication and Industry Dynamics,” *SSRN eLibrary*.
- BURDA, M. C. (1992): “A Note on Firing Costs and Severance Benefits in Equilibrium Unemployment,” *The Scandinavian Journal of Economics*, 94(3), 479–489.
- CABALLERO, R. J., AND P. D. KURLAT (2008): “Flight to Quality and Bailouts: Policy Remarks and a Literature Review,” *SSRN eLibrary*.

- DJANKOV, S., R. L. PORTA, F. LOPEZ-DE-SILANES, AND A. SHLEIFER (2002): “The Regulation Of Entry,” *The Quarterly Journal of Economics*, 117(1), 1–37.
- GARIBALDI, P. (1998): “Job flow dynamics and firing restrictions,” *European Economic Review*, 42(2), 245–275.
- GAUTIER, P. A., AND C. N. TEULINGS (2006): “How Large are Search Frictions?,” *Journal of the European Economic Association*, 4(6), 1193–1225.
- HAGEDORN, M., AND I. MANOVSKII (2008): “The Cyclical Behavior of Equilibrium Unemployment and Vacancies Revisited,” *American Economic Review*, 98(4), 1692–1706.
- HALL, R. E., AND P. R. MILGROM (2008): “The Limited Influence of Unemployment on the Wage Bargain,” *American Economic Review*, 98(4), 1653–1674.
- HASKEL, J., B. KERSLEY, AND C. MARTIN (2003): “Labour Market Flexibility and Employment Adjustment: Micro Evidence from UK Establishments,” *Oxford Economic Papers*, 49(3), 362–379.
- HOPENHAYN, H., AND R. ROGERSON (1993): “Job Turnover and Policy Evaluation: A General Equilibrium Analysis,” *Journal of Political Economy*, 101(5), 915–938.
- JORGENSEN, D. W., M. S. HO, AND K. J. STIROH (2008): “A Retrospective Look at the U.S. Productivity Growth Resurgence,” *Journal of Economic Perspectives*, 22(1), 3–24.
- LAZEAR, E. P. (1990): “Job Security Provisions and Employment,” *The Quarterly Journal of Economics*, 105(3), 699–726.
- LJUNGQVIST, L. (2002): “How Do Lay-off Costs Affect Employment?,” *The Economic Journal*, 112(482), 829–853.
- MCAFEE, A., AND E. BRYNJOLFSSON (2008): “Investing in the IT that makes a Competitive Difference,” *Harvard Business Review*.
- MICHAU, J.-B. (2009): “Optimal policy in a dynamic search model with risk aversion,” mimeo LSE.

- MORTENSEN, D. T., AND R. LENTZ (2008): “An Empirical Model of Growth Through Product Innovation,” *Econometrica*, 76(6), 1317–1373.
- MORTENSEN, D. T., AND C. A. PISSARIDES (1994): “Job Creation and Job Destruction in the Theory of Unemployment,” *Review of Economic Studies*, 61(3), 397–415.
- (1999): “Job Reallocation, Employment Fluctuations and Unemployment,” in *Handbook of Macroeconomics*, ed. by J. B. Taylor, and M. Woodford, vol. 1, chap. 18, pp. 1171–1228. Elsevier Science.
- MOSCARINI, G. (2003): “Skill and Luck in the Theory of Turnover,” mimeo.
- NICKELL, S., AND R. LAYARD (1999): “Labour market institutions and economic performance,” in *Handbook of Labor Economics*, ed. by O. Ashenfelter, and D. Card, vol. 3, chap. 46, pp. 3029–3084. Elsevier Science.
- NICOLETTI, G., S. SCARPETTA, AND O. BOYLAUD (2000): “Summary Indicators of Product Market Regulation with an Extension to Employment Protection Legislation,” Discussion paper, OECD, Economics Department.
- O’MAHONY, M., AND M. P. TIMMER (2009): “Output, Input and Productivity Measures at the Industry Level: The EU KLEMS Database,” *The Economic Journal*, 119(538), F374–F403.
- ONS (2008): “ICT impact assessment by linking data from different sources,” .
- PETRONGOLO, B., AND C. A. PISSARIDES (2001): “Looking into the Black Box: A Survey of the Matching Function,” *Journal of Economic Literature*, 39(2), 390–431.
- PISSARIDES, C. A. (2000): *Equilibrium Unemployment Theory*. MIT Press, Cambridge, MA.
- (2001): “Employment protection,” *Labour Economics*, 8(2), 131–159.
- (2009): “The Unemployment Volatility Puzzle: Is Wage Stickiness the Answer?,” *Econometrica*, 77(5), 1339–1369.
- POSCHKE, M. (2007): “Employment Protection, Firm Selection, and Growth,” *IZA DP3164*.

