The Impact of Productivity Shocks on Hiring, Separations and Tenure Distribution

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Abstract

We use a panel of Austrian social security data to study hiring and separation policies in establishments with different growth rates. We decompose the separation rates into two components: the hazard rate of separation at different tenures, and the distribution of workers across tenures. We find that in growing establishments, the hazard rate of separation for workers with longer tenures increases with the growth rate. In contracting establishments, the hazard rate of separation increases with contraction rate across all tenures, but the relative increase is higher for workers with long tenures. These patterns have not been documented before. We show that productivity shocks in a model with learning about match quality cannot explain the observed patterns because a positive (negative) productivity shock translates into lower (higher) hazard rate of separation for workers with short tenures but leaves hazard rates for workers with long tenures unaffected. We argue that a model where productivity shocks are associated with a shock to match quality might be consistent with empirical evidence.

1 Introduction

Empirical evidence shows that firms with different growth rates have different rates of hiring, quits and layoffs. Davis, Faberman, and Haltiwanger (2011) study establishment level data for the U.S. and document a non-linear "ice-hockey stick" relationship of hiring and separation rates to the establishment's growth rate in the cross-section. The hiring rate is rising more than one-to-one with the establishment growth rate for growing establishments, and it is positive and slightly increasing for contracting establishments. Separations are almost a mirror image of hiring: the share of separated workers is increasing more than one-to-one with the negative growth rate for contracting establishments, while it is positive for growing establishments. Davis, Faberman, and Haltiwanger (2011) argue that changes in this cross-sectional relationship go a long way in understanding aggregate movements in labor market flows over the business cycle. More precisely, they decompose aggregate hiring and separation rates into two components: hires and separations in establishments with different growth rates, and the distribution of establishment growth rates in the economy. They show that the distribution of establishment growth rates is very similar in recessions and expansions, and therefore most of the variation in labor market flows is accounted for by changes in the cross-sectional relationship.

Motivated by the importance of the cross-sectional relationship in explaining aggregate worker flows, we seek to understand mechanisms that give rise to the observed patterns. There are several theories that provide guidance. In Jovanovic (1979) and Moscarini (2005), learning about match quality can explain why the separation rate can be increasing in establishment's growth rate. After forming a match, a firm and a worker do not know their productivity, and only gradually learn about it by observing output realizations over time. If the match turns out to be of low quality, they separate. The model implies that the hazard rate of separation is eventually decreasing in tenure, and thus young workers face the highest risk of separation. Since firms that grow faster have a high share of young workers, the separation rate can rise with employment growth.

Faberman and Nagypal (2008) study a search model in the spirit of Mortensen and Pissarides (2000) where a firm faces idiosyncratic profitability shocks and workers can search while on the job. This model delivers the result that after a negative profitability shock, the outside option of workers improves compared to staying in a firm, and thus workers are more likely to accept an outside option and leave the firm. This implies that the separation rate increases after an adverse shock. Workers behave as "rats leaving a sinking ship" and leave the firm. If their quit rate exceeds the desired contraction rate of the firm, the firm may hire new workers even if the net employment growth is negative. This mechanism can explain why we observe positive hiring rates in shrinking establishments, and why the separation rate increases more than one-to-one with contraction rate.

Kiyotaki and Lagos (2007) develop a model that generates simultaneous hiring and separations at the establishment level. Heterogeneity in match quality, pairwise worker-firm matches, and search on the job on both worker's and firm's side are the main ingredients of the model which imply that when a firm finds a better-suited worker, it separates with an old one to hire her, thus generating hires and separations at the same time.

All these models can help us understand the observed relationship of hiring and separation rates to the employment growth rate. However, mainly due to data limitation little is known about their relative importance. Indeed, to distinguish different theories, one needs to look deeper into the structure of hires and separations in firms with different growth rates and examine whether these are in line with the implications of the models. We proceed as follows. We take the learning about match quality model as developed in Moscarini (2005) as our benchmark, derive its implications for how the hazard rate of separation at different tenures changes with establishment's growth and check whether it is consistent with patterns in the data. For this exercise, we utilize a rich dataset containing labor market histories of Austrian workers. We then identify where and why the model fails, and suggest extensions.

The main findings can be summarized as follows. We decompose the hazard rate of separation in different establishments into two components, the hazard rate of separation at different tenures, and distribution of workers across tenures. We find systematic differences in hazard rates: the hazard rate of separation for workers with longer tenures increases with establishment's growth or contraction rate. In growing establishments, the lower the establishment's growth rate, the higher the risk of separation for workers with low tenures. In contracting establishments, the hazard rate of separation increases with contraction rate across all tenures, but the relative increase is higher for workers with long tenures. Our benchmark model generates simultaneous hires and separations, but cannot explain all aspects of regularities found in the data. The model does well in explaining why the hazard rate of separation for workers with short tenures decreases (increases) when a firm grows (shrinks), but does not generate any changes in hazard rates for workers with longer tenures. This is because establishment growth affects the threshold at which matches of weak quality separate, which has an immediate impact on workers close to the threshold who turn out to be those with short tenures, but this has almost no impact on longer tenures. The model misses a mechanism through which a shock affects workers with longer tenures relatively more than those with short tenures. This is also a reason why a mechanism as in Faberman and Nagypal (2008) will not help since their profitability shock affects all workers in the same way regardless of their tenure. We argue that a productivity shock which is associated with a need to restructure the workforce in the firm can go a long way in resolving this issue.

The paper proceeds as follows. Section 2 describes data which we use for the empirical analysis. We then identify the key patterns in the data in section 3. In section 4, we develop our benchmark model of learning about quality, extend it to study firm's growth, and based on simulations we identify which aspects of the data the model fails to explain. Section 5 concludes and what mechanisms are capable of explaining the data.

2 Data

2.1 General Description

For the empirical analysis, we use a dataset constructed from Austrian social security records called Synthesis 2010. The database contains labor market histories of almost all individuals employed in Austria during the period 1972 - 2007, with the exception of tenured public employees who are included only starting from 1988 or in some cases from 1995. The data contains information on individuals' spells of employment, unemployment, retirement and maternity leave, with an exact begin and end date of each spell. Also recorded are basic demographic indicators for individuals, namely gender, nationality, year of birth and region of residence. Education data are provided by Austrian Employment Service (AMS) and only exist for individuals who went through at least one unemployment spell in their career, which is around 35% of individuals in the database.

For employed individuals, we observe the establishment identification code, together with the 4-digit European industrial classification code (NACE) and the region of residence. Each employment spell contains annual income, days worked, and imputed hours worked per week. The annual income is top and bottom coded, which in no year affects more than 1% or 10% of individuals for bottom and top coding, respectively.

There are other variables that are not directly recorded but can be calculated from the available data. Using the establishment identifier, we calculate a time series for employment, number of separated and newly hired workers for each establishment in the database. For each worker, we can calculate her tenure using the recorded begin date of employment. Tenure is left-censored for workers who started working in a firm before 1972, since in this case the date when the dataset has started (January 1, 1972) would be recorded as the begin date.

2.2 Sample Selection and Basic Definitions

We use a sample extracted from the original Synthesis 2010 database. We randomly select 25% from the universe of establishments which had more than 5 workers in at least one year during their existence. This results in about $900,000$ year-establishment observations. For each firm that has been selected we keep individual records for workers employed there. We only consider full-time workers between 16 and 65 years old, which leaves us with approximately $750,000$ individual observations per year.

The measures of establishment growth, hiring and separation rates are defined as in Davis, Haltiwanger, and Schuh (1998). We measure the growth rate (g_{et}) of an establishment e at time t as the change in number of employees between time t and $t-1$, divided by the average number of employees in periods t and $t-1$:

$$g_{et} = \frac{N_{et} - N_{e,t-1}}{0.5\left(N_{et} + N_{et-1}\right)}, \tag{1}$$

where N_{et} is the number of workers in establishment e at time t. The main advantage of this measure is that it is symmetric around zero and lies between $[-2, 2]$, with $g = 2$ corresponding to an entering establishment and $g = -2$ to an exiting establishment. The measures of hiring and separation rates are defined so that they are consistent with the definition of establishment growth. Let H_{et} and S_{et} be the number of newly hired workers and separated workers, respectively, in establishment e at time t. Then the hiring rate h_{et} and separation rate s_{et} are defined as

$$h_{et} = \frac{H_{et}}{0.5\left(N_{et} + N_{et-1}\right)}, \quad s_{et} = \frac{S_{et}}{0.5\left(N_{et} + N_{et-1}\right)}. \tag{2}$$

We choose one year as one period for measuring the growth, and we measure the stock of workers in an establishment e at time t as number of workers employed at establishment e on November 30. New hires H_{et} and separations S_{et} at time t are the cumulative number of workers who joined or left, respectively, the establishment during the year t (that is, between two measurement dates).

2.2.1 Labor Market in Austria

The data covers years $1972 - 2007$, which is a period characterized by a steady growth in employment, and low unemployment. Based on the Labor Force Survey, the unemployment rate was under 2% in 1970s, $3 - 4\%$ in 1980s and a little above 4% in 2000s. The unemployment spells in our data however correspond to unemployed who are registered in Austrian Employment Service (AMS), and unemployment rates calculated by their methodology are higher by about 2 percentage points during the covered period.

