The Life-cycle Profile of Worker Flows in Europe*

Jonathan Créchet† University of Ottawa

Etienne Lalé‡ Université du Québec à Montréal, CIRANO and IZA

Linas Tarasonis§ Bank of Lithuania and Vilnius University

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Abstract

Using survey micro-data for 31 European countries, we establish three results concerning cross-country differences in aggregate employment: separations from employment play a larger explanatory role than entries into employment for men, transitions from nonparticipation explain most of the variation of women's aggregate employment, and for both genders life-cycle variation in worker flows is quantitatively more important than cross-country variation in explaining these patterns. We propose a life-cycle search model with labor market institutions, a participation margin and endogenous search intensity, with all primitives independent of age, that reproduces salient features of the life-cycle profiles of worker flows across employment, unemployment, and nonparticipation observed in the data. The model shows that the effects of unemployment insurance benefits, taxes, and employment protection legislation on worker flows vary substantially over the life cycle, and quantifies their impacts on cross-country differences in aggregate employment.

Keywords: Employment, Unemployment, Labor Force Participation, Life cycle, Worker Flows, Labor Market Institutions

JEL codes: E02, E24, J21, J64, J82

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†Address: Department of Economics, University of Ottawa, 75 Av. Laurier E, Ottawa, ON K1N 6N5, Canada – Phone: +1 613-562-5753, – E-mail: jcrechet@uottawa.ca.

‡Address: Department of Economics, Université du Québec à Montréal, C.P. 8888, Succursale centre ville, Montréal (QC) H3C 3P8, Canada – Phone: +1 514 987 3000, ext. 3680 – E-mail: lale.etienne@uqam.ca.

§Address: CEFER, Bank of Lithuania, Totorių g. 4, 01121, Vilnius, Lithuania – Phone: +370 659 39906 – E-mail: ltarasonis@lb.lt.

1 Introduction

What is the role of the working life cycle, labor-market institutions, and their interactions in explaining cross-country differences in employment outcomes? Our goal in this paper is to answer this question using a mix of empirical evidence and inference from a quantitative model. First, we use micro datasets from thirty-one European countries to study the behavior of worker flows and estimate life-cycle transition probabilities across employment, unemployment, and nonparticipation. We use these transition probabilities to run several statistical decompositions, which measure the contribution of life-cycle and cross-country variations in explaining aggregate differences in employment rates. We analyze these patterns through the lens of a model featuring both search frictions and an operative labor force participation margin. The model enables us to separate out the role of technology, preferences for work, and labor market institutions in driving the life-cycle profiles of worker flows and their contribution to aggregate employment outcomes. Overall, we find that incorporating life-cycle features and modeling three distinct states (employment, unemployment, and nonparticipation) substantially improve our understanding of the functioning of the labor market.

In our empirical work, the first step is to estimate transition probabilities across employment, unemployment, and nonparticipation at every age between ages 16 and 65 for both men and women in each country covered by our data. We uncover large differences in worker mobility between European regions. In terms of labor market flows, Nordic countries appear to be the most dynamic for both genders, whereas the flows between different labor market statuses in Eastern European countries are the smallest. This extends the work of Elsby et al. [2013], who documented cross-country differences in aggregate worker flows in fourteen OECD countries.

Part of our focus is on how worker flows vary with age. We show that the life-cycle profiles are similar qualitatively for most European countries. For both genders, the probability of moving out of employment shows an increase until workers' early 20s and then a steady decrease during the rest of their working life. Transition probabilities to nonparticipation both from employment and from unemployment portray stable patterns for prime-age individuals (those aged 25 to 54), while they show a negative slope at younger ages and an increase for older workers. The probability of moving from unemployment to employment increases until workers are in their mid-20s and then decreases slowly but persistently. These findings are consistent with Choi et al. [2015], who use data from the Current Population Survey to study how worker flows shape the rates of unemployment and labor force participation in the U.S.

While most European countries display similar profiles in terms of their shape, the levels vary significantly. When focusing on France, Germany, and Italy – the 'big three' of continental Europe –, we show that large differences exist when focusing on specific periods of the life cycle. French workers are facing transition probabilities that are overall similar to European averages. However, older workers of both genders confront a significantly lower probability of moving from unemployment to employment compared to workers in other European countries. In our data, the German labor market does not appear to be very dynamic. The probability of moving to employment is low, but once employed, workers face a high probability of not moving out until towards the end of the working life. A striking difference appears when looking at the probability of gaining employment in the Italian labor market. Young Italian workers of both genders are facing a significantly lower job-finding probability than their peers in the rest of Europe. The gap closes down only when Italian workers are in their 40s. These findings suggest that focusing on the life cycle aspect of worker flows is relevant and that large cross-country differences persist despite similar transition rates in the aggregate.

To assess the importance of each worker flow in accounting for each country's aggregate labor market outcomes, we develop a decomposition method that relies on a first-order Markov chain to link worker stocks and flows. The method allows us to decompose aggregate employment differences into the following three components: demographics, i.e., the composition of workers of different ages in the population, initial conditions, i.e., the distribution of workers across different labor market states at the age of 16, and transition probabilities. The latter can be further decomposed into a contribution of each transition probability. In doing so, we establish three stylized facts.

First, we show that labor flows are key in understanding differences in male and female aggregate employment gaps across countries: transition probabilities explain 91.91% and 97.55% of total cross-country variance in male and female aggregate employment rates, respectively.

Our second stylized fact stems from the substantial cross-gender heterogeneity with respect to the role of worker flows that we find. For males, separation rates, not job-finding rates, are the main driver of cross-country differences in employment. They account for almost half of the cross-country variance in aggregate employment. This result is in contrast with the literature that documents the importance of fluctuations in job-finding probability in accounting for the fluctuations in the unemployment rate at the business cycle frequencies in the U.S. (see Shimer [2012], Fujita and Ramey [2009] among others). For female workers, the picture is very different: two-thirds of the total variance is accounted for by the job-finding rate out of non-participation, and it remains the most important flow for all age groups.

Finally, we decompose the variation of employment rates and of each transition probability into a within-component (measuring the role of age within each country) and a between-component (measuring the role of cross-country differences). We show that the life cycle plays a major role: it explains around 90 percent of the variance of employment rates and over 50 percent of the variance of transition probabilities (for both genders).

We set up a general equilibrium search model usable for counterfactual analysis to further investigate the determinants of life-cycle worker flows across countries. This model has a finite retirement horizon, endogenous search intensity and labor-force participation margins, and idiosyncratic shocks to utility and productivity. Crucially, we impose all the model primitives (preferences, technology, and the distribution of shocks) to be independent of age, allowing us to uncover fundamental (rather than proximate) sources of worker-flow variations and to conduct counterfactual policy analysis. We calibrate this model to the aggregate labor-market flows across employment, unemployment, and nonparticipation, and to employment rates by age. We do so for men and women in the four largest E.U. countries (France, Germany, Italy, Spain) and the U.K.

The calibrated model captures well the salient features of the *untargeted* life-cycle profiles for the *twelve* transition rates (six for each gender) in the *five* targeted countries. In particular, the model predicts a declining shape for transitions out of nonparticipation (into both unemployment and employment) and an increasing shape for transitions out of the labor force (from both unemployment and employment) as observed in our data by country and gender—in addition to predicting plausible flows in and out of employment and unemployment. The combined role of endogenous search intensity with an exogenous finite retirement horizon and utility shocks is key in shaping the life-cycle transitions in and out of nonparticipation; the closer is retirement, the weaker the incentives to participate in market activities, as shown by Chéron, Hairault, and Langot [2013] studying individuals' transitions out of unemployment—a mechanism that we generalize to a stock-flow setup with a distinction between unemployment and nonparticipation.

So far, most of the literature on labor market flows has focused on the business cycle.[1] Ward-Warmedinger and Macchiarelli [2014] provides evidence that worker flows vary significantly by age but their analysis is limited to large age groups and they do not investigate the consequences of it. Our paper is the first to provide a comprehensive picture of labor market flows over the life cycle in European labor markets.

We think of labor force participation as being driven by idiosyncratic shocks to leisure utility, for example, as in Garibaldi and Wasmer [2005] and Lalé [2018]. The model features search frictions since we are ultimately interested in the determinants of employment. Finally, we model the two types of labor market institutions that are most often scrutinized when looking at differences in labor market performances, namely unemployment benefit (UI insurance) and employment protection legislation (EPL).

We use this model to quantify how much of the life-cycle variation of flows is coming from preferences, technology, and most notably from labor market institutions, which are age-independent but whose effects on worker flows vary substantially over the life cycle.

The remainder of the paper is organized as follows. Section 2 introduces the data, describes the measurement framework briefly and presents our main empirical findings. A full description of the measurement framework is provided in the appendix. Section 3 presents our theoretical model. The calibration is carried out in Section 4, and the quantitative results based on the calibrated model are discussed in Section 5. Section 6 concludes.

2 Data, measurement and empirical findings

This section introduces our data and measurement framework. We briefly describe the framework here and defer a longer description to Appendix. This section then presents our main empirical findings.