- POSTEL-VINAY, F., AND H. TURON (2008): “Severance Packages,” mimeo Bristol University.
- RAJAN, R. G., AND L. ZINGALES (1998): “Financial Dependence and Growth,” *American Economic Review*, 88(3), 559–86.
- REINHART, C. M., AND K. S. ROGOFF (2008): “Is the 2007 US Sub-Prime Financial Crisis So Different? An International Historical Comparison,” *American Economic Review*, 98(2), 339–344.
- SAINT-PAUL, G. (2002): “Employment protection, international specialization, and innovation,” *European Economic Review*, 46(2), 375–395.
- SAMANIEGO, R. M. (2006): “Employment protection and high-tech aversion,” *Review of Economic Dynamics*, 9(2), 224–241.
- SHIMER, R. (2005): “The Cyclical Behavior of Equilibrium Unemployment and Vacancies,” *American Economic Review*, 95(1), 25–49.
- VAN ARK, B., M. O’MAHONY, AND M. P. TIMMER (2008): “The Productivity Gap between Europe and the United States: Trends and Causes,” *Journal of Economic Perspectives*, 22(1), 25–44.

# Appendix

## A Proofs

### A.1 Characterization

In this Appendix, we give an analytical characterization of the equilibrium.

**Proposition 1** *The job destruction margin is implicitly defined by*

$$y + x_d = b + \frac{\beta}{(1-\beta)} (\theta_0 c_0 + \theta_1 c_1) - \frac{\lambda}{r + \lambda + \delta} \int_{x_d}^{x_u} [1 - F(z)] dz - (r + \delta) k, \quad (17)$$

*the job creation condition in the risky sector is given by*

$$\frac{m_1}{\theta_1} = \frac{c_1}{J_1(0)} = \frac{c_1}{(1-\beta) S_1(0)} = \frac{(r + \lambda + \delta) c_1}{-(1-\beta) (x_d + (r + \lambda + \delta) k)} \quad (18)$$

*and job creation in the safe sector follows from from (20) and (25):*

$$\frac{m_0}{\theta_0} = \frac{c_0 (r + \lambda + \delta) (r + \delta + \beta m_0)}{(1-\beta) (r + \lambda + \delta) (y - b) + \beta (1-\beta) m_1 (x_d + (r + \lambda + \delta) k)}. \quad (19)$$

#### Proof.

First substitute (8), (12) and (14) in the surplus equation (4):

$$(r + \delta) S_0 = y - b - m_0 [E_0 - U] - m_1 [E_1(0) - U]$$

Using(6) and (7) yields

$$(r + \delta + \beta m_0) S_0 = y - b - \beta m_1 S_1(0) \quad (20)$$

Next, we turn to sector 1 and derive an expression for  $S_1$

Substitute (9), (12) and (15) in the surplus equation for sector 1 given by (5)

$$\begin{aligned} r S_1(x) &= y + x - w_1(x) - \delta J_1 + \lambda (1 - \beta) \int_{x_d}^{x_u} [S_1(z) - S_1(x)] dF(z) + w_1(x) - \delta [E_1 - U] \\ &\quad + \lambda \beta \int_{x_d}^{x_u} [S_1(z) - S_1(x)] dF(z) - rU - \lambda F(x_d) (S_1(x) + k) \end{aligned}$$

Simplifying yields:

$$(r + \lambda + \delta) S_1(x) = y + x + \lambda \int_{x_d}^{x_u} S_1(z) dF(z) - rU - \lambda F(x_d)k \quad (21)$$