The business cycle in Austria is rather weak. During the period $1972 - 2007$ Austria did not experience a strong recession. Several periods were characterized by lower economic growth, see Figure 1, but these do not seem to have a significant impact on labor market performance. Figure 1 shows time series for the unemployment, job finding and separation rates, which we consider to be important indicators of the labor market conditions[1]. The grey regions indicate periods with negative real GDP growth rates. Two patterns stand out. First, there is a trend change in all labor market indicators in 1980s - an increase in the unemployment and job separation rates, and decline in the job finding rate. Second, these variables do not appear to have common co-movement with business cycle as measured by real GDP growth. Therefore, we will not focus on business cycle changes, and instead consider Austrian labor market to be stationary.

The comparison of Austria to other OECD countries reveals that labor turnover is relatively high within OECD countries. Table 1 summarizes the unemployment rate, and unemployment inflow and outflow rates for several OECD countries including Austria[2]. The unemployment outflow and inflow rates are the highest in continental Europe. Outflow is twice as high as outflow rates in France, Germany or Portugal, even though still much lower than in the U.S. The unemployment inflow rate in Austria is almost twice as large as in France or Portugal. This illustrates that there is quite a lot of turnover in the Austrian labor market.

In the OECD Employment Outlook (2004), Austria has an average position in the ranking of the worker protection among OECD countries, with a much higher index than the U.S. or UK but lower than Portugal, France or Germany. Despite the fact that more than 95% of the workforce in Austria is unionized, the wage setting is relatively flexible and industries and firms have room for negotiations. There are more than 400 collective agreements signed

[1] Data on real GDP growth are from the OECD website (www.oecd.org), unemployment rate from AMS (www.ams.at). Job finding and separation rates are author's calculations using Synthesis 2010 data.

[2] All data except for Austria are from Elsby, Hobijn, and Sahin (2009). The numbers for Austria are author's calculations.

each year which basically constitute a minimum wage for individual industries. The wage determined by these agreements (contractual wage) is however not binding for most workers. Based on Pollan (2005), only 10% of workers were actually paid the contractual wage in 1980s. Wagner (2009) states that after 2000, this number is probably around 20%. The wage dispersion in Austria and its comparison to other OECD countries suggests that there is sufficient wage flexibility. Based on OECD report 2004, the 90-10 percentile ratio for the gross earnings of full-time employees is 3.56 in Austria, which is one of the highest among OECD countries.

3 Patterns in Data

Empirical evidence from the U.S. shows that establishments with different growth rates have different rates of hiring, quits and layoffs, see Figure 6 in Davis, Faberman, and Haltiwanger (2011). We replicate the same figure following their methodology using Austrian data. For each establishment, we calculate its annual growth rate g_{et} using equation (1). We partition the range of possible growth rates $[-2, 2]$ into non-overlapping intervals of length 0.01 which we call bins, and sort the establishments into these bins based on their growth rate values g_{et}. For each bin, we calculate the employment-weighted average of separation and hiring rates, and plot them as a function of employment growth in Figure 2. We find the same pattern as Davis, Faberman, and Haltiwanger (2011) report for the US data.

Since the hiring and separation rate must add up to the employment growth rate, a 45-degree line is the minimum feasible hiring rate for growing establishments, and −45-degree line is the minimum separation rate for contracting establishments. Figure 2 shows an "ice-hockey stick" relationship between the establishment growth rate and hiring rate and separation rates, with a kink at the zero growth rate establishments. The hiring rate is rising more than one-to-one with the establishment growth rate for growing establishments, and it is positive and slightly growing for contracting establishments. The separations are almost a mirror image of hiring: the share of separations is increasing more than one-to-one with the negative growth rate for contracting establishments, while it is positive for growing establishments. The averages for each bin can be equivalently calculated by regressing hiring and separation rates on the full set of bin dummy variables, which is an approach that accommodates regression with establishment fixed effects. We also report the results from this regression as well. This regression mainly removes the kink at zero, but qualitatively results stay unchanged, as illustrated in Figure 3.

Several patterns, which we aim to explain in the rest of the paper, stand out. First, hires and separations occur along the entire scale of establishment growth rates implying that net employment growth is not a result of hiring or separations only, but always a combination of both. Second, for contracting establishments, the hiring rate is slightly increasing in the contraction rate. Third, for growing establishments, the separation rate is slightly decreasing in the growth rate. Finally, the magnitude of the hiring rate for contracting establishments and magnitude of the separation rate for growing establishes is quite large.

3.1 Structure of Separations

We start with the analysis of tenure structure of separations, and examine the differences between growing and shrinking establishments. To guide our analysis, we decompose the hazard rate of separation in an establishment e at time t into the hazard rate of separation for different tenures τ and the tenure distribution in an establishment. For simplicity we omit indices e, t. The separation rate s can be written as

$$s = \frac{S}{N} = \frac{\sum_{\tau=0}^{\tau_{\max}} N_\tau f_\tau}{N} = \sum_{\tau=0}^{\tau_{\max}} \frac{N_\tau}{N} f_\tau,$$

where N_τ/N is the share of workers with tenure τ, and f_τ is the hazard rate of separation of a worker with tenure τ. To examine whether $\{f_\tau\}_\tau$ and $\{E_\tau/E\}_\tau$ differ across firms with different employment growth rates, we sort establishments into several bins based on their growth, and calculate the hazard rate of separation $f_{\tau;b}$ for tenure τ, and the tenure distribution g_τ for each bin b. We choose one quarter as tenure length, and thus for consistency we calculate tenure distributions in each quarter $i = 1, 2, 3, 4$. We pool data in each bin together, obtaining tenure distributions in quarters $i = 1, 2, 3, 4$ for each bin. The hazard rate of separation at tenure τ in bin b is then the average of hazard rates $f_{i,\tau;b}$ in each quarter $i = 2, 3, 4$ in that bin b:

$$f_{\tau;b} = \frac{1}{3} \sum_{i=2}^{4} f_{i,\tau;b}, \text{ where } f_{i,\tau;b} = \frac{S_{i\tau;b}}{N_{i-1,\tau-1;b}} = \frac{N_{i\tau;b} - N_{i-1,\tau-1;b}}{N_{i-1,\tau-1;b}},$$

and $N_{i\tau;b}$ is the number of workers with tenure τ in bin b in quarter i. We sort establishments into 9 growth bins: $[-2, -0.2]$, $[-0.2, -0.1]$, $[-0.1, -0.05]$, $[-0.05, 0]$, $[0]$, $[0, 0.05]$, $[0.05, 0.1]$, $[0.1, 0.2]$, $[0.2, 2]$. The hazard rate of separation and tenure distribution for growing establishment is depicted in Figure 4. Figure 5 shows the same for contracting establishments.

We start by looking at growing establishments. As we have already learned from Figure 2, the separation rate is rather constant for growing establishments regardless of their growth rate, and thus we expect the average hazard rate of separation to be the same across different bins. Figure 4 shows that hazard rates are ordered in a particular way: the hazard rate as a function of establishment growth is increasing for short tenures (up to 5 quarters) and decreasing for longer tenures. This indicates, maybe unexpectedly, that workers with long rather than short tenures have the highest change in the risk of separation after a good firm-specific shock. The differences across growth bins are not negligible: at longer tenures, the hazard rates almost double, rising from less than 4% in non-growing firms to more than 6% in establishments growing more than 20% per year. The differences in tenure distribution across different growth bins are less surprising. Faster-growing firms have more newly hired workers, and thus a bigger share of workers with short tenures. The densities cross and switch order at about 8-10 quarters.

We now turn to the analysis of shrinking establishments. Figure 5 shows that, with the exception of non-growing firms, the hazard rate curves shift upward as the rate of employment contraction goes up. This is not so surprising, since we know that firms with higher contraction rates have a larger percentage of separations which is expected to show up in higher hazard rates. Interestingly, the curves shift almost uniformly by a constant, which means that hazard rate of separation for workers with longer tenures is two- to three-times higher in shrinking than in non-growing establishments. The tenure distributions are ordered as well: establishments with a higher contraction rate have a higher ratio of short-tenured workers.

To summarize, workers with long tenure face the lowest risk of separation in non-growing firms. Positive or negative employment growth means an increased risk for these workers.

4 Model

In the remainder of the paper we explore whether the model of learning about match quality in the style of Jovanovic (1979) can explain the observed patterns in hiring and separation policies in firms with different growth rates. We take Moscarini (2005) as a benchmark model, and extend it to a multi-worker firm setup to be able to study firm's growth. To make the analysis tractable, we consider a firm endowed with constant returns to scale technology with labor being the only input into production. Due to this structure, it is possible to express the value of a worker to the firm independently from other workers, and thus directly apply the approach from Moscarini (2005) who studies one-firm one-worker relationship. We therefore start with the model as developed in Moscarini (2005).

4.1 Basic Model (Steady State)

There is a large mass of workers and firms who form matches to produce a consumption good. Productivity of the match is unknown to both the worker and the firm, and can be either high (μ_H) or low (μ_L). A firm and a worker share common belief p_0 that the productivity of their match is high: $\Pr(\mu = \mu_H) = p_0$. The output of the match depends on the unknown parameter μ and its cumulative output at time t, X_t, is given by a Brownian motion

$$X_t = \mu t + \sigma Z_t \sim N\left(\mu t, \sigma^2 t\right).$$

Here Z_t is a Wiener process which creates noise around the true μ, and thus creates an inference problem. Over time, the firm and the worker observe realizations $\langle X_t \rangle$ and update in Bayesian fashion their belief that the match is of high quality from the prior belief p_0 to the posterior $p_t = \Pr\left[\mu = \mu_H | F_X^t\right]$. Here F_X^t is a filtration generated by $\langle X_t \rangle$ and the prior p_0 and represents information available at time t. On top of this, there is an exit shock with a Poisson arrival rate δ, independent of histories and across matches, which destroys matches.