2.1 Data sources

We use micro-data from the Statistics on Income and Living Conditions (EU-SILC) collected by Eurostat. The EU-SILC is an unbalanced panel survey that collects comparable multidimen-

[1] See Petrongolo and Pissarides [2008], Gomes [2012], Fujita and Ramey [2009], Ward-Warmedinger and Macchiarelli [2014].

sional annual micro-data on a few thousand households per country. The dataset is particularly well suited for our study as it contains the monthly labor force status (employment, unemployment, nonparticipation) of workers living in the following countries: Austria, Belgium, Bulgaria, Croatia, the Czech republic, Cyprus, Denmark, Estonia, Finland, France, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. Information about monthly labor force statuses are collected via a retrospective calendar.[2] The EU-SILC starts in 2004 and our sample covers the period 2004-2016. Sample size varies depending on the country and ranges from 2,250 households in Malta to 5,750 households in the U.K. We end up with a total of 4,167,231 individual-year observations corresponding to 1,392,329 individuals in our final sample. The EU-SILC does not have longitudinal data for Germany and Switzerland. We add micro data for Germany by using recent waves of the German Socio-Economic Panel (GSOEP) and data for Switzerland using the Swiss Household Panel (SHP).

2.2 Measurement framework

Our goal is to measure transition probabilities across three labor force statuses: employment (E), unemployment (U) and nonparticipation (N). Our measurement approach proceeds in several consecutive steps.

Measurement error. Measurement error is a potentially important concern, especially for flows between unemployment and nonparticipation. To address this issue, we develop an approach in the spirit of Elsby et al. [2015] de-NUN-ification procedure. We treat our data as being quarterly instead of monthly. Suppose for instance that we look at data from January (month 1) to June (month 6) for individual i. We define i's labor force status during the first quarter as her labor force status in February (month 2). Likewise, her status in the second quarter is taken to be that in May (month 5). If we observe the sequence NUN within the first (second) quarter, then we recode i's labor status in month 2 (5) as being N. We treat the sequence UNU in the same fashion, by recoding i's labor status in month 2 (or 5, if looking at the second quarter) into U. Our procedure to deal with measurement error leaves the stocks and flows roughly unchanged in levels, and it increases the precision of our estimates.

The other concern related to measurement error is "recall bias", as our data come from retrospective calendars contained in the EU-SILC. Approaches that have been proposed in the literature to address recall bias often rely on sophisticated statistical models of measurement errors, such as latent-variable models of the "true" labor force status of individuals. Using this type of models to check whether our data suffers from recall bias is very costly and somewhat beyond the scope of our study. What we can do, instead, is compare our estimates based on the EU-SILC with estimates obtained from other data sources that do not rely on retrospective calendar. We do so using the national labor force survey data of France and the United Kingdom. In Appendix XX, we show that the two data sources deliver estimates that are

[2] There is evidence of what is called "recall bias" in retrospective calendars of some labor force surveys. We discuss this issue further below (see Subsection 2.2).

virtually the same. This suggests that the retrospective calendar of the EU-SILC does not suffer from large recall biases.

Measuring transition probabilities. To calculate stocks and flows for each country, we proceed as follows. Letting $s_{i,a,t}$ denote the indicator function that takes the value of 1 if individual i's labor force status is $s \in \{E, U, N\}$ in period t, when i's age is a, and denoting by w_i the relevant (cross-sectional) survey weight of individual i, we calculate

$$S_{a,t} = \sum_i w_i s_{i,a,t}. \tag{1}$$

$S_{a,t}$ is the stock (or count) of individuals of age a in period t whose labor force status is s. Likewise, we construct $F_{a,t}^{ss'}$, worker flows from labor force status s to status s' at age a in period t, based on age-specific individual indicator function $f_{i,a,t}^{ss'}$ that takes the value of 1 if individual i's labor force status is $s \in \{E, U, N\}$ in period t and $s' \in \{E, U, N\}$, $s \neq s'$, in period $t+1$, and using the relevant (longitudinal) survey weights.[3] Further, in order to increase the precision of our calculations, we use three-year bins centered on each age a and period t. For instance, to calculate $S_{30,t}$, we pool data on individuals aged 29, 30 and 31 in period t. We proceed in the same fashion with respect to t, i.e. we pool data from $t-1$, t and $t+1$ to compute the period-t stocks and flows statistics. Last, by taking the ratio between flows and stocks data, we obtain estimates of quarterly transition probabilities across employment, unemployment and nonparticipation, $P_{a,t}^{ss'} = \frac{F_{a,t}^{ss'}}{S_{a,t}}$.

Life-cycle profiles. Next, we extract the life-cycle profile of transition probabilities, meaning we remove the time effects (business cycle fluctuations, etc.) contained in the $P_{a,t}^{ss'}$'s. To this end, we use a non-parametric approach. We run the following regressions:

$$P_{a,t}^{ss'} = p_a^{ss'} \mathbf{D_a} + \psi_t \mathbf{D_t} + \varepsilon_{a,t}, \tag{2}$$

for each $P_{a,t}^{ss'}$, where $\mathbf{D_a}$ ($\mathbf{D_t}$) is a full set of age (time) dummies and $\varepsilon_{a,t}$ is the residual of the regression. Then, the life-cycle profile of the transition probability from labor force status s to status s' refers to the coefficients $p_a^{ss'}$ on the age dummies, which we normalize using the (arithmetic) mean of the coefficients on the time dummies, the ψ_t's.

Time aggregation. We clear the life-cycle transition probabilities from time aggregation bias using the continuous-time adjustment procedure developed by Shimer [2012]. For each country, we then store the time-aggregation adjusted, age-a quarterly transition probabilities

[3] In the EU-SILC, we do not have longitudinal weights tailored to our empirical exercise. Therefore we take the average of an individual's cross-sectional weights to construct longitudinal weights. The other datasets we use provide longitudinal in addition to cross-sectional weights. In particular, for France and the United Kingdom, we compare the flows based on the longitudinal weights that we construct with those based on weights provided in the micro data of the French and U.K. labor force surveys. We find no significant differences.

in a matrix denoted as Γ_a:

$$\Gamma_a = \begin{bmatrix} p_a^{EE} & p_a^{EU} & p_a^{EN} \\ p_a^{UE} & p_a^{UU} & p_a^{UN} \\ p_a^{NE} & p_a^{NU} & p_a^{NN} \end{bmatrix}. \tag{3}$$

Initial conditions. While transition probabilities are our main object of interest, we are ultimately interested in recovering statistics such as labor force participation and/or employment rates. The collection of matrices $(\Gamma_a)_{a=16}^{65}$ are necessary but not sufficient for this purpose: we need what we call 'initial conditions', that is to say a distribution of workers across E, U, N at age $a = 16$. Denoting such a distribution as $\begin{bmatrix} E & U & N \end{bmatrix}_{16}'$, stocks for workers in any higher age group, $a > 16$, can be calculated using:

$$\begin{bmatrix} E \\ U \\ N \end{bmatrix}_a = \prod_{\tau=16}^{a-1} \left(\Gamma_\tau'\right)^4 \begin{bmatrix} E \\ U \\ N \end{bmatrix}_{16}. \tag{4}$$

Thus, for each country we retrieve initial conditions by searching the vector $\begin{bmatrix} E & U & N \end{bmatrix}_{16}'$ that maximizes the fit between the employment rates implied by Equation (4) and the actual life-cycle employment rates.[4,5] As will be shown in the next section, we obtain a very good fit in all instances, allowing us to put the focus on transition probabilities.

2.3 Empirical findings

To set the stage for our empirical investigation, we display data derived from our empirical set-up for France, Germany, and Italy – the 'big three' of continental Europe. We start with the life-cycle employment rates, both the Markov-implied (i.e., implied by the initial conditions and transition probabilities based on Equation (4)) and actual rates.[6] They are displayed in Figure 1. The Markov chain model does very well in capturing the patterns of the actual employment rates, including the hump in female employment around ages 25-40 in France and Germany. This holds true for all countries in our sample: in fact, the R-squared of the regression of the dotted line against the solid line is always above 95 percent.

Next, Figure 2a, 2b and 2c portray life-cycle transition profiles of male and female workers in France, Germany, and Italy. Loosely speaking, transition probabilities display substantial variations over the working life of individuals. Separation rates, as measured by EU and EN transitions, are high when workers are in their 20s. Then they tend to fall rapidly, but with transitions from E to N that jump up again towards the end of the working life, when workers move into retirement. The effect of retirement is also discernible in transitions from U to N: they are relatively flat throughout the working life and increase substantially after age 55. The

[4]We use the simplex Nelder-Mead algorithm to find the vector of initial conditions.

[5]Results are very similar if we compute $\begin{bmatrix} E & U & N \end{bmatrix}_{16}'$ by targeting the fit between the Markov-implied and the actual life-cycle labor force participation rates.

[6]To calculate the actual employment rates, we extracted the life-cycle profile of stocks (the $S_{a,t}$'s defined in Equation (1)) using regression (2). We also use the life-cycle profile of stocks to calculate the weight of workers in age group a in the overall population of working age, denoted as W_a below.