Use  $E_0 - U = \beta S_0$ ,  $E_1 - U = \beta S_1(0)$  and  $U = \beta S_1(x_d) = -\beta k$  to rewrite (12) as

$$rU = b + m_0 [\beta S_0] + m_1 [\beta S_1(0)]$$

Plug this in (21)

$$(r + \lambda + \delta) S_1(x) = y - b + x + \lambda \int_{x_d}^{x_u} S_1(z) dF(z) - \beta (m_0 S_0 + m_1 S_1(0)) - \lambda F(x_d)k \quad (22)$$

Integrating by parts gives

$$\int_{x_d}^{x_u} S_1(z) dF(z) = S_1(x_u) - S_1(x_d)F(x_d) - \int_{x_d}^{x_u} S_1'(z)F(z) dz$$

Using  $S_1(x_d) = -k$  from (11) and adding and subtracting  $S_1(x_d)$  yields,

$$\int_{x_d}^{x_u} S_1(z) dF(z) = \int_{x_d}^{x_u} S_1'(z) [1 - F(z)] dz - (1 - F(x_d)k),$$

plugging this back in (21) gives

$$\begin{aligned} (r + \lambda + \delta) S_1(x) &= y - b + x + \lambda \int_{x_d}^{x_u} S_1'(z) [1 - F(z)] dz - \lambda (1 - F(x_d)k) \\ &\quad - \beta (m_0 S_0 + m_1 S_1(0)) - \lambda F(x_d)k \end{aligned}$$

$$(r + \lambda + \delta) S_1(x) = y - b + x + \lambda \int_{x_d}^{x_u} S_1'(z) [1 - F(z)] dz - \beta (m_0 S_0 + m_1 S_1(0)) - \lambda k \quad (23)$$

Taking the derivative of  $S(x)$  in (21) with respect to  $x$  gives  $S_1'(x) = \frac{\sigma}{r + \lambda + \delta}$  and substituting this expression into (23) yields:

$$(r + \lambda + \delta) S_1(x) = y - b + x + \frac{\lambda}{r + \lambda + \delta} \int_{x_d}^{x_u} [1 - F(z)] dz - \beta (m_0 S_0 + m_1 S_1(0)) - \lambda k \quad (24)$$

Next, return to the free entry conditions. Equation (2) implies:

$$J_0 = \frac{\theta_0}{m_0} c_0,$$

use

$$J_0 / (1 - \beta) = \frac{c_0 \theta_0}{(1 - \beta) m_0} = S_0 \quad (25)$$

Evaluate (24) in  $x = x_d$  and substitute (11) and (25) in :

$$-(r + \delta) k = y - b + x_d + \frac{\lambda}{r + \lambda + \delta} \int_{x_d}^{x_u} [1 - F(z)] dz - \frac{\beta}{(1 - \beta)} (\theta_0 c_0 + \theta_1 c_1)$$

Some rearrangement gives the job destruction equation for sector 1:

$$y + x_d = b + \frac{\beta}{(1 - \beta)} (\theta_0 c_0 + \theta_1 c_1) - \frac{\lambda}{r + \lambda + \delta} \int_{x_d}^{x_u} [1 - F(z)] dz - (r + \delta) k$$

In order to derive the Job creation curve in sector 1, use (23) to get:

$$(S_1(x) - (S_1(x_d))) = \frac{(x - x_d)}{(r + \lambda + \delta)}$$

This implies that

$$S_1(0) = \frac{-x_d}{(r + \lambda + \delta)} + S_1(x_d) = \frac{-x_d}{(r + \lambda + \delta)} - k$$

where  $x_d < 0$ .

We can now derive the job creation condition for sector 1 from (3):

$$\frac{m_1}{\theta_1} = \frac{c_1}{J_1(0)} = \frac{c_1}{(1 - \beta) S_1(0)} = \frac{(r + \lambda + \delta) c_1}{-(1 - \beta) (\sigma x_d + (r + \lambda + \delta) k)}$$

The job creation condition for sector 0 follows from From (20), (25):

$$\frac{m_0}{\theta_0} = \frac{c_0 (r + \lambda + \delta) (r + \delta + \beta m_0)}{(1 - \beta) (r + \lambda + \delta) (y - b) + \beta (1 - \beta) m_1 (x_d + (r + \lambda + \delta) k)}$$