An unemployed worker enjoys a flow value b. Both firm and worker are risk-neutral and discount future at the rate r. We assume that $b \in \left[\mu_L, p_0\mu_H + (1-p_0)\mu_L\right]$ which guarantees that a match is always formed if a firm and a worker meet, and that the match is ultimately dissolved if $\mu = \mu_L$ because $\mu_L \leq b$.

To hire a worker, the firm must post a vacancy. An unemployed worker finds a job at Poisson rate λ while a vacancy gets filled at Poisson rate $\hat{\lambda}$.

4.1.1 Learning

Conditional on the output process X, the posterior probability p_t that a match is of a high type given a prior belief p_0 is given by a diffusion process p_t solving

$$dp_t = p_t\left(1-p_t\right) s d\bar{Z}_t$$

where

$$d\bar{Z}_t = \frac{1}{\sigma}\left[dX_t - p_t\mu_H dt - \left(1-p_t\right)\mu_L dt\right].$$

The variance of the posterior belief is $2\Sigma(p)$,

$$\Sigma(p) = \frac{1}{2}s^2p^2(1-p)^2, \quad \text{where } s = \frac{\mu_H - \mu_L}{\sigma}.$$

Here $d\bar{Z}_t$ is the so-called innovation process, which is the difference between the realized flow output dX_t and the expected flow output at time t conditional on F_X^t, $(p_t\mu_H + (1-p_t)\mu_L)dt$, normalized by the standard deviation of the noise, σ. $\bar{Z}$ is a martingale under F_X^t. Learning is fast when $p_t(1-p_t)s$ is large, which happens when there is a lot of uncertainty in the belief p_t (p_t is close to 0.5), and when the process X_t is more informative, as measured by s.

4.1.2 Value Functions and Wage Setting

Let $W(p)$ be the value of an employed worker of type p, U the value of unemployment and $J(p)$ the value of a worker of type p to the firm. Let $w(p)$ be the flow wage. Then the Hamilton-Jacobi-Bellman (HJB) equations for a worker satisfy

$$rU = b + \lambda[W(p_0) - U] \quad (3)$$

$$rW(p) = w(p) + \Sigma(p)W''(p) - \delta[W(p) - U] \quad (4)$$

The opportunity costs of unemployment rU equals the flow benefit from unemployment b plus the capital gain from forming a match, which has a prior belief p_0 of being of high quality, and happens at the rate λ. The opportunity costs of being employed with a belief p equals the flow wage rate, plus benefit from learning, minus the capital loss of exogenously separating the match at the rate δ. The worker optimally chooses to separate at a belief $\underline{p}_W$ such that $W(\underline{p}_W) - U = 0$, and $W'(\underline{p}_W) = 0$ (smooth-pasting).

The HJB equation for the firm is similar:

$$rJ(p) = \bar{\mu}(p) - w(p) + \Sigma(p)J''(p) - \delta J(p), \quad (5)$$

where $\bar{\mu}(p) = \mu_H p + \mu_L(1-p)$ is the expected output flow. The value to the firm of a worker, whose posterior belief about the match quality being high is p, equals the expected net output flow, $\bar{\mu}(p) - w(p)$, plus the expected gain from learning $\Sigma(p)J''(p)$, net of expected loss from separation, $\delta J(p)$. The firm optimally fires a worker at a belief $\underline{p}_J$ such that $J(\underline{p}_J) = 0$, and $J'(\underline{p}_J) = 0$. The free entry condition implies that the value of a vacancy is zero in equilibrium, $V = 0$, which we will use from now on.

We assume that a worker and a firm bargain about the wage when the match is formed, and that the bargained wage $w(p)$ maximizes the Nash product

$$w(p) = \arg\max_w [W(p) - U]^\beta J(p)^{1-\beta},$$

where β is the bargaining power of a worker. The first-order condition implies that a worker and a firm split the joint surplus $S(p) = W(p) - U + J(p)$ in $\beta/(1-\beta)$ ratio, which can also be written as

$$\beta J(p) = (1-\beta)(W(p) - U). \tag{6}$$

Equation (6) together with an observation that $\beta J''(p) = (1-\beta)(W''(p) - U)$ leads to a solution for the wage rate,

$$w(p) = (1-\beta) b + \beta [\bar{\mu}(p) + \lambda J(p_0)]. \tag{7}$$

We derive this result in Appendix A. Moreover, equation (6) implies that a firm and a worker optimally choose to separate at the same belief $\underline{p}_J = \underline{p}_W = \underline{p}$.

We plug the wage equation (7) into the value function of the firm (5) to get an ordinary differential equation that $J(p)$ must satisfy,

$$(r+\delta) J(p) = (1-\beta)(\bar{\mu}(p) - b) - \beta\lambda J(p_0) + \Sigma(p) J''(p),$$

with boundary conditions $J(p) < \infty$, and $J(\underline{p}) = J'(\underline{p}) = 0$. The solution is of the form

$$\begin{aligned} J(p) &= c_J p^{1/2-\sqrt{\phi}} (1-p)^{1/2+\sqrt{\phi}} + \frac{(1-\beta)[\bar{\mu}(p) - b] - \beta\lambda J(p_0)}{r+\delta} \\ \phi &= 1/4 + 2(r+\delta)/s^2 \end{aligned}$$

where the constant c_J and the optimal stopping rule $\underline{p} \in (0, p_0)$ uniquely solve a system of two equations $J(\underline{p}) = 0$, $J'(\underline{p}+) = 0$.

We will refer to this environment as teh steady state.

4.1.3 Hazard Rate of Separation

The model implies that the hazard rate of separation is initially increasing and then decreasing in tenure. Even though as Moscarini (2005) argues it is not possible to derive a closed-form expression for the hazard rate at different tenures, nor it is possible to prove that the hazard rate is single peaked, in our simulations presented later this is always the case. We provide an intuitive explanation below.

Recall that all matches start with a belief p_0 and separate when the belief reaches the separation threshold $\underline{p}$. The hazard rate of separation is thus related to the probability that the belief reaches the separation threshold before discovering that the match is of the high quality for sure, i.e. reaching $p = 1$. The higher the p, the lower this probability is. But p is on average increasing in tenure because of selection — bad matches with low belief p reach the threshold and separate. These two pieces explain why on average the hazard rate of separation is (eventually) decreasing in tenure. The early phase is different, and the hazard rate of separation is increasing there. This is because a match cannot separate immediately after being formed due to continuity of the belief p_t — p_t cannot immediately jump from initial p_0 to separation threshold $\underline{p}$.

4.2 Firm's Problem Outside of the Steady State

We now want to study decisions of a firm that can employ multiple workers but has convex costs of hiring. This firm is negligible relative to the economy, and will take aggregate variables, namely the value of being unemployed (U), the job finding rate (λ) and the job filling rate ($\hat{\lambda}$), as given and fixed at their steady state levels.

In order to generate dynamics in the hiring decision of the firm, we need to extend the model to allow for productivity shocks. In particular, we consider a firm that starts in the steady state and at time 0 experiences a temporary productivity shock which makes every worker more productive. The output flow of each worker, regardless of her quality, increases by $S(t)$ at time t. The evolution of $S(t)$ is deterministic, $S(t) = S_0 e^{-\rho t}$. This productivity jump eventually phases out and thus the firm has incentives to hire more workers early on even though it has to pay higher hiring costs. The production function exhibits constant returns to scale and thus it is possible to study each worker separately. The size of the firm is then determined by convex hiring costs: a firm will hire up to the point where the marginal costs of hiring equal the value of employing a new worker.

The analysis of firm's and worker's decision is similar to the previous part. We start by writing down the HJB equation for a firm and a worker, which are analogous to the case without shocks, only that now they are time dependent. The HJB equations for the value of a worker with a prior belief p is

$$rW(p,t) = w(p,t) + \Sigma(p) W_{pp}(p,t) - \delta [W(p,t) - U] + W_t(p,t),$$

where as before $\Sigma(p) = 0.5 s^2 p^2 (1-p)^2$. The last term arises due to the fact that the value of a worker changes over time. A worker optimally decides to separate at $\underline{p}^W(t)$ such that $W(\underline{p}^W(t), t) - U = 0, W_p(\underline{p}^W(t), t) = 0$. The HJB for the firm is

$$\begin{aligned} rJ(p,t) &= \bar{\mu}(p,t) - w(p,t) + \Sigma(p) J_{pp}(p,t) - \delta J(p,t) + J_t(p,t) \\ \bar{\mu}(p,t) &= \mu_H p + \mu_L(1-p) + S(t) \end{aligned}$$

The expected flow output $\bar{\mu}(p,t)$ is now increased by $S(t)$ coming from the productivity shock. The firm optimally decides to separate at a belief $\underline{p}^J(t)$ such that $J(\underline{p}^J(t), t) = 0$ and $J_p(\underline{p}^J(t), t) = 0$.