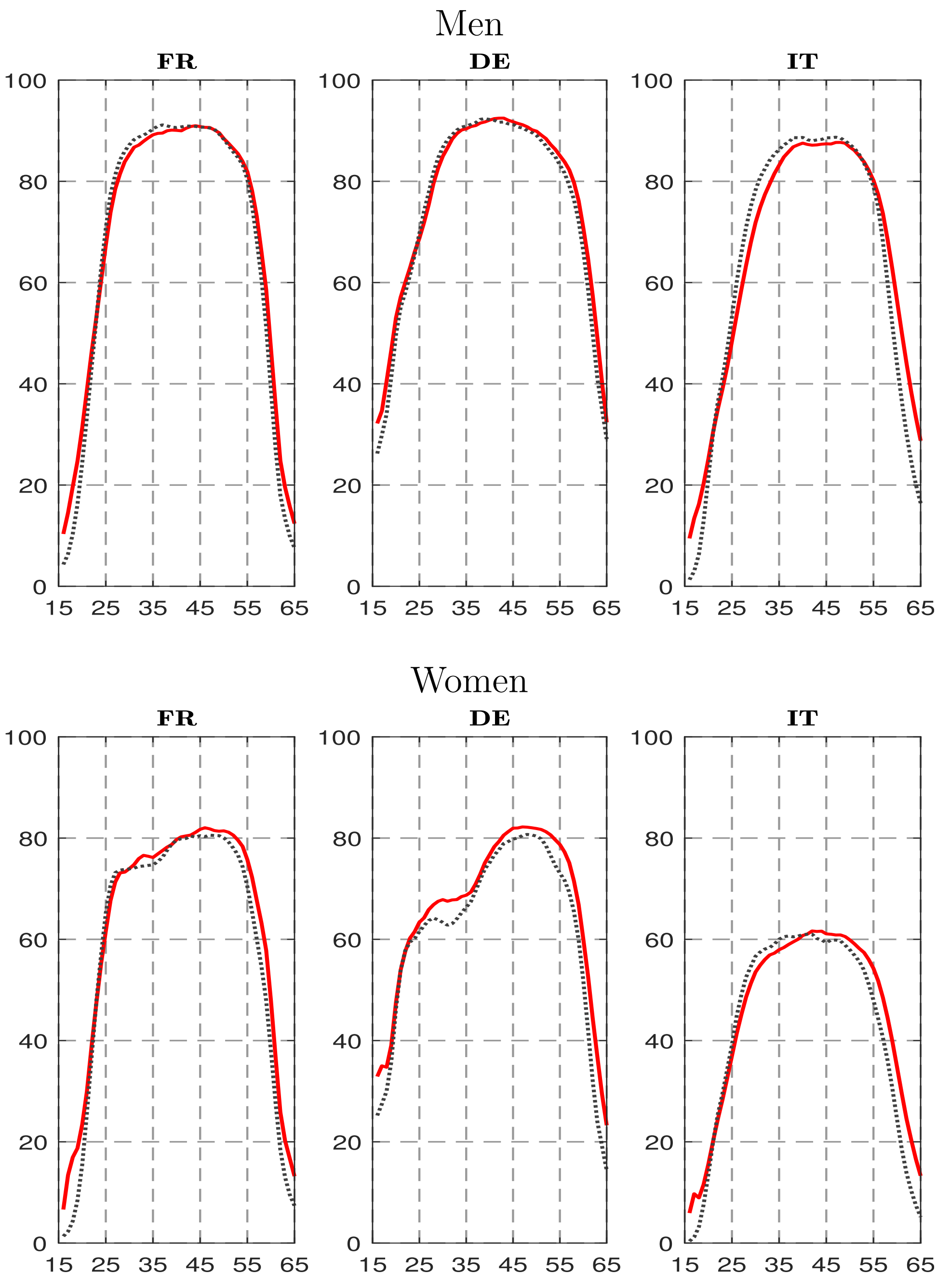

Figure 1: Markov-implied vs. actual employment rates: Men (top) and women (bottom)

NOTE: The plots show the employment rates in France, Germany and Italy. The solid lines are the Markov-implied and the dotted lines are the actual employment rates.

shape of the job-finding rates underlying UE and NE transitions is also worthy of attention. Like separation rates, job-finding rates are higher among younger individuals. But they are also more persistent, as they remain much higher than zero until workers get into their 50s. Last, transitions from N to U reflect the fact that prime-age workers tend to search for jobs more often from within unemployment rather than nonparticipation. These qualitative patterns are also present in the transition probabilities of the other countries of our sample. Quantitatively, there are substantial differences across countries. We quantify the impact of these differences below.

We now move on to our main empirical findings. They follow naturally from using the data to decompose cross-country differences in aggregate employment. Denote by E^c the aggregate employment rate of country c, and let E^r refer to some reference employment rate (say, the average of employment rates across the thirty-one countries in our sample). The employment rate of country c is given by

$$E^c = \sum_a W_a^c E_a^c, \tag{5}$$

where W_a^c is the population weight of workers at age a and E_a^c denotes the employment rate of these workers. In the sequel, E_a^c is what we call the age, or life-cycle, profile of employment in country c.

Finding no. 1: Transition probabilities are the main driver of cross-country differences in employment. Consider comparing E^c and E^r by relating them to the life-cycle profile of employment E_a^c and E_a^r. Further, consider using r's initial conditions (instead of country c's initial conditions) together with country c's transition probabilities to calculate a counter-factual employment profile, denoted as $\widetilde{E_a^c}$. This profile interests us because it puts the focus on the role of transition probabilities in country c. We have:

$$E_a^c - E_a^r = E_a^c - \widetilde{E_a^c} + \widetilde{E_a^c} - E_a^r, \tag{6}$$

which we can relate to aggregate employment differences based on:

$$E^c - E^r = \underbrace{\sum_a \left(W_a^c - W_a^r\right) E_a^c}_{\text{demographics}} + \underbrace{\sum_a \left(E_a^c - \widetilde{E_a^c}\right) W_a^r}_{\text{initial conditions}} + \underbrace{\sum_a \left(\widetilde{E_a^c} - E_a^r\right) W_a^r}_{\text{transition probabilities}}. \tag{7}$$

In this equation, the first term measures the role of demographics in explaining employment differences between c and r. The second term measures the role of initial conditions *per se*, as this is the only difference between the two age profiles E_a^c and $\widetilde{E_a^c}$. In the third term, initial conditions are the same (that is, individuals at age 16 start from r's initial conditions) and differences are fully explained by the transition probabilities of country c relative to r.

Table 1 shows the results of using equation (7) to run a variance decomposition. The message of this table is straightforward: differences in aggregate employment are mostly explained by differences in transition probabilities. For men, transition probabilities account for 92 percent of the dispersion of aggregate employment rates, while for women the variance contribution is

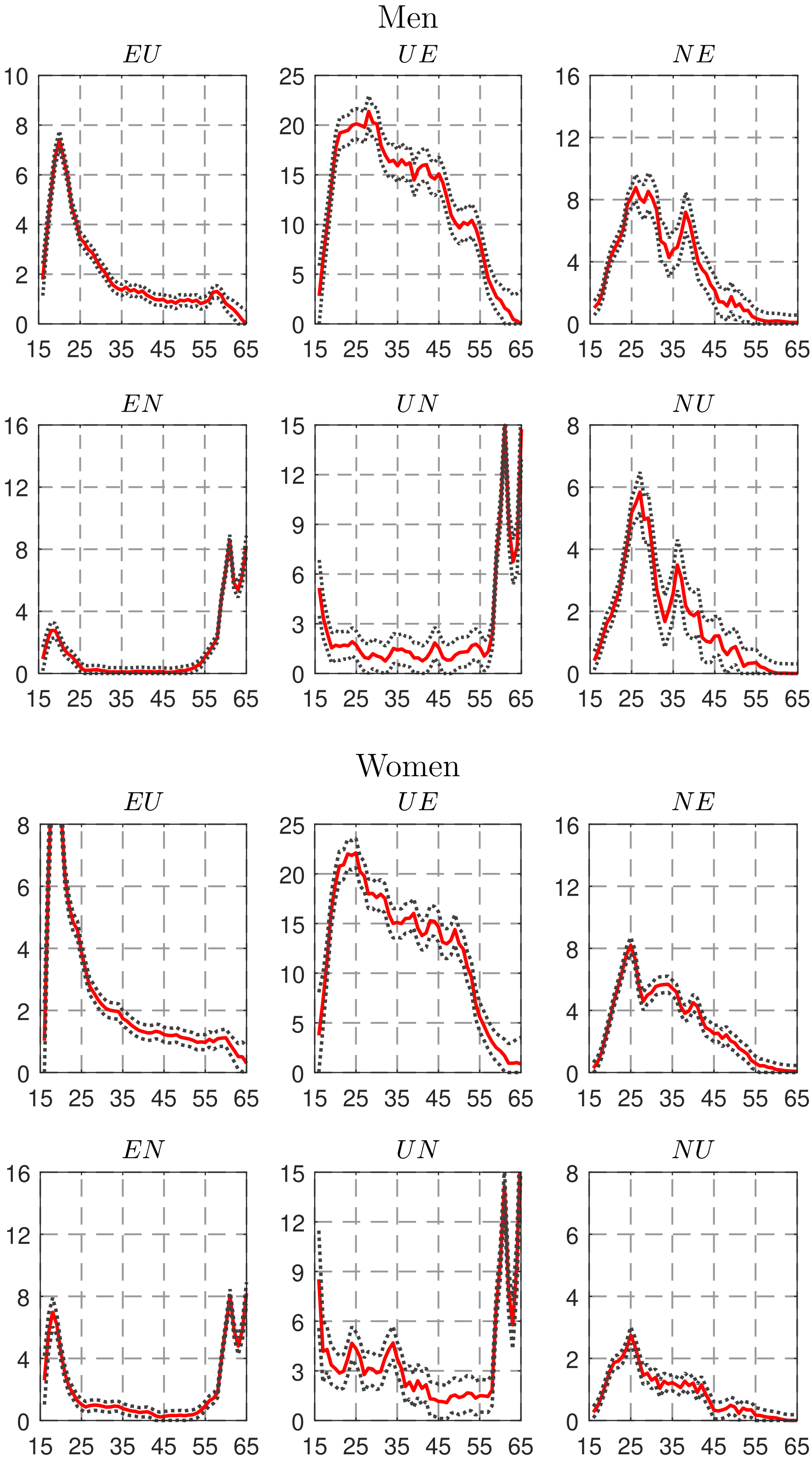

Figure 2a: Transition probabilities in France: Men (top) and women (bottom)

NOTE: The plots show quarterly transition probabilities expressed in percentage points. The dotted lines are 95 percent confidence intervals.