■

Equation (17) states that the lowest acceptable level of output for a firm is equal to the opportunity cost of employment for the worker (i.e. the participation constraint) which is equal to the value of home production,  $b$ , plus the value of search. In order for the worker to be willing to continue working, the firm must compensate this worker for the foregone value of search.  $\theta_i c_i$  are vacancy creation cost per unemployed worker in sector  $i$ , the higher this is, the higher the wage and the expected value of search will be, see Pissarides (2000)). Wages and the value of search are also increasing in  $\beta$ . The third term on the rhs of (17) is the option value of keeping the job open which is increasing in  $\lambda$ , the larger this option value, the lower the minimum acceptable level of output is. Finally, the higher the exit cost is, the lower the acceptable level of output will be. Besides the exit cost, what is new relative to Mortensen and Pissarides (1994) is that if  $\theta_0$  goes up  $x_d$  will go up and job destruction in sector 1 as well. As we will see, exit cost will increase  $\theta_0/\theta_1$ . Equations (18) and (19) tell us that labor market tightness in a sector is decreasing in worker's bargaining power and increasing in the expected match surplus in that sector.

To close the model, we use the steady state flow equations that give the Beveridge curve which allows us to calculate the equilibrium unemployment and vacancy rates. In each sector, in- and outflow must be equal.

$$m_0 u = \delta e_0 \tag{26}$$

$$m_1 u = (\delta + \lambda F(x_d)) (l - u - n - e_0). \tag{27}$$

Finally, the size of the labor force is given by

$$l = H(rU) = H\left(b + \frac{\beta}{(1-\beta)} (\theta_0 c_0 + \theta_1 c_1)\right).$$

where we eliminated  $rU$  in a similar way as in (17).

## B Appendix Tables

Country	overall EPL	reg. EPL	Firing Rules	Firing Cost	Exit Cost	Exit Loss
AUS	1.19	1.50				
AUT	1.93	2.37	2.0	0.02	0.18	0.27
BEL	2.18	1.73	0.5	0.16	0.04	0.14
CZE	1.90	3.31	1.5	0.22	0.18	0.85
DNK	1.42	1.47	0.5	0.00	0.04	0.37
ESP	3.05	2.61	1.5	0.56	0.15	0.23
FIN	2.02	2.17	2.0	0.26	0.04	0.12
FRA	3.05	2.47	2.0	0.32	0.09	0.54
GER	2.35	2.68	2.0	0.69	0.01	0.44
GRC	2.83	2.41	2.0	0.24	0.09	0.57
IRL	1.11	1.60	1.0	0.13	0.09	0.12
JPN	1.84	2.44				
HUN	1.52	1.92				
ITA	1.95	1.77	2.0	0.02	0.18	0.57
NLD	2.12	3.05	3.5	0.17	0.04	0.13
POL	1.74	2.23				
PRT	3.67	4.33	2.5	0.95	0.09	0.27
SVK	1.92	3.47				
SWE	2.24	2.86	2.0	0.26	0.09	0.19
UK	0.75	1.12	0.5	0.22	0.06	0.14
USA	0.21	0.17	0.0	0.00	0.07	0.20

**Table 13: Exit Cost Indicators**

(X excludes countries from sample)					
ALL	EUN	EU	EURO	OECD	
AUS	X	X	X		
AUT					
BEL					
CZE		X		X	
DNK			X		
ESP					
FIN					
FRA					
GER					
GRC					
HUN		X		X	
IRL					
ITA					
JPN	X	X	X		
NLD					
POL		X		X	
PRT					
SVK		X		X	
SWE					
UK			X		
USA	X	X	X		

**Table 14: Country samples used in empirical exercise**

Mnemonic	Description
	Food, Beverages and Tobacco
	Clothing
	Wood, Wood Products, Cork
	Pulp, paper, publishing
	Coke, refined petroleum and nuclear fuel
	Chemicals
	Rubber and plastics
	Other Non-metallic minerals
	Metals and Machinery
	Machinery n.e.c.
	Equipment
	Motor Vehicles and Transport Equipment
	Misc Manufacturing
	Electricity, Gas and Water Supply
	Construction
	Sale, maintenance and repair of motor vehicles
	Wholesale trade and commission trade, ex of motor vehicles
	Retail trade, except of motor vehicles and motorcycles
	Hotels and Restaurants
	Transport
	Post and Telecommunications
	Banking
	Business Services
	Personal Services

**Table 15: Industries included in empirical exercise**