As before, the wage is given by Nash bargaining, where the firm and the worker split the surplus. The first order condition again implies that the worker gets a share β and the firm a share $(1-\beta)$ of the surplus, or that

$$\beta J(p,t) = (1-\beta)[W(p,t) - U]. \tag{8}$$

The derivation of the wage is the same as before and thus we only state the equation for wage $w(p,t)$,

$$w(p,t) = (1-\beta)b + \beta(\bar{\mu}(p,t) + S(t)) + \beta\lambda J(p_0,t). \tag{9}$$

Equation (8) implies that the firm and the worker both optimally decide to separate at the same threshold $\underline{p}^J(t) = \underline{p}^W(t) = \underline{p}(t)$. By substituting the expression for the wage from (9) into the value function of the firm, we find a partial differential equation that $J(p,t)$ must satisfy,

$$(r+\delta)J(p,t) = (1-\beta)(\bar{\mu}(p,t) - b) + \Sigma(p) J_{pp}(p,t) - \beta\lambda J(p_0,t) + J_t(p,t), \tag{10}$$

with boundary conditions

$$J(1,t) = (1-\beta)[\frac{\mu_H - rU}{r+\delta} + \frac{S_0 e^{-\rho t}}{r+\delta+\rho}], \quad J\left(\underline{p}(t), t\right) = 0, \quad J_p\left(\underline{p}(t), t\right) = 0.$$

The boundary condition for $J(1,t)$ is derived in Appendix B. The PDE (10) does not have a closed form solution, and we therefore solve it numerically.

After experiencing a productivity shock, the surplus of a match increases. Part of this surplus gets captured by the firm, and part by the worker through an increased wage. Due to higher productivity, the firm wants to increase its employment and thus posts more vacancies until the marginal cost of posting a vacancy equals to the expected value of the match. For a worker, the value of being employed increases as well due to higher wage, and thus the threshold at which a worker is willing to separate decreases, and then over time converges back to its steady state level. As a result, the hazard rate of separation for short tenures initially decreases, and there will be a bigger mass of workers with short tenure employed at a firm. The lower hazard rate of separation and the increased posted vacancies result in positive growth of firm's employment. Over time, however, the growth rate converges back to its steady state level.

We solve the model numerically. For given productivity path $S(t)$, we find optimal separation threshold $\underline{p}(t)$ and value of a new worker $J(p_0, t)$. We then simulate the economy repeatedly and look at the hazard rate of separation at different growth rates of the firm.

4.2.1 Calibration

To proceed further, we calibrate the model. This part should be viewed as an exercise which helps us qualitatively understand the implications of the model for the hazard rate of separation at different tenures in firms with different employment growth. We do not aim at finding the best fit of the model to the data.

The choice of parameters is described in Table 2. The calibration to large extent follows Moscarini (2003), but is adjusted to capture some aspects of Austrian labor market. One period is chosen to be one month.

The discount rate is chosen so that the annual interest rate equals 5%. The exogenous separation rate of 0.0125 per month implies that on average, the exogenous shock hits once in 6.5 years. The magnitude of the productivity parameters is not important, but the ratio $(\mu_H - \mu_L)/\sigma$ determines the speed of learning. We choose the prior belief to be $p_0 = 0.5$. We set the values for high and low match quality output flow to $\mu_H = -\mu_L = 0.5$, the standard deviation to $\sigma = 7$, and the value of leisure to $b = -0.28$. These values satisfy the restriction $b \in [\mu_L, p_0\mu_H + (1 - p_0)\mu_L]$, and thus a match is always created when a firm and a worker meet. These values were chosen so that in the steady state, the share of endogenously separated workers corresponds to the share of workers who are observed to switch their status from employment to unemployment (1.7% of workers per month), and the share of workers who separate due to exogenous shock corresponds to share of workers who are observed to switch from employment to out-of-labor force (also around 1.7% of workers per month). The parameter λ is set so that the average duration of unemployment, $1/\lambda$, equals one quarter, close to what is observed in the data (it is 1.5 quarters in the data). We do not have any good data on vacancy filling rate $\hat{\lambda}$ in Austria, and set it to the inverse of job finding rate. This relationship between λ and $\hat{\lambda}$ would be implied by a constant returns to scale matching function with elasticity of 0.5. For the hiring costs, we choose $\eta = 2$ and set κ so that the number of posted vacancies is normalized to 100 in the steady state.

4.2.2 Simulations and Results

We describe the numerical procedure and simulations in more detail in Appendix B and C. Here we discuss the results.

We examine firm's response to a positive and a negative shock. Figure 6 depicts a time path of the positive productivity shock S_t, the value of a newly hired worker $J(p_0, t)$ and the separation threshold $\underline{p}(t)$. As discussed in the previous section, the value of a newly hired worker jumps up while the separation threshold jumps down upon the impact of the shock, and then they both converge back to their steady state values. This motivates firms to post extra vacancies and hire more workers. The firm grows initially but soon starts shrinking to get back to its steady state size as is depicted in the bottom panel of Figure 8.

We simulate the economy 50 times and depict the hazard rate of separation at different tenures for two values of employment growth, 0 and 3.8%, where 3.8% is the highest quarterly growth rate generated in the simulations. Figure 7 shows that the hazard rate in a faster growing firm is lower at shorter tenures and stays mostly unchanged for workers with longer tenures. This is so because the separation threshold jumps down upon arrival of the shock, which has only a limited impact on workers further away from the threshold. This is partly consistent with the data - workers with short tenures indeed face a higher risk of separation in non-growing firms (see Figure 4), but the hazard rate for workers with longer tenures is higher in faster growing firms.

We repeat the same exercise for a negative productivity shock, the time path of which is depicted in the top panel of Figure 9. The time path for the value of a new worker and the separation threshold are symmetric to the case of a positive shock. Upon impact, productivity decreases which is reflected in both a lower wage and a lower value of a worker to the firm. The value of unemployment relative to being employed increases, and thus a worker is willing to separate at a higher value of p, and the separation threshold jumps up. This again has the biggest impact on workers close to the threshold, which are short-tenured workers. Indeed, Figure 11 illustrates that in a shrinking firm, the hazard rate of separation increases for short tenures, while it stays unchanged for long tenures. This is only partly consistent with the data where we observe the entire hazard rate curve shifting up.

The shock that we have considered so far generated a rather mild response in hiring decision, and thus in employment growth, even though the magnitude of the shock is sizable. The main determinant of the number of new hires is the degree of convexity of hiring costs, which in the calibration has been chosen ad hoc because there is no observable counterpart to it. To examine a bigger response in hiring decision, we decrease η from 2 to 1.3 and again simulate the economy. We find that the initial response in hiring is significantly higher, it increases from around 9% to 14%, and thus the firm's growth rate increases from 3.5 to almost 9%. The decay of the growth rate is fast and the hiring rate quickly converges to its steady state level. We observe the same pattern for the negative shock. The comparison of the hazard rates in growing (shrinking) versus non-growing establishments is not qualitatively different - the hazard for long tenures does not change, while it decreases (increases) for short tenures, see Figure 12.

To summarize, the pure learning about match quality model does not explain all differences in hazard rate of separations between growing and shrinking establishments. In response to a positive (negative) productivity shock, the separation threshold decreases (increases), which has an immediate impact on the hazard rate of separation of workers with short tenures, but almost no impact on workers with longer tenures.

4.3 Changes in Match Quality

Empirical evidence discussed in the previous section suggests that workers with longer tenures are significantly affected by changes in the establishment's growth rate, which our benchmark model fails to capture. It is apparent that the model misses a mechanism that affects workers with long tenures relatively more than workers with short tenures.

One might argue that search on the job, or a mechanism similar to Faberman and Nagypal (2008), will resolve this issue at least in shrinking establishments. A negative productivity shock is associated with a wage drop, and thus the value of staying employed in such a firm decreases relative to the outside option of a worker. Even workers with long tenures will be more likely to accept an outside offer and separate from the current firm. We would therefore expect that, unlike in our simulation results, a hazard rate of separation in a shrinking firm will be higher along all tenure scale. While this is definitely a step in the right direction, this mechanism affects all workers regardless of their tenure in the same way, and thus will probably fail to generate larger responses for workers with long tenures as we observe in the data.

Idiosyncratic shocks associated with a shock to match quality might be able to resolve this issue. Consider a productivity shock that affects how well workers with different skills are suited for the task. Some skills that the workers used to exploit in the job before the shock might now become obsolete, and similarly, some skills that were not so important before might be now better suited for the task. This change affects everyone regardless of their tenure which is why we believe this could be a step in the right direction.

We model this mechanism in the following way. Any idiosyncratic productivity shock, whether positive or negative, that hits the firm will with some known probability change the type of the match from low to high or vice-versa. Whether the match quality has been changed or not is unobserved, but the firm and the worker will take this possibility into account when they update their belief about the match quality. After the shock hits, the belief p will be revised downward for matches that workers and firms are currently quite confident that are of high quality, i.e. those with high p. On the other hand, p will be revised upward after the shock for matches that are believed to be of low quality before the shock, i.e. those with low p. This mechanism will tend to increase the hazard rate of separation for workers with longer tenures, and tend to decrease it for short-tenured workers. We therefore believe that this mechanism can help to explain the patterns in the data that the benchmark model couldn't. This extension of the model is currently work in progress.

5 Conclusion

We use Austrian social security panel data to study hiring and separation policies in establishments with different growth rates. We start by confirming that the same relationship between worker and job flows that have already been documented for the U.S. exist also in Austria, then proceed further and decompose the separation rates in establishments with different growth rates into two main components: the hazard rate of separation at different tenures, and the distribution of workers with different tenures. We find that the hazard rate of separation for workers with long tenures is increasing in contraction rate of shrinking establishments, but is also increasing in the growth rate of growing establishments. These patterns have not been documented before.

To explain these patterns, we use a model of learning about the match quality as developed in Moscarini (2003), extend it so that it allows us to study firm's growth, and derive its implications for the hazard rate of separations at different tenures conditional on the firm's growth. We find that this is only partly consistent with the patterns in the data. We suggest that a productivity shock that is associated with a shock to match quality can be one way to generate hazard rates that are consistent with the data.