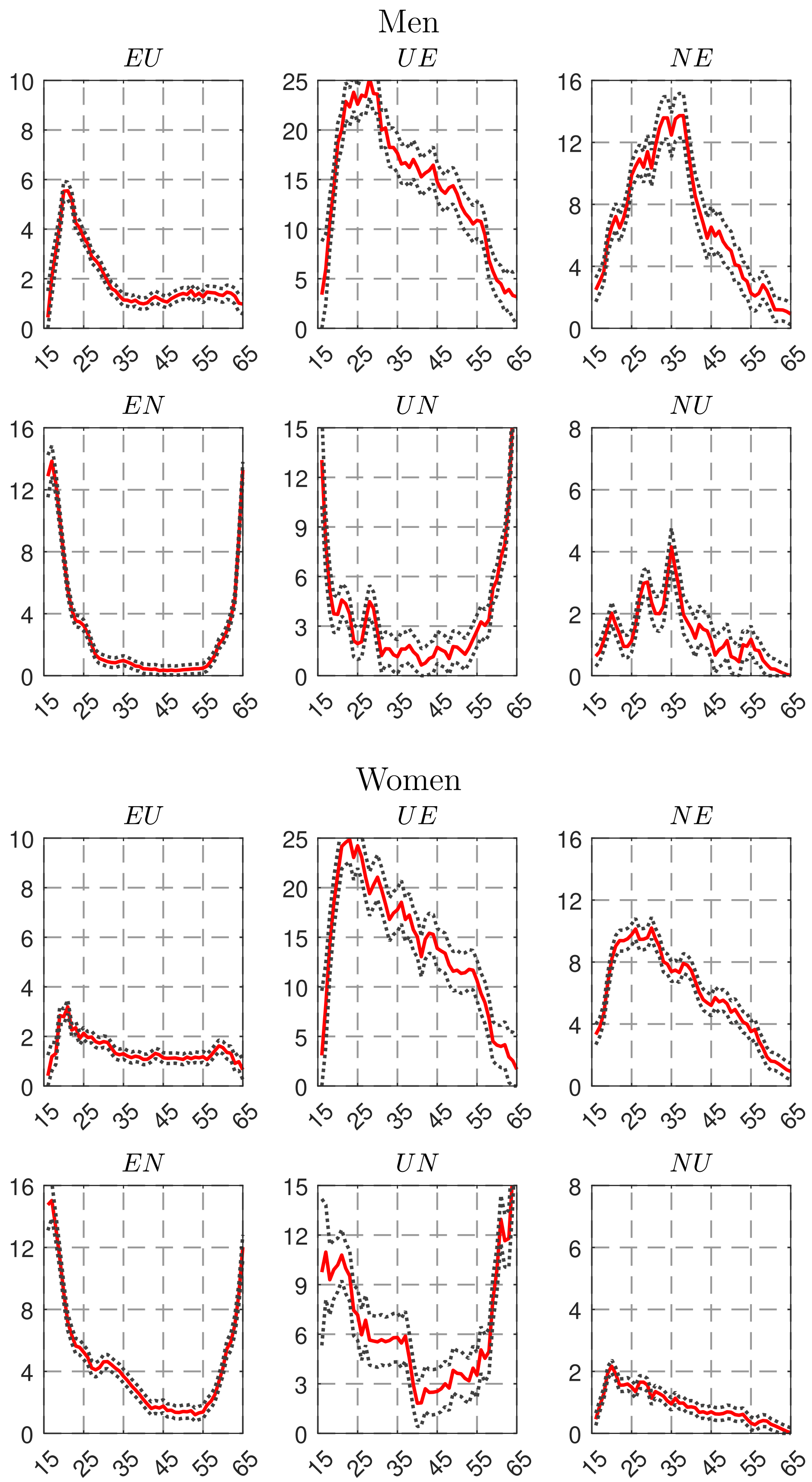

Figure 2b: Transition probabilities in Germany: Men (top) and women (bottom)

NOTE: The plots show quarterly transition probabilities expressed in percentage points. The dotted lines are 95 percent confidence intervals.

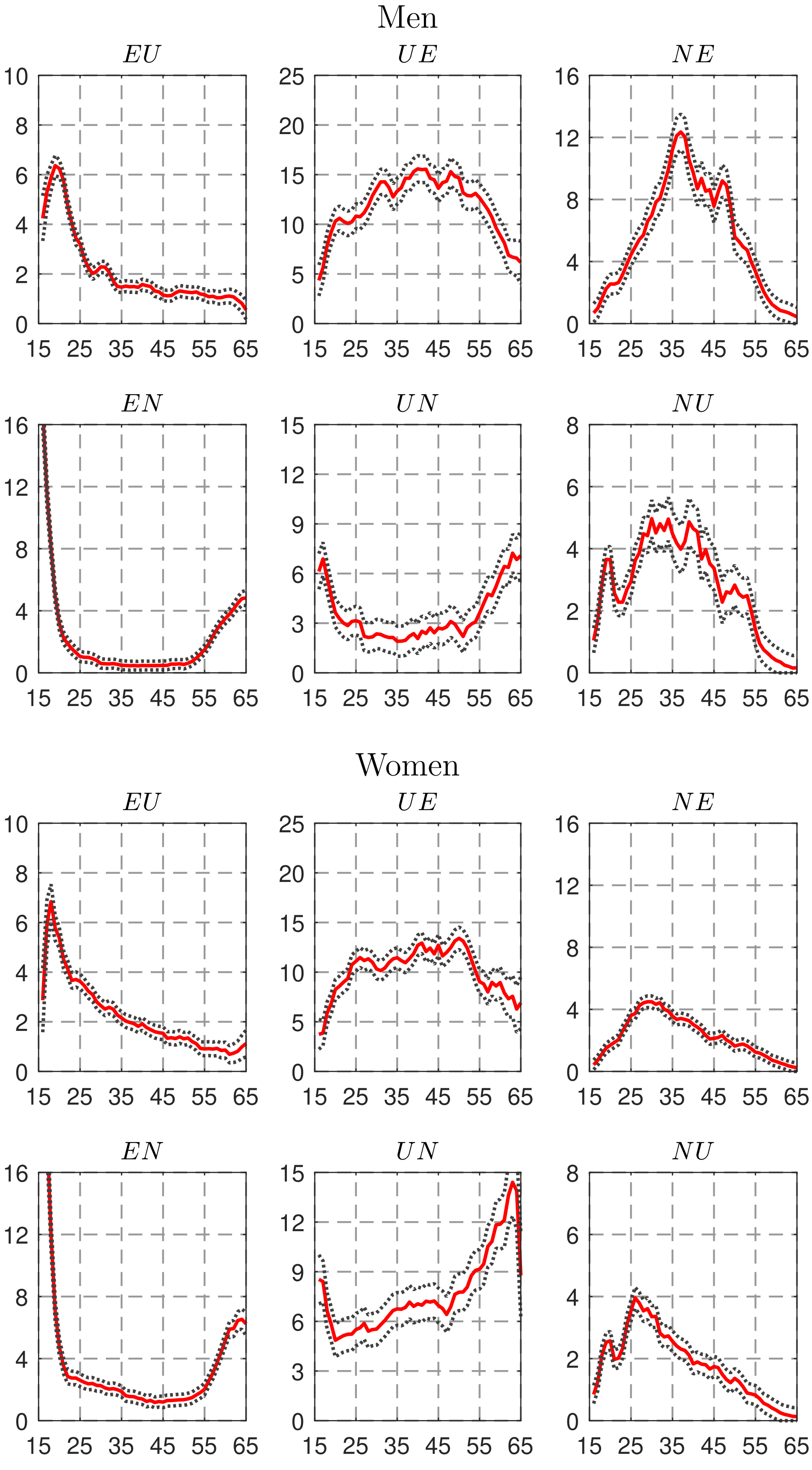

Figure 2c: Transition probabilities in Italy: Men (top) and women (bottom)

NOTE: The plots show quarterly transition probabilities expressed in percentage points. The dotted lines are 95 percent confidence intervals.

Table 1: Decomposition of aggregate employment differences based on Equation (7)

	Employment rate	**Demographics**	**Initial conditions**	**Transition probabilities**
	(standard dev.)	(variance contributions)		
Men:	6.15	5.03	3.06	91.9
Women:	7.32	0.82	1.63	97.6

Notes: The entries in the table are the standard deviation of aggregate employment (first column) and the variance contributions of all three components (from the second to the last column) shown in Equation (7). All entries are expressed in percent.

almost 98 percent.