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A Deriving Expression for Wage

We derive the expression for wage, $w(p)$. Use the value functions for $rW(p)$ and rU to get $(1-\beta)r(W(p)-U)$,

$$(1-\beta)r(W(p)-U)=(1-\beta)(w(p)-b+\Sigma(p)W''(p)-\delta[W(p)-U]-\lambda[W(p_0)-U]).$$

From the value function for a firm we have

$$\beta rJ(p)=\beta(\bar{\mu}(p)-w(p)+\Sigma(p)J''(p)-\delta J(p)).$$

Subtract the two expressions,

$$\begin{aligned}0 &= (1-\beta)r(W(p)-U)-\beta rJ(p)\\ &= (1-\beta)(w(p)-b+\Sigma(p)W''(p)-\delta[W(p)-U]-\lambda[W(p_0)-U])\\ &\quad -\beta(\bar{\mu}(p)-w(p)+\Sigma(p)J''(p)-\delta J(p))\end{aligned}$$

Use that $\beta J''(p)=(1-\beta)(W''(p)-U)$ and $\beta J(p)=(1-\beta)(W(p)-U)$ to simplify the expression

$$\begin{aligned}0 &= (1-\beta)(w(p)-b-\lambda[W(p_0)-U])-\beta(\bar{\mu}(p)-w(p))\\ &= w(p)-(1-\beta)b-\lambda(1-\beta)[W(p_0)-U]-\beta\bar{\mu}(p)\end{aligned}$$

Use again that $\beta J(p_0)=(1-\beta)(W(p_0)-U)$ to substitute out $[W(p_0)-U]$,

$$0=w(p)-\beta\bar{\mu}(p)-(1-\beta)b-\lambda\beta J(p_0),$$

and express the wage

$$w(p)=(1-\beta)b+\beta[\bar{\mu}(p)+\lambda J(p_0)].$$

B Numerical Solution

We need to solve a second-order PDE (10) with boundary conditions

$$J(\underline{p}(t),t) = 0 \tag{11}$$

$$J(1,t) = (1-\beta)[\frac{\mu_H - rU}{r+\delta} + \frac{S_0 e^{-\rho t}}{r+\delta+\rho}] \tag{12}$$

which we derive below, and smooth-pasting condition $J_p(\underline{p}(t),t) = 0$.

Since $p=1$ is an absorbing state, we can easily calculate the value at $p=1$ at any time t. Start with the worker. The value of a worker at $p=1$ is the present value of discounted wages from time t onwards, adjusted for the probability of separation:

$$W(1,t) = \int_t^\infty e^{-r(s-t)} \left(e^{-\delta(s-t)} w(1,s) + \delta e^{-\delta(s-t)} U\right) ds.$$

Here $e^{-\delta s}$ is the probability that the separation shock does not hit within a time interval of length s, while $\delta e^{-\delta s}$ is the probability that the separation shock hits for the first time at time s. After some manipulation we get

$$W(1,t) = \int_t^\infty e^{-(r-\delta)(s-t)} w(1,s)\, ds + \frac{\delta}{r+\delta} U.$$

The value of a worker of type $p=1$ to a firm at time t is the present value of the net output flow:

$$J(1,t) = \int_t^\infty e^{-(r+\delta)(s-t)} \left(\mu_H + S_0 e^{-\rho s} - w(1,s)\right) ds.$$

Rearrange the terms to get

$$J(1,t) = \frac{\mu_H}{r+\delta} + \frac{S_0 e^{-\rho t}}{r+\delta+\rho} - \int_t^\infty e^{-(r+\delta)(s-t)} w(1,s)\, ds,$$

and substitute the present value of wages from the worker's value function,

$$J(1,t) = \frac{\mu_H}{r+\delta} + \frac{S_0 e^{-\rho t}}{r+\delta+\rho} - \left[W(1,t) - \frac{\delta}{r+\delta} U\right], \tag{13}$$

and use the fact that since the wage is set through Nash bargaining, the firm's and worker's values are proportional,

$$\beta J(1,t) = (1-\beta)(W(1,t) - U) \Rightarrow W(1,t) = \frac{\beta}{1-\beta} J(1,t) + U. \tag{14}$$

Finally, substituting $W(1,t)$ out from (13) using (14), we get an analytical expression for $J(1,t)$,

$$J(1,t) = (1-\beta)\left[\frac{\mu_H - rU}{r+\delta} + \frac{S_0 e^{-\rho t}}{r+\delta+\rho}\right].$$

The numerical procedure works as follows. We know that in the steady state (some large time $T^{\max}$), the value of a firm is known and equals $J^{SS}(p)$. We iterate backwards: knowing $J(p, t+\Delta t)$ for all p at time $t+\Delta t$, we can calculate value $J(p,t)$ for all p. Discretize the PDE (10),

$$\begin{aligned}
(r+\delta) J(p,t) &= (1-\beta)(\bar{\mu}(p,t) - b) + \Sigma(p) J_{pp}(p,t) - \beta\lambda J(p_0,t) + J_t(p,t) \\
(r+\delta) J(p,t) &= (1-\beta)(\bar{\mu}(p,t) - b) - \beta\lambda J(p_0,t) \\
&+ \Sigma(p)\frac{J(p+\Delta p,t) - 2J(p,t) + J(p-\Delta p,t)}{(\Delta p)^2} + \frac{J(p,t+\Delta t) - J(p,t)}{\Delta t}
\end{aligned}$$

and collect terms,

$$- \frac{\Sigma(p)}{(\Delta p)^2} J(p+\Delta p,t) + \left[(r+\delta) + 2\frac{\Sigma(p)}{(\Delta p)^2} + \frac{1}{\Delta t}\right] J(p,t) \tag{15}$$

$$-\frac{\Sigma(p)}{(\Delta p)^2} J(p-\Delta p,t) + \beta\lambda J(p_0,t) = (1-\beta)(\bar{\mu}(p,t) - b) + \frac{J(p,t+\Delta t)}{\Delta t}, \tag{16}$$

or, in matrix form,

$$AJ(\cdot,t) = (1-\beta)(\bar{\mu}(\cdot,t) - b) + \frac{J(\cdot,t+\Delta t)}{\Delta t}, \tag{17}$$

where A is an almost 3-diagonal matrix whose elements are determined from (15) and the boundary conditions (11) and (12). However, $\underline{p}(t)$ in condition (11) is unknown. We therefore guess a value of $\underline{p}(t)$, calculate $J(p,t)$ using (17), and check whether the smooth-pasting condition is satisfied. If not, we adjust our guess of $\underline{p}(t)$ and repeat the previous steps until $J'\left(\underline{p}(t), t\right) = 0$ holds.

C Simulations

We use the threshold $\underline{p}(t)$ and the value of a new worker $J(p_0, t)$ to simulate the model. That is, we start with a high number of matches which start with the belief p_0, and for which we have drawn a value of μ. We use the random number generator to 1) generate output flow ΔX_t and 2) to determine whether the match separates due to exogenous shock. If the match does not separate, we use discretized version of the diffusion process for p_t to update the belief to $p_{t+\Delta t}$,

$$\begin{aligned} p_{t+\Delta t} &= p_t + \left[p_t \left(1 - p_t\right) s \Delta \bar{Z}_t\right] \\ \Delta \bar{Z}_t &= \frac{1}{\sigma} \left[\Delta X_t - p_t \mu_H \Delta t - \left(1 - p_t\right) \mu_L \Delta t\right] \end{aligned}$$

The match separates for endogenous reasons if $p_t \leq \underline{p}(t)$. The step Δt corresponds to one day.

We throw away the first $15,000$ days of the data so that we get the steady state distribution of employed workers. Then we introduce the productivity shock and simulate the economy for 150 more quarters. For each quarter, we record the number and tenure distribution of employed workers, which we use to the calculate hazard rate of separation for workers with different tenures at different phases of the firm's lifecycle.

Tables and Figures

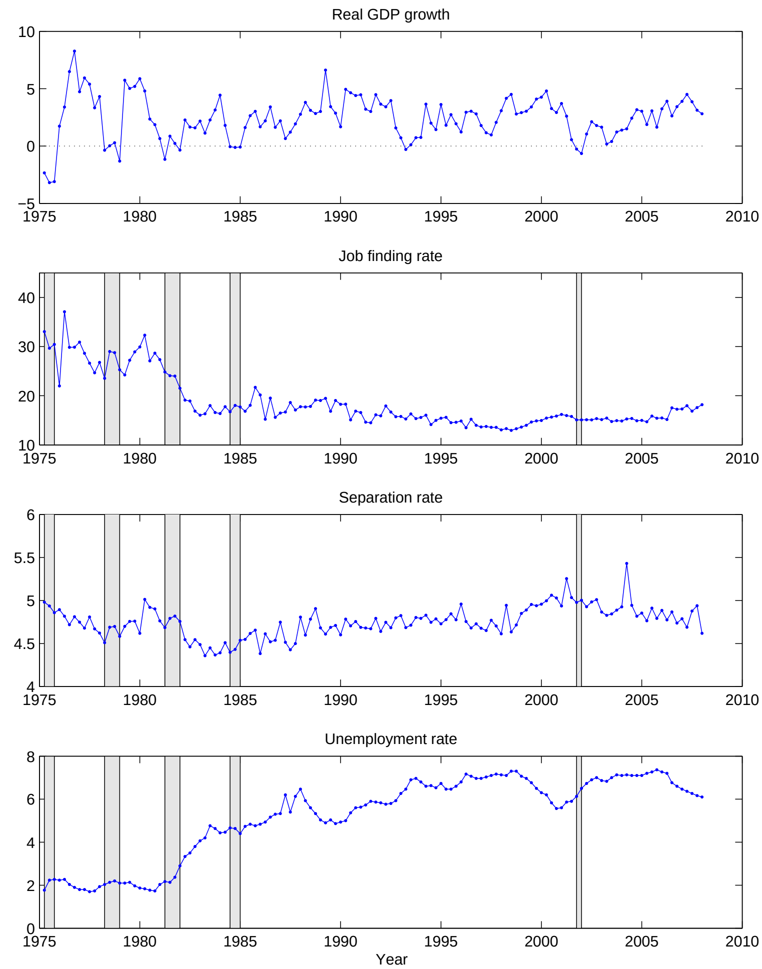

Figure 1: Labor market in Austria. Quarterly real GPD growth is from the OECD website, unemployment rate from AMS website, job finding rate and separation rate are author's calculations. Except for GDP growth, the series are quarterly averages of the seasonally adjusted monthly series. Shaded areas indicate periods with negative GDP growth.

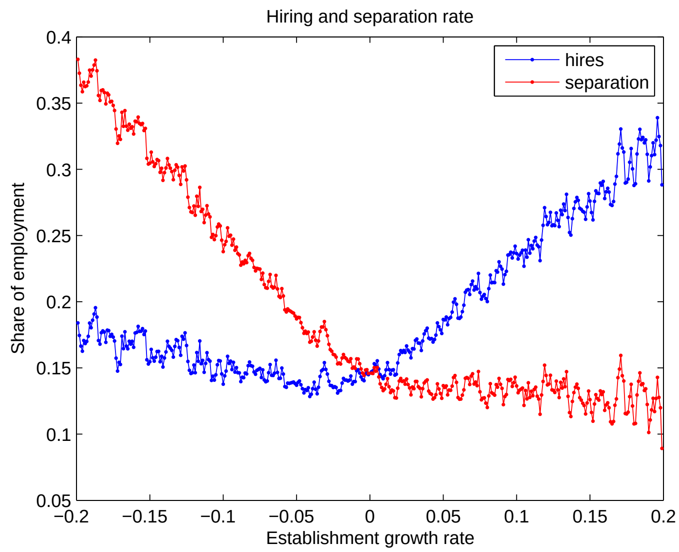

Figure 2: Worker flow rate as a function of establishment-level growth. Source: Author's calculations using a sample from Austrian social security data for period 1972-2007. Estimates are employment-weighted averages of annual establishment-level growth rates within growth bins. Estimates are smoothed by 3-bin moving averages.

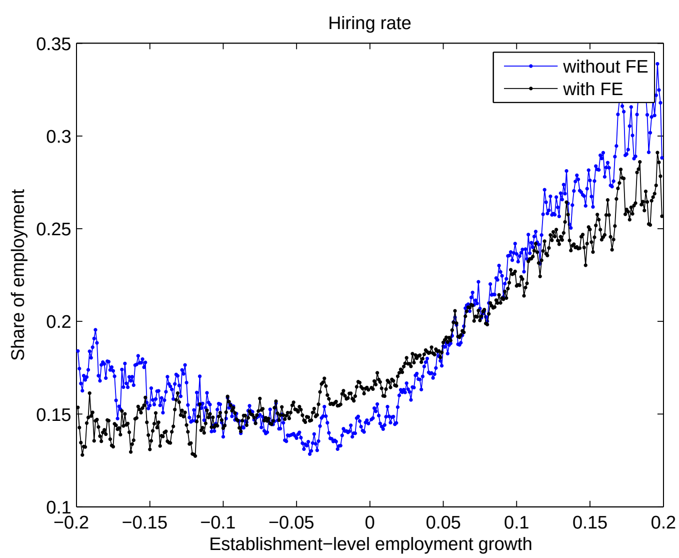

Figure 3: Worker flow rate as a function of establishment-level growth, comparison of regression with and without establishment-level fixed effects. Source: Author's calculations using a sample from Austrian social security data for period 1972-2007. Estimates are employment-weighted averages of annual establishment-level growth rates within growth bins. Estimates are smoothed by 3-bin moving averages.

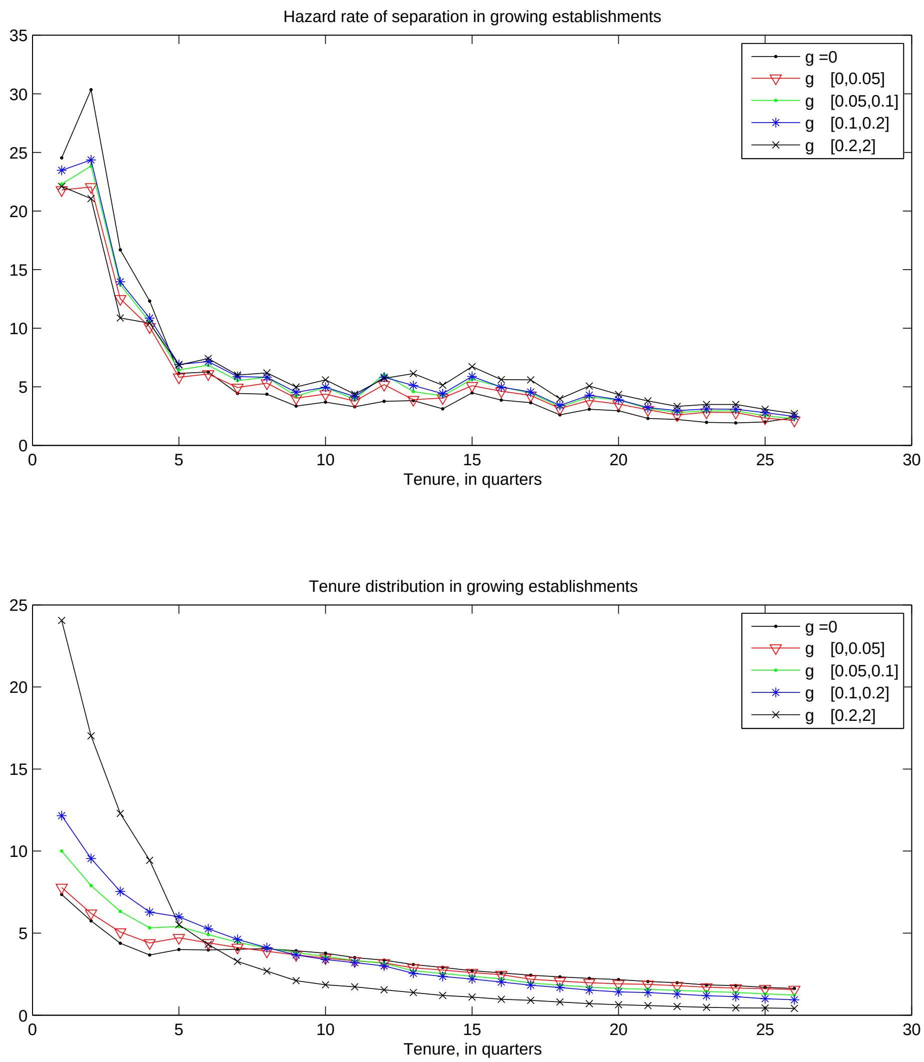

Figure 4: Decomposition of the separation rate in growing establishments. Source: Author's calculations using a sample from Austrian social security data for period 1972-2007. Top panel shows the quarterly hazard rate of separation at different tenures, measured in quarters, for establishments with different growth rates. The bottom panel depicts the distribution of workers' tenures in establishments with different growth rates.