We complement this information in Tables 8a and 8b of the appendix, where the components of equation (7) are displayed. This table offers additional evidence on what might drive the larger variance contributions of demographics for men shown in Table 1. Indeed, we observe that in the Baltic states, and to a lower extent in the Eastern Europe, demographics exert a negative role on the aggregate employment rates of those countries. For example, in the Baltic states the employment rate of men is lower than the European average by about 6 percentage points (pp.), and demographics alone lower the employment rate by 1.2 pp. This might be explained by migration towards the rest of Europe, leading to missing fractions of those workers who are most likely to have higher employment rates.

Finding no. 2: Separation rates, not job-finding rates, are the main driver of cross-country differences in male employment. Having established that $\widetilde{E_a^c} - E_a^r$ is the main object of interest, we turn to the issue of isolating the contribution of each transition probability to aggregate employment differences. Let $\widetilde{E_a^c}^{p_1,p_2,\ldots}$ denote the life-cycle profile of employment in country c starting from r's initial condition *and* using r's transition probabilities $p_1, p_2, \ldots$, while the remaining probabilities of the counterfactual transition matrices ($\widetilde{\Gamma}_a$'s) are those measured in country c.[7]. Using these counterfactuals, we can decompose the difference in life-cycle employment profiles between c and r as:

$$\widetilde{E_a^c} - E_a^r = \underbrace{\widetilde{E_a^c} - \widetilde{E_a^c}^{EU}}_{EU} + \underbrace{\widetilde{E_a^c}^{EU} - \widetilde{E_a^c}^{EU,EN}}_{EN} + \underbrace{\widetilde{E_a^c}^{EU,EN} - \widetilde{E_a^c}^{EU,EN,UE}}_{UE} \tag{8}$$

$$+ \underbrace{\widetilde{E_a^c}^{EU,EN,UE} - \widetilde{E_a^c}^{EU,EN,UE,UN}}_{UN} + \underbrace{\widetilde{E_a^c}^{EU,EN,UE,UN} - \widetilde{E_a^c}^{EU,EN,UE,UN,NE}}_{NE} + \underbrace{\widetilde{E_a^c}^{EU,EN,UE,UN,NE} - E_a^r}_{NU}.$$

It is important to note that the decomposition of $\widetilde{E_a^c} - E_a^r$ along the lines of equation (8) is path-dependent and thus not unique. In fact, there are $6! = 720$ ways of writing the decomposition of $\widetilde{E_a^c} - E_a^r$, and $2^{6-1} = 32$ ways of measuring the contribution of a given transition probability based on these decompositions. The employment rate depends on the transition probabilities

[7]We keep the $\widetilde{\Gamma}_a$'s well defined (i.e., a stochastic matrix) by adjusting the probabilities of staying in each labor market status (EE, UU, NN)

Table 2: Decomposition measuring the role of each transition probability

		EU	EN	UE	UN	NE	NU
Men:	**15-65**	48.7	16.3	17.7	-5.40	23.5	-0.69
	15-24	18.4	22.5	11.7	-0.12	48.1	-0.62
	25-54	57.1	22.6	15.8	-5.12	10.5	-0.92
	55-65	11.6	39.3	18.6	-0.051	28.7	1.84
Women:	**15-65**	23.0	-2.50	15.7	-4.02	66.6	1.17
	15-24	13.2	13.3	12.9	2.07	58.4	0.12
	25-54	28.0	4.11	14.2	-3.73	55.2	2.15
	55-65	2.40	40.2	11.4	0.54	42.3	3.17

Notes: The entries in the table are the variance contributions of each transition probability to differences in aggregate employment rates. Aggregate employment rates are calculated either for all workers aged 15 to 65 or for specific groups of workers such as young (15 to 24), prime age (25 to 54) and older (55 to 65) workers. All entries are expressed in percent.

in a non-linear fashion, and therefore those different approaches to decomposing $\widetilde{E_a^c} - E_a^r$ might lead to different results.

To address this issue, we use the Shapley decomposition that has been developed to study income inequality. Our approach is based on Shorrocks [2013]. The procedure consists in computing the marginal contribution of each transition probability to the aggregate employment gap in all 720 decompositions and then average these contributions out. So doing, we obtain for each transition probability a single number measuring its contribution to employment differences.

Tables 2 takes stocks of the results. Despite a lot of variance in the data, some patterns emerge. We see that employment separations towards unemployment (EU) explain almost half of the variance in total employment differences. The second most important flow is moving from nonparticipation to employment (NE), which accounts for almost half of the total variance. The rest of the variance is accounted by separations to unemployment (EU) and the unemployment-to-employment transition probability (UE). The flows between unemployment and nonparticipation (UN and NU) do not appear to be of any importance in understanding employment gaps across Europe. Our findings change a bit quantitatively when considering age subgroups. Not surprisingly, for young individuals the most important margin is the job finding rate out of nonparticipation (NE). It explains almost half of the variance in employment of young male workers across countries. For older workers, flows between employment and nonparticipation account for more than two-thirds of the variance with the most important being separations from employment into nonparticipation. Looking at the results for female workers, two-thirds of the variance is explained by the nonparticipation-to-employment flow (NE). The latter flow remains the most important when considering the results by age subgroups. Again, for older female workers, flows between employment and nonparticipation (EN and NE) account for the majority of the cross-country variance in employment differences.

Our results shed light on the importance of separations when accounting for differences

Table 3: Decomposition measuring the role of age within each country

		E rate	EU	EN	UE	UN	NE	NU
Men:	**15-65**	93.2	69.3	93.6	52.2	82.3	55.3	75.2
	25-54	54.7	27.6	64.0	29.0	38.4	47.6	58.2
Women:	**15-65**	89.6	66.0	94.0	49.3	75.8	54.4	63.1
	25-54	48.1	24.9	68.1	25.8	37.9	40.9	36.8

Notes: The entries in the table are the variance contributions of the within-component (age within each country) to aggregate employment rates and each transition probability. Aggregate employment rates are calculated either for all workers aged 15 to 65 or for prime-age workers (25 to 54). All entries are expressed in percent.

in employment outcomes both aggregate and over the life-cycle across Europe. This result is in contrast with a literature that documents the importance of fluctuations in job finding probability in accounting the fluctuations in the unemployment rate at the business cycle frequencies (see Shimer [2012], Fujita and Ramey [2009] among others).

Finding no. 3: Country vs. the life-cycle as a source of dispersion. We continue our investigation by comparing the role of the two sources of variations present in our data: ages and countries. Specifically, we decompose the variation of employment rates, and of each transition probability into a within-component (measuring the role of age within each country) and a between-component (measuring the role of cross-country differences).

The variance contributions of the within component are reported in Table 3. Several patterns emerge. First, the life cycle plays a major role: it explains around 90 percent of the variance of employment rates, and over 50 percent of the variance of transition probabilities (for both genders). Second and related, this is largely due to the variation seen at the two ends of the working life. After removing the variation coming from aged 15 to 24 and 55 to 65, the role of life cycle in explaining employment differences drops to about 50 percent. For both genders, the life cycle remains the main source of variation of employment separations towards nonparticipation (NE) when younger and older workers are dropped from the analysis. For all other transition probabilities, cross-country differences are the primary driver of differences in transition probabilities among prime-age workers. Notice that the numbers are remarkably similar for men and women when we focus on prime-age individuals. Third, as we have seen in Table 2 that employment separations play a dominant role for male workers, we now see in Table 3 that this calls for understanding country-specific patterns: they explain more than two-thirds in the dispersion of the employment-to-unemployment transition probability (EU). For women, whose main transition probability of interest is the nonparticipation-to-employment flow (NE), country-specific patterns explain about 60 percent of the flow.

3 The model

To delve further into the relationship between flows across the three labor market states (employment, unemployment, nonparticipation), the life cycle, and labor market institutions, we set up a macro-search model that can be calibrated and is usable for counterfactual analysis. The model features heterogeneity in workers' age and a deterministic retirement horizon, permanent heterogeneity in match quality and match-specific productivity shocks, human capital accumulation and depreciation, and endogenous workers' search intensity.

Finally, we model labor market institutions that are most often scrutinized when looking at differences in labor market performances, namely unemployment benefits (UI insurance) and employment protection legislation (EPL), and taxes (under the form of value added taxes and social-security contributions).

3.1 Economic environment

Time is discrete and runs forever. We will confine ourselves to stationary equilibria, and therefore we do not introduce any time subscript. We use a prime ($'$) to denote the one-period-ahead value of variables. We consider an economy with search frictions, populated by workers and firms, with access to a technology of production of a final consumption good (the numéraire).

Workers. On one side of the market, there is a unit continuum of risk-neutral workers living for $T > 0$ periods. A worker's age is denoted $\tau = 0, 1, ..., T$. At age T, the worker retires (dies) and is replaced by a new-born worker with age $\tau = 0$: generations overlap and entries equal exits to keep the population measure at a constant level. The population is composed of men and women. For the sake of clarity, we abstract from this distinction in the model presentation of this section, but it is explicitly reintroduced in the calibration (section 4) and quantitative analysis (section 5) sections. It is straightforward but cumbersome to extend the model to account for such a distinction; we leave a presentation of the full model in the appendix.

Workers discount the future at rate $\beta^{-1} - 1$. Workers derive utility from both consumption and leisure. Workers can be in three distinct labor-market states: employment, unemployment, or nonparticipation, with associated population denoted by $\mathcal{L}_e$, $\mathcal{L}_u$ and $\mathcal{L}_n$, respectively. The two latter states are referred to as out-of-work or non-employment states. All workers are born in nonparticipation.