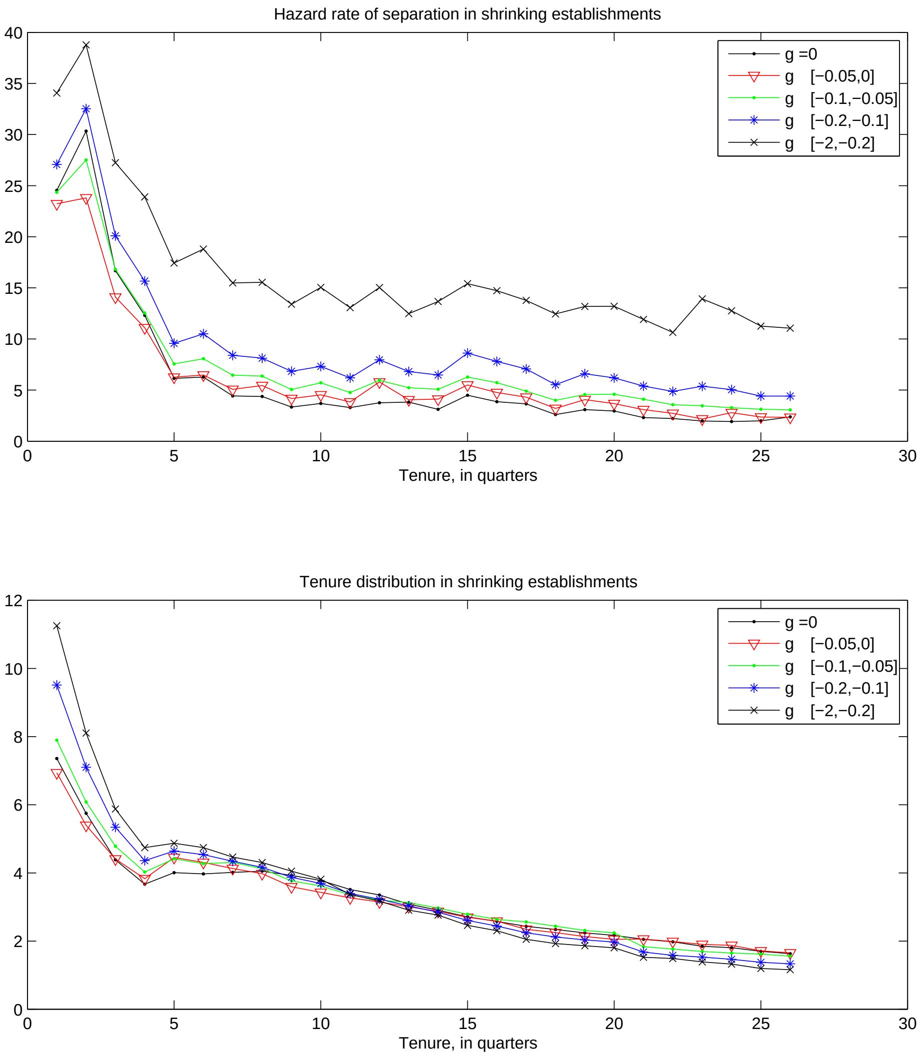

Figure 5: Decomposition of separation rate in shrinking establishments. Source: Author's calculations using a sample from Austrian social security data for period 1972-2007. Top panel shows the quarterly hazard rate of separation at different tenures, measured in quarters, for establishments with different contraction rates. The bottom panel depicts the distribution of workers' tenures in establishments with different contraction rates.

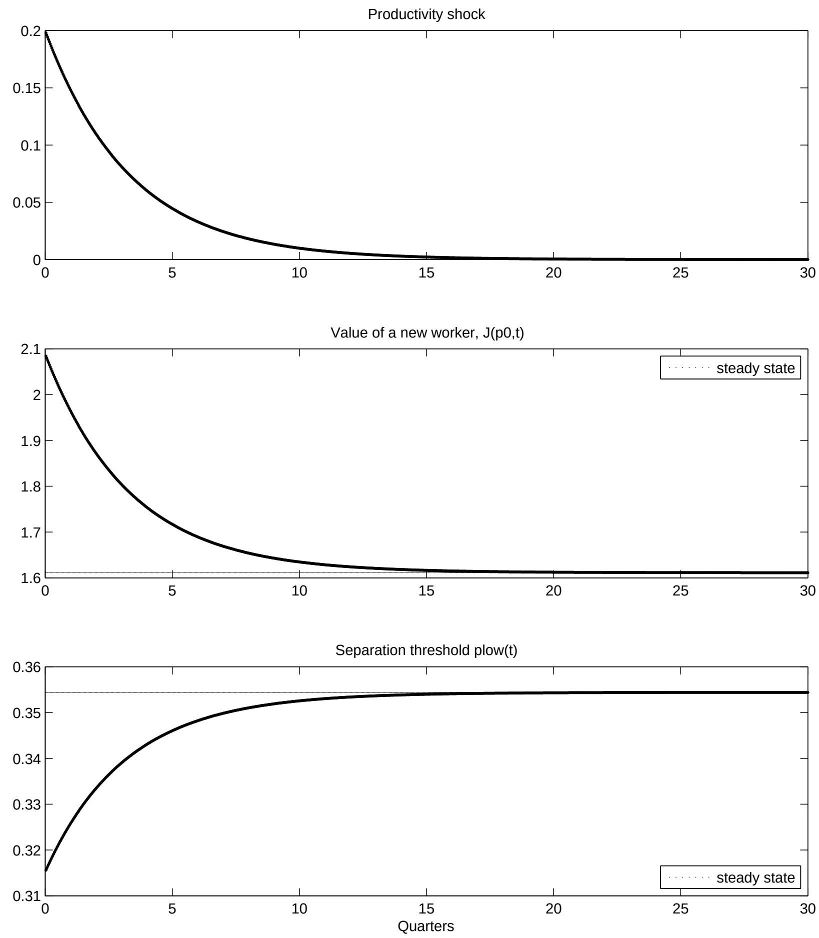

Figure 6: Time path of the productivity shock $S(t)$, separation threshold $\underline{p}(t)$ and value of a new worker $J(p_0, t)$. The figure shows time path for S_t, $J(p_0, t)$ and $\underline{p}(t)$ for a firm which starts in the steady state and experiences a positive productivity shock at time 0.

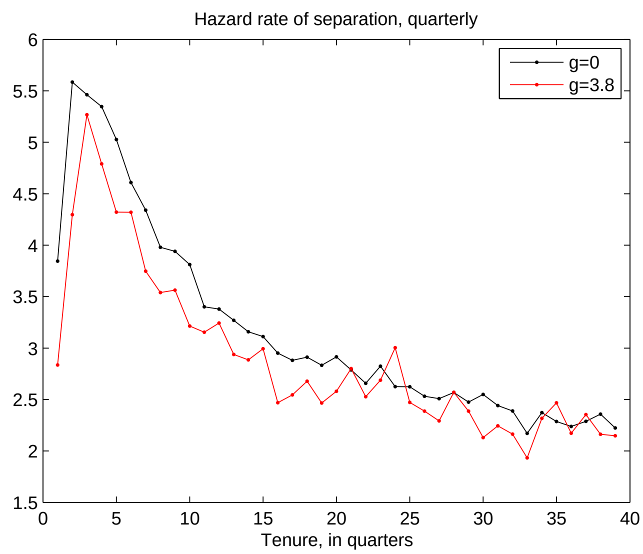

Figure 7: Simulated hazard rate, positive shock. Source: Model simulations. The figure shows the quarterly hazard rate of separation at different tenures (measured in quarters) for two values of firm's growth rate.

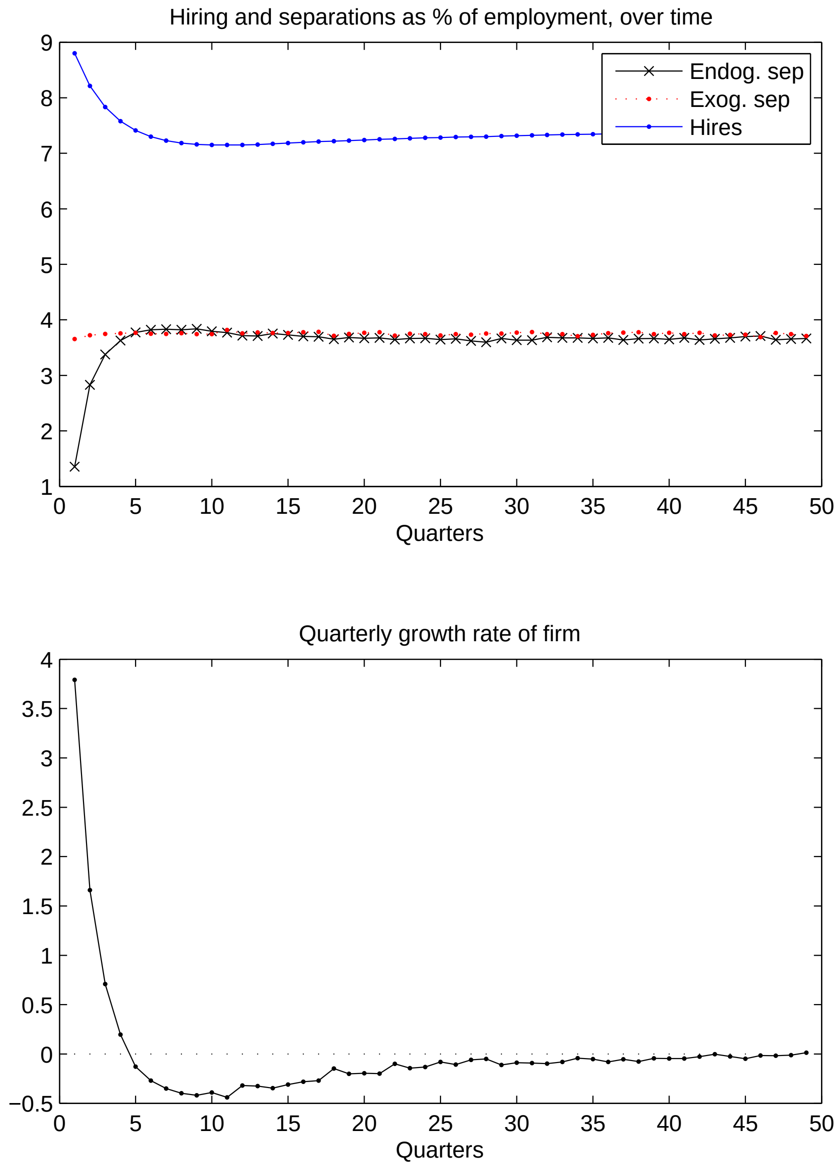

Figure 8: Decomposition of employment growth, positive shock. Source: Model simulations. The bottom panel shows the time path of the employment growth rate of the firm which starts in the steady state and gets a positive productivity shock at time 0. The top panel depicts the decomposition of the firm's growth rate into hiring, and endogenous and exogenous separation rates.

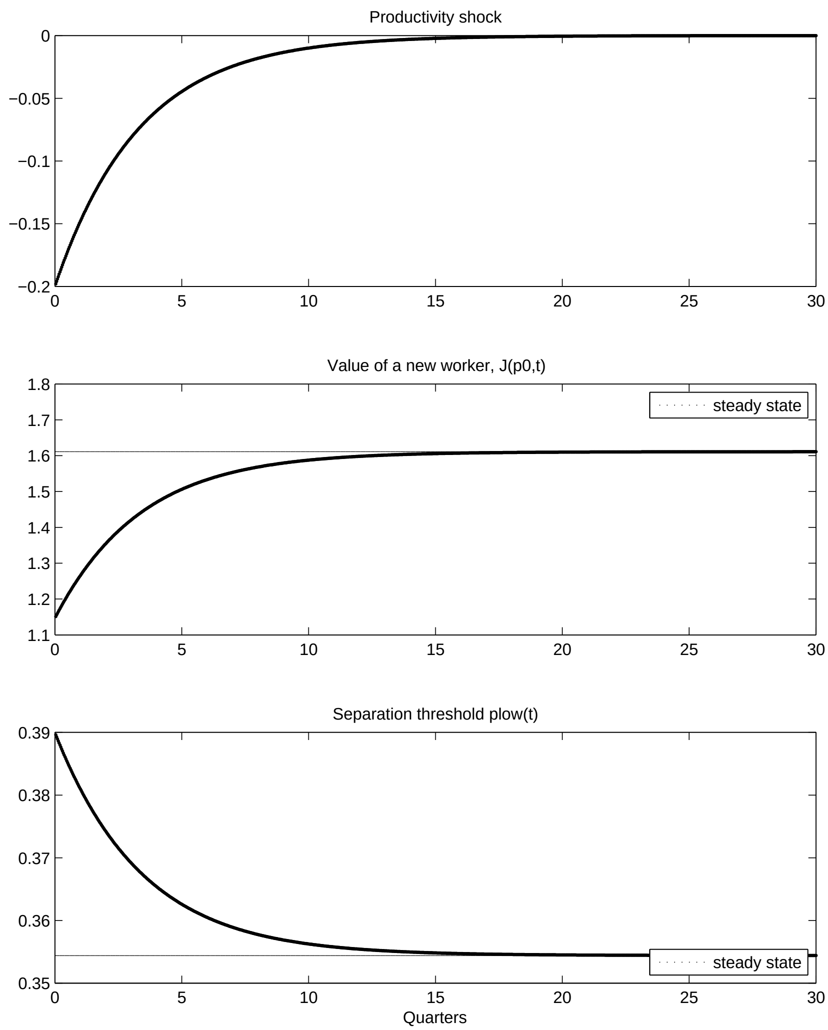

Figure 9: Time path of the productivity shock $S(t)$, separation threshold $\underline{p}(t)$ and value of a new worker $J(p_0, t)$. The figure shows time path for S_t, $J(p_0, t)$ and $\underline{p}(t)$ for a firm which starts in the steady state and experiences a negative productivity shock at time 0.

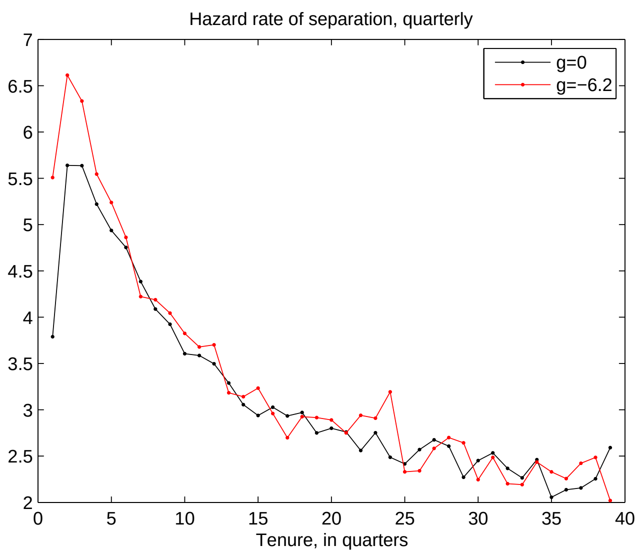

Figure 10: Simulated hazard rate, positive shock. Source: Model simulations. The figure shows the quarterly hazard rate of separation at different tenures (measured in quarters) for two values of firm's growth rate.

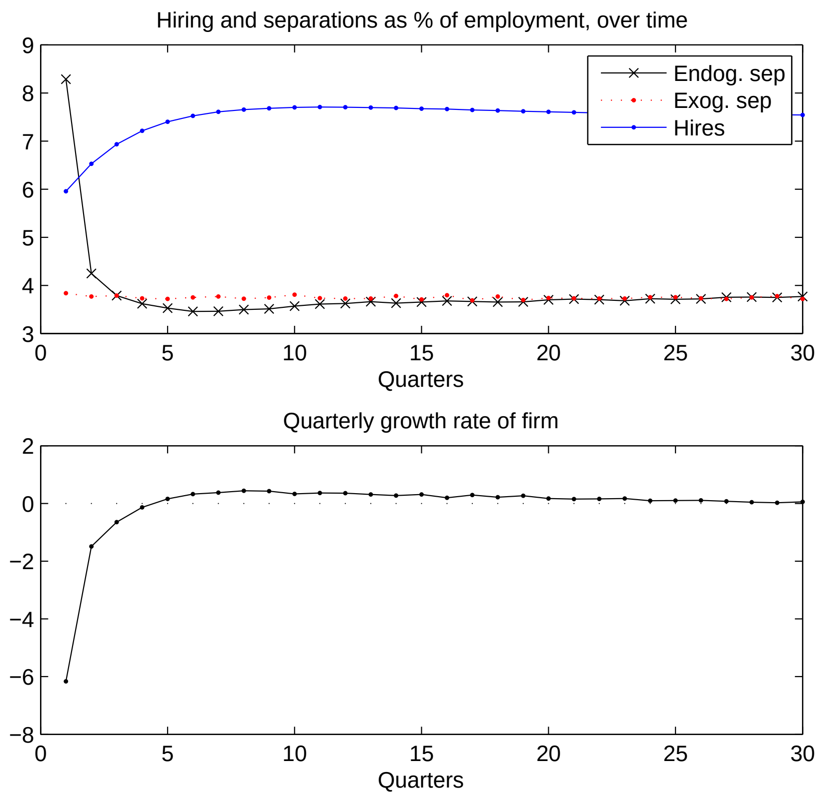

Figure 11: Decomposition of employment growth, positive shock. Source: Model simulations. The bottom panel shows the time path of the employment growth rate of the firm which starts in the steady state and gets a negative productivity shock at time 0. The top panel depicts the decomposition of the firm's growth rate into hiring, and endogenous and exogenous separation rates.

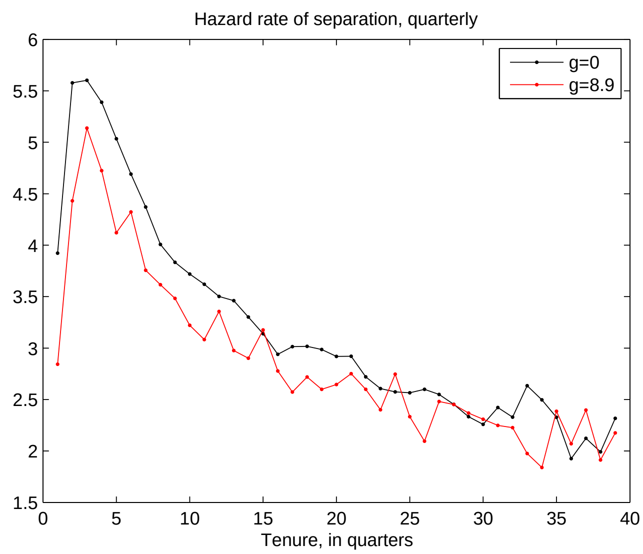

Figure 12: Simulated hazard rate, positive shock. Source: Model simulations. The figure shows the quarterly hazard rate of separation at different tenures (measured in quarters) for two values of firm's growth rate in the case of less convex hiring costs, $\eta = 1.3$.

Country	Sample start	Unemployment rate	Outflow rate	Inflow rate
Austria	1986	6.4%	15.8%	1.6%
France	1975	9.1%	7.8%	0.8%
Germany	1983	7.9%	6.0%	0.5%
Italy	1983	10.1%	4.1%	0.4%
Norway	1983	4.2%	38.3%	1.6%
Portugal	1986	6.1%	6.5%	0.4%
Spain	1977	15.3%	6.2%	1.0%
Sweden	1976	4.9%	28.9%	1.3%
United Kingdom	1983	7.7%	13.3%	1.0%
United States	1968	6.0%	57.5%	3.6%

Table 1: Cross-country comparison of selected labor market variables. The table shows comparison of unemployment rates, monthly unemployment outflow and inflow rates in the selected OECD countries. The numbers are averages of seasonally adjusted monthly series over the sample period. For all countries, the sample ends in 2007. The initial year for each country is listed in the second column. All data except for Austria are from Elsby, Hobijn, and Sahin (2009). Numbers for Austria are author's calculations.

Name	Description	Value
r	discount factor	0.004
δ	exogenous separation rate	0.0125
μ_H	low productivity	0.5
μ_L	high productivity	-0.5
σ	standard deviation of output flow	7
β	worker's bargaining power	0.4
b	value of leisure	-0.28
p_0	prior belief	0.5
$S_0e^{-\rho t}$	productivity shock	$0.2e^{-0.1t}$
λ	job finding rate	0.3
$\hat{\lambda}$	vacancy filling rate	1/0.3
η	costs of hiring	2

Table 2: Calibration. The table shows the values of parameters for the model.