In each period, workers are endowed with one unit of time. Employed workers allocate their entire time endowment to selling labor to firms against wage payments denominated in the final consumption good. There is no saving, and workers' income is entirely consumed in each period. Nonemployed workers allocate their time to home production and searching for a job. Specifically, they allocate a fraction $s \in [0, 1]$ of their time endowment to search in each period. This comes at a cost $c_u(s)$ when the worker is unemployed, and $c_n(s)$ when the worker is employed, where $c_u : [0, 1] \to \mathbb{R}_+$ and $c_n : [0, 1] \to \mathbb{R}_+$ are search costs functions that are specific to the labor-market status. We assume the functional forms

$$c_j(s) = \frac{\chi_j^{\zeta}}{1 + \zeta} s^{1+\zeta}, \tag{9}$$

for all $s \in [0, 1]$, $j \in \{n, u\}$, with the parameters $\chi_n, \chi_u, \zeta > 0$. Search is more efficient in the unemployment state, in the sense that $\chi_u \leq \chi_n$, traducing differences in the search technology across labor-market states.[8] A nonemployed worker produces at home (and consumes) a constant amount equivalent to $y_o > 0$ units of the final good in each period, regardless of their state and the time dedicated to search. Moreover, unemployed workers receive unemployment benefits, as discussed in the following.

At the end of each period, a nonemployed agent chooses between unemployment and nonparticipation for the following period. At the end of each period, an out-of-work agent draws random, transitory i.i.d. and non-observable state variables ν'_u and ν'_n for the following period, with c.d.f. denoted by H. For the sake of analytical and computational tractability, we assume that ν_u and ν_n follow standard extreme value type-I distributions. These random variables are interpreted as non-monetary transitory utility shocks associated with unemployment and nonparticipation. At the beginning of each period, the labor-market state is predetermined; an agent remaining nonemployed must wait until the end of the period to draw new utility shocks and reallocate across nonparticipation and unemployment.

An agent entering unemployment from employment and nonparticipation must pay a fixed entry sunk cost $\bar{c}_{eu} \geq 0$ or $\bar{c}_{nu} \geq 0$, depending on the origin state. This entry cost allows the agent to access the unemployment search technology, assumed to be more efficient than in nonparticipation. These are interpreted as set-up costs for accessing the unemployment-state search technology (i.e., costs associated with search intensity high enough to be counted as a labor-force participant). Lastly, the unemployed worker pays a constant search cost $\bar{c}_u \geq 0$ in each period to maintain access to the unemployment search technology. In addition to that, denote by $\bar{s}_n$ and $\bar{s}_u$ the aggregate search effort of the nonparticipants and the unemployed, respectively.

Finally, workers have heterogeneous skills or human capital $k \in \mathcal{K} \equiv \{k_0, ..., k_J\}$, with $0 \leq k_0 \leq ... \leq k_J$. A newborn worker has human capital k_0. Human capital is subject to stochastic accumulation and depreciation depending on the employment state. When employed, workers with human capital k_j, $j < J$, gain human capital k_{j+1} with probability $\bar{\pi}_e$. In the out-of-work state, human capital depreciates from k_j, $j > 0$, to k_{j-1} with probability $\bar{\pi}_o$.

Firms. On the other side of the market, there is a continuum of risk-neutral, infinitely-lived firms with a discount rate $\beta^{-1} - 1$. To produce, a firm must post a vacancy at a per-period cost of c to attract a worker. The output of a match between a worker and a firm is $y(k, x, z)$, where $y : \mathcal{K} \times \mathcal{X} \times \mathcal{Z} \to \mathbb{R}_+$. Hence, in addition to workers' human capital k, the output depends on a match-specific pair $(x, z) \in \mathcal{X} \times \mathcal{Z}$. The component $x \in \mathcal{X} \subset \mathbb{R}_+$ is called the *match quality*, drawn at the beginning of the match in a distribution with c.d.f. G_x and support $\mathcal{X}$. This is assumed constant throughout the match duration. The match quality is assumed to be an experience good, unobserved upon matching but eventually discovered by agents throughout their employment relationship. The quality of a match is discovered with probability α in each period subsequent to matching. Prior to observing the true match quality, the agents form beliefs for the expected output that are consistent with the distribution G_x: expectations for

[8] Alternatively, one could assume a cost function independent of the state, with state-specific matching efficiency.

the match output are taken over the distribution G_x. Finally, worker-firm matches are subject to idiosyncratic productivity shocks (independent of x) materialized by $z \in \mathcal{Z}$. New matches start at a fixed value $z = z_0 \in \mathcal{Z} \subset \mathbb{R}_+$, and subsequent values evolve following a first-order Markov process with transition function $G_z(.|z)$.

Search and matching. The labor market features search frictions, and search is random. The number of contacts between non-employed workers and firms with a vacancy in each period is $m(\mathcal{L}_n^* + \mathcal{L}_u^*, \mathcal{V})$, where $\mathcal{L}_n^* \equiv \bar{s}_n \mathcal{L}_n$ and $\mathcal{L}_u^* \equiv \bar{s}_u \mathcal{L}_u$ represent the effective measures of job seekers, determined by aggregate search intensity and the number of out-of-work agents in nonparticipation and unemployment, respectively; $\mathcal{V}$ is the vacancy rate. The function m is Cobb-Douglas $m(\mathcal{L}_n^* + \mathcal{L}_u^*, \mathcal{V}) = A(\mathcal{L}_n^* + \mathcal{L}_u^*)^\eta \mathcal{V}^{1-\eta}$, with efficiency of matching $A > 0$, and elasticity with respect to the effective mass of job seekers $\eta \in (0,1)$. For future reference, a worker's job-finding probability per search intensity unit is $p(\theta) \equiv m(1, \theta)$, where $\theta \equiv \mathcal{V}/(\mathcal{L}_n^* + \mathcal{L}_u^*)$ is the labor-market tightness, defined as the ratio of the number of vacant jobs to the effective mass of job seekers. The job-filling probability of a vacancy is $q(\theta) = p(\theta)/\theta$. Search frictions imply employment rents. As is standard in the literature, we assume that these rents are split through Nash bargaining; the workers' relative bargaining is $\gamma \in (0,1)$.

Labor market institutions. We consider three types of labor-market institutions: unemployment insurance (UI) benefits, employment protection legislation (EPL), and labor taxes.

First, we model an UI system with work-history and active job-search conditions, as typically seen in actual legislation. Specifically, we distinguish between low ($b_0 > 0$) and high ($b_1 > b_0$) UI benefits. We also distinguish between conditions for eligibility and the provision of UI benefits. On the one hand, all workers are *eligible* to receive these UI benefits (either low or high), but eligibility for high UI benefits depends on some work-history conditions (shortly described). On the other hand, *provision* of UI benefits is conditional choosing the unemployment state (and paying the associated nonmonetary utility costs), reflecting job-search activity requirements seen in actual legislation. The work-history conditions are as follows: eligibility for high UI benefits is granted to any employed worker experiencing a separation into employment. When the individual is nonemployed, eligibility exhausts with probability $\overline{\mu}_o$. After exhaustion, an individual choosing the unemployment state will receive low UI benefits (i.e., is eligible to receive low UI benefits). After exhaustion, regaining eligibility for high UI benefits requires reentering into employment. We assume that a newborn worker is only eligible for low UI benefits.

Second, we model a two-tier EPL system, reflecting the job seniority dependence on the stringency of unemployment protection and the large incidence of temporary jobs, as seen in many countries. Jobs are subject to firing costs F_i, $i = 0, 1$, paid by employers upon match termination. We distinguish between a low and high firing-cost regime indexed by $i = 0, 1$, with $0 \leq F_0 \leq F_1$. Any newly formed job is subject to the low firing cost regime with firing costs F_0. With probability $\overline{\mu}_e$, the job becomes subject to high firing costs F_1.

Third, we consider proportional value-added and social-security contribution taxes. The value-added tax is collected on a match output, and the associated tax rate is $\phi \in (0,1)$. The social security tax is a fraction $\psi \in (0,1)$ of the period wage rate. For simplicity, we assume statutory tax incidence on the worker, but we calibrate ψ so that the tax wedge is consistent with rates of employee and employer contributions seen in the data.

Assuming stochastic durations for UI and EPL regimes allows us to economize on the model state space. To fix ideas, one should think about the high UI regime lasting for about one year and the low EPL regime for about two years, i.e., a typical maximum duration for temporary contracts in the European Union. In sum, the parameters b_0 and b_1 are proxies for the generosity of UI systems, whereas F_0 and F_1 proxy the stringency of EPL. Note, lastly, that firing costs and taxes are assumed to be deadweight losses and that we abstract from the government budget.

Timing. First, recall that we assume that a newborn individual ($\tau = 0$) is born in nonparticipation. At the end of age $\tau = 0$, the individual chooses between staying in nonparticipation and transiting into unemployment for the following period ($\tau = 1$).

In addition, the sequence of events and actions for a nonemployed agent with age $\tau = 1, ..., T-1$ within a period t is the following. (i) At the beginning of age t and conditional on the labor-force status, the agent receives period utility from home production and possible UI transfers, net of search costs; the agent sets the optimal (i.e., maximizing expected lifetime utility) search intensity; (ii) the age, UI status and skill level (subject to depreciation) are stochastically updated; (iii) the agent meets a vacancy with probability determined by the labor-market tightness and search intensity predetermined in step (i) and gets hired if the associated surplus is nonnegative; otherwise, the agent stays nonemployed. (v) The hired worker starts in employment in $t+1$; the agent remaining out of work chooses between nonparticipation and unemployment for the period $t+1$.

For an employed worker, the sequence is the following: (i) at the beginning of t, production and wage payments occur; (ii) the age, EPL status, skill level, and match-specific state are updated; (iii) the match continues if the surplus remains positive or is terminated otherwise. (iv) A continuing worker remains employed in $t+1$; a terminated worker goes to nonemployment and chooses the labor-force status for $t+1$.

At age T, an employed or nonemployed individual (i) produces (at home or on the market), collects payments, and (ii) retires at the end of the period. The worker "dies"; equivalently, the worker leaves the labor force forever and receives lifetime utility normalized to zero. A newborn worker of age $\tau = 0$ enters the labor force, replacing the retiring worker. This worker makes a participation decision according to (i) upon entry in the labor market, and starts to search for a job at age $\tau = 1$.

3.2 Bellman equations

Worker. We formulate the decision problems of workers using a system of (finite horizon) value functions that can be solved by backward induction. To begin with, let $V_{\tau,n,i} : \mathcal{K} \to \mathbb{R}$ and $V_{\tau,u,i} : \mathcal{K} \to \mathbb{R}$ represent the value functions of a worker of age τ in nonparticipation and unemployment, respectively, for all $\tau = 1, ..., T$ and all $i = 0, 1$. Let the index i indicates whether this worker is eligible ($i = 1$) or not ($i = 0$) to receive high unemployment benefits b_1.

One must distinguish between a match with revealed and unrevealed quality when valuing the employed worker's lifetime utility. Denote by $\tilde{V}_{\tau,e,i} : \mathcal{K} \times \mathcal{Z} \to \mathbb{R}$ the expected lifetime utility value of a worker in a match with unrevealed quality, and by $V_{\tau,e,i} : \mathcal{K} \times \mathcal{X} \times \mathcal{Z} \to \mathbb{R}$ the value of a match with revealed quality, for $\tau = 2, ..., T$ and $i = 0, 1$.[9] Here, the index indicates the match's EPL status, with associated firing costs F_i.

Observe that the assumption of Nash Bargaining and flexible wages subject to renegotiation in each period implies that period wages payments (and profits) depend on the current match state and the agents' outside options. These outside options are determined by the worker's UI and job's EPL status and on whether one considers a match in a *hiring stage* (i.e., a new match) or in a *renegotiation stage* (i.e., a continuing match). As such, let $\tilde{V}_{\tau,ne,i} : \mathcal{K} \times \{z_0\} \to \mathbb{R}$ and $\tilde{V}_{\tau,ue,i} : \mathcal{K} \times \{z_0\} \to \mathbb{R}$, $\tau = 2, ..., T$, $i = 0, 1$, represent the value functions of an individual at the hiring stage, coming from nonparticipation and unemployment, respectively. Here, we use the index i to denote the individual's UI status upon hiring. Recall that a new match starts with stochastic productivity $z = z_0$ by assumption.

A worker of age τ in nonparticipation has an expected lifetime discounted utility value given by

$$V_{\tau,n,i}(k) = \max_{s \in [0,1]} \Bigg\{ y_o - c_n(s) + \beta \sum_{i' \in \{0,1\}} \mu_o(i'|i) \sum_{k' \in \mathcal{K}} \pi_o(k'|k) \Big[sp(\theta) \max\big(\tilde{V}_{\tau+1,ne,i'}(k', z_0), \, \overline{V}_{\tau+1,n,i'}(k') \big) + (1 - sp(\theta)) \overline{V}_{\tau+1,n,i'}(k') \Big] \Bigg\}, \tag{10}$$

for all $\tau = 1, ..., T-1$, $i \in \{0, 1\}$, and $k \in \mathcal{K}$, where

$$\overline{V}_{\tau+1,n,i'}(k') \equiv \log \Big[\exp\big(V_{\tau+1,n,i'}(k')\big) + \exp\big(V_{\tau+1,u,i'}(k') - \bar{c}_{nu}\big) \Big], \tag{11}$$

for all $i' = 0, 1$ and $k' \in \mathcal{K}$, which represents the expected value of remaining out-of-work at the end of period τ, which closed-form expression follows from the assumption of i.i.d. extreme value shocks of type I (Aguirregabiria and Mira [2010]). Note that this value depends on the labor-force status at age τ due to the fixed unemployment entry cost $\bar{c}_{nu}$, which is specific to nonparticipation. Moreover, in expression (10), μ_o denotes the transition function for the UI eligibility state summarized by i, as implied by the stochastic duration parameter $\overline{\mu}_o$; π_o is the transition function of human capital in the out-of-work state, reflecting the risk of skill depreciation induced by the exogenous probability $\bar{\pi}_o$.

Hence, the nonparticipating worker chooses search effort to maximize lifetime utility, composed of (i) period home production net of search costs and (ii) the discounted next-period value of nonemployment taken over the conditional distribution of the UI eligibility state and human capital. With probability $sp(\theta)$, the worker meets a vacancy and gets the value of a job with unrevealed match quality in the low EPL regime ($i = 0$). With the complement proba-

[9] An individual cannot be employed before age $\tau = 2$, as $\tau = 0$ (birth) is dedicated to making a participation decision and $\tau = 1$ is dedicated to search accordingly.

bility, the worker stays in the out-of-work state and obtains the expected value given by (11), determined by optimal participation choices conditional on nonmonetary shocks. As discussed above, leaving nonparticipation for unemployment implies paying the fixed set-up cost $\overline{c}_{nu}$.

Similarly, the value function of an unemployed worker is

$$V_{\tau,u,i}(k) = \max_{s\in[0,1]} \Big\{ y_o + b_i - c_u(s) - \overline{c}_u + \beta \sum_{i'\in\{0,1\}} \mu_o(i'|i) \sum_{k'\in\mathcal{K}} \pi_o(k'|k) \big[sp(\theta) \max(\tilde{V}_{\tau+1,ue,i'}(k', z_0), \overline{V}_{\tau+1,u,i'}(k')) + (1 - sp(\theta)) \overline{V}_{\tau+1,u,i'}(k') \big] \Big\}, \tag{12}$$

for all $\tau = 1, ..., T-1$, $i \in \{0,1\}$, and $k \in \mathcal{K}$, where the value of remaining out of worker at the end of τ is

$$\overline{V}_{\tau+1,u,i'}(k') \equiv \log \Big[\exp\big(V_{\tau+1,n,i'}(k')\big) + \exp\big(V_{\tau+1,u,i'}(k')\big) \Big], \tag{13}$$

for all $i' = 0, 1$ and $k' \in \mathcal{K}$. This value function is similar to (10) except that an unemployed worker receives unemployment benefits b_i dependent on the UI eligibility status and that there is no cost of reallocation across labor-market states, as seen in the expected maximized value function (13).

The terminal values are given by

$$V_{T,n,i}(k) = y_o \tag{14}$$

$$V_{T,u,i}(k) = y_o + b_i - \overline{c}_u \tag{15}$$

for all $i' = 0, 1$ and $k \in \mathcal{K}$.

It is convenient to focus now on the case of a continuing match taken at the renegotiation stage. The expected discounted utility of a worker employed in a job with unrevealed match quality is

$$\begin{aligned} \tilde{V}_{\tau,e,i}(k,z) = \; & (1-\psi)\tilde{\omega}_{\tau,i}(k,z) + \beta \sum_{i'\in\{0,1\}} \mu_e(i'|i) \sum_{k'\in\mathcal{K}} \pi_e(k'|k) \\ & \times \int \Big\{ (1-\alpha) \max\big(\tilde{V}_{\tau+1,e,i'}(k',z'), \overline{V}_{\tau+1,e}(k')\big) \\ & + \alpha \int \max\big(V_{\tau+1,e,i'}(k',x',z'), \overline{V}_{\tau+1,e}(k')\big) dG_x(x') \Big\} dG_z(z'|z) \end{aligned} \tag{16}$$

for all $\tau = 2, ..., T-1$, $i = 0, 1$, $k \in \mathcal{K}$, and $z \in \mathcal{Z}$. The value of a worker in a job with revealed quality is

$$V_{\tau,e,i}(k,x,z) = (1-\psi)\omega_{\tau,i}(k,x,z) \\ + \beta \sum_{i'} \mu_e(i'|i) \sum_{k'} \pi_e(k'|k) \int \max\left(V_{\tau+1,e,i'}(k',x,z'), \overline{V}_{\tau+1,e}(k')\right) dG_z(z'|z), \tag{17}$$

for all $\tau = 2, ..., T-1$, $i = 0, 1$, and $(k, x, z) \in \mathcal{K} \times \mathcal{X} \times \mathcal{Z}$. In (16) and (17), we let

$$\overline{V}_{\tau+1,e}(k') \equiv \log\left[\exp\left(V_{n,\tau+1,1}(k')\right) + \exp\left(V_{u,\tau+1,1}(k') - \overline{c}_{eu}\right)\right], \tag{18}$$

for $\tau = 2, ..., T-1$, $k' \in \mathcal{K}$, which represents the expected value of a job separation into nonemployment, similar to the out-of-work values (11) and (13). Note that the latter is independent of the EPL status indexed by i (attached to the match) and that this expectation is taken over out-of-work values associated with UI status with high benefits b_1 ($i = 1$). Indeed, by assumption, the employed worker is always eligible for high UI benefits. Also note that the relevant unemployment entry cost is now $\overline{c}_{eu}$, which is specific to employment as an origin state. Moreover, we denote by $\omega_{\tau,i}(k, z)$ and $\omega_{\tau,i}(k, x, z)$ the worker's (pre-tax) wage in these value functions (shortly analyzed).

As such, the unrevealed match-quality value function (16) consists of the current after-tax wage and a discounted expected value, taken over the distribution of next-period possible EPL status i', skills k', and stochastic match-specific shocks z'. The expectation also depends on the possible next-period match quality; with probability α, the match quality is revealed, i.e., drawn from the distribution with c.d.f. G_x. The value function (17) has the same structure, except that the match quality remains constant once it is revealed to the agents. When the match surplus is negative, termination occurs, and the worker receives utility given by (18).

The terminal values satisfy

$$\tilde{V}_{T,e,i}(k,z) = (1-\psi)\tilde{\omega}_{T,i}(k,z); \quad k \in \mathcal{K},\ z \in \mathcal{Z} \tag{19}$$

$$V_{T,e,i}(k,x,z) = (1-\psi)\tilde{\omega}_{T,i}(k,x,z); \quad k \in \mathcal{K},\ x \in \mathcal{X},\ z \in \mathcal{Z}. \tag{20}$$

In addition, observe that the worker's value at the hiring stage (showing up in (10) and (12) and for individuals hired from nonparticipation and unemployment) must satisfy

$$\tilde{V}_{\tau,ne,i}(k,z) = \tilde{V}_{\tau,e,0}(k,z) + (1-\psi)(\tilde{\omega}_{\tau,ne,i}(k,z) - \tilde{\omega}_{\tau,e,0}(k,z)) \tag{21}$$

$$\tilde{V}_{\tau,ue,i}(k,z) = \tilde{V}_{\tau,e,0}(k,z) + (1-\psi)(\tilde{\omega}_{\tau,ue,i}(k,z) - \tilde{\omega}_{\tau,e,0}(k,z)), \tag{22}$$

for $\tau = 2, ..., T$, $i = 0, 1$, $k \in \mathcal{K}$, and $z \in \{z_0\}$; $\tilde{\omega}_{\tau,ne,i}(k, z)$ and $\tilde{\omega}_{\tau,ne,i}(k, z)$ represent the wage paid to the worker in the period upon which hiring takes place.

Firm's profits. We now analyze value functions for the expected lifetime profits of a firm with an occupied job (i.e., matched with a worker). We impose from now on the zero profit condition for vacant jobs and let the analysis of the associated equilibrium labor-market tightness to subsection 3.7. We let $\tilde{\Pi}_{\tau,i} : \mathcal{K} \times \mathcal{Z} \to \mathbb{R}$ and $\Pi_{\tau,i} : \mathcal{K} \times \mathcal{X} \times \mathcal{Z} \to \mathbb{R}$ $\tau = 2, ..., T$, $i = 0, 1$ be asset continuation values for jobs with unrevealed and revealed quality, respectively, occupied by a worker with age τ and EPL status indexed by i. We also let $\tilde{\Pi}_{\tau,ne,i} : \mathcal{K} \times \{z_0\} \to \mathbb{R}$ and $\tilde{\Pi}_{\tau,ue,i} : \mathcal{K} \times \{z_0\} \to \mathbb{R}$ be asset values for a job taken at the hiring stage, occupied by a worker coming from nonparticipation and unemployment, respectively.

The asset value of an occupied (continuing) job with unrevealed quality is

$$\tilde{\Pi}_{\tau,i}(k, z) = (1 - \phi) \int y(k, x', z) dG_x(x') - \tilde{\omega}_{\tau,i}(k, z) + \beta \sum_{i'} \mu_e(i'|i) \sum_{k'} \pi_e(k'|k)$$
$$\times \int \left\{ (1 - \alpha) \max\left(\tilde{\Pi}_{\tau+1,i'}(k', z'), -F_{i'}\right) + \alpha \int \max\left(\Pi_{\tau+1,i'}(k', x', z'), -F_{i'}\right) dG_x(x') \right\} dG_z(z'|z); \tag{23}$$

for all $\tau = 2, .., T - 1$, $i = 0, 1$, and $(k, z) \in \mathcal{K} \times \mathcal{Z}$. For a job with revealed match quality, we have

$$\begin{aligned} \Pi_{\tau,i}(k, x, z) &= (1 - \phi) y(k, x, z) - \omega_{\tau,i}(k, x, z) \\ &\quad + \beta \sum_{i'} \mu_e(i'|i) \sum_{k'} \pi_e(k'|k) \int \max(\Pi_{\tau+1,i'}(k', x, z'), -F_{i'}) dG_z(z'|z), \end{aligned} \tag{24}$$

for $\tau = 2, .., T - 1$, $i = 0, 1$, and $(k, x, z) \in \mathcal{K} \times \mathcal{X} \times \mathcal{Z}$. These values are symmetric to (16) (17), except that the period return is now composed of the (expected) match output net of taxes and wage payments, and that the employer's outside option appearing in the expectation term depends directly on firing costs F_i.

Note that an unrevealed match-quality job is valued using the expected output taken over the match-quality distribution G_x. The firm's terminal profit values are:

$$\tilde{\Pi}_{T,i}(k, z) = (1 - \phi) \int y(k, x', z) dG_x(x') - \tilde{\omega}_{T,i}(k, z); \quad k \in \mathcal{K},\ z \in \mathcal{Z} \tag{25}$$

$$\Pi_{T,i}(k, x, z) = (1 - \phi) y(k, x, z) - \omega_{T,i}(k, x, z); \quad k \in \mathcal{K},\ x \in \mathcal{X},\ z \in \mathcal{Z}. \tag{26}$$

Finally, the hiring-stage profits satisfy:

$$\tilde{\Pi}_{T,ne,i}(k, z) = \tilde{\Pi}_{T,0}(k, z) - (\tilde{\omega}_{\tau,ne,i}(k, z) - \tilde{\omega}_{\tau,e,0}(k, z)) \tag{27}$$

$$\tilde{\Pi}_{T,ue,i}(k, z) = \tilde{\Pi}_{T,0}(k, z) - (\tilde{\omega}_{\tau,ue,i}(k, z) - \tilde{\omega}_{\tau,e,0}(k, z)) \tag{28}$$

for $\tau = 2, ..., T$, $i = 0, 1$, $k \in \mathcal{K}$, and $z \in \{z_0\}$. The next subsection analyzes wage equilibrium conditions.

3.3 Wages

In the following, we give conditions for wages as a solution to a Nash Bargaining problem faced by workers and employers. As discussed above, the agents' outside options depend on whether one considers a hiring stage or renegotiation stage and on the worker's UI and the job's

EPL status. As it will be clear in what follows, we assume that the worker's outside option is evaluated before the participation choice. We consider two cases.

(i) Hiring stage. For a new match, the wage satisfies:

$$\omega_{\tau,je,i}(k,z) = \arg\max \left(\tilde{V}_{\tau,je}(k,z) - \overline{V}_{\tau,j,i}(k)\right)^{\gamma} \tilde{\Pi}_{\tau,je}(k,z)^{1-\gamma}; \tag{29}$$

$\tau = 2, ..., T; i = 0, 1; (k, z) \in \mathcal{K} \times \{z_0\}$, for all origin labor-force status $j \in \{n, u\}$. Observe that the worker's outside option is the nonemployment value satisfying (11) and (13), and that the employer's outside is simply zero due to free entry of vacancies and that fact that firing costs only apply to continuing matches.

We have the first-order condition

$$(1-\gamma)\left(\tilde{V}_{\tau,je}(k,z) - \overline{V}_{\tau,j,i}(k)\right) = \gamma(1-\psi)\tilde{\Pi}_{\tau,je}(k,z), \tag{30}$$

for $\tau = 2, ..., T; i = 0, 1; (k, z) \in \mathcal{K} \times \{z_0\}$.

(ii) Renegotiation stage. Consider now a continuing match. The wage is the solution to

$$\begin{aligned}\tilde{\omega}_{\tau,i}(k,z) &= \arg\max \left(\tilde{V}_{\tau,e}(k,z) - \overline{V}_{\tau,e}(k)\right)^{\gamma} \left(\tilde{\Pi}_{\tau,e}(k,z) - F_i\right)^{1-\gamma} \\ \omega_{\tau,i}(k,x,z) &= \arg\max \left(V_{\tau,e}(k,x,z) - \overline{V}_{\tau,e}(k)\right)^{\gamma} \left(\Pi_{\tau,e}(k,x,z) - F_i\right)^{1-\gamma}\end{aligned} \tag{31}$$

with the FOC

$$\begin{aligned}(1-\gamma)\left(\tilde{V}_{\tau,je}(k,z) - \overline{V}_{\tau,j,i}(k)\right) &= \gamma(1-\psi)\tilde{\Pi}_{\tau,je}(k,z); \quad (k,z) \in \mathcal{K} \times \mathcal{Z} \\ (1-\gamma)\left(V_{\tau,je}(k,x,z) - \overline{V}_{\tau,j,i}(k)\right) &= \gamma(1-\psi)\Pi_{\tau,je}(k,x,z); \quad (k,x,z) \in \mathcal{K} \times \mathcal{X} \times \mathcal{Z}.\end{aligned} \tag{32}$$

for $\tau = 2, ..., T; i = 0, 1$.

Combining the FOC (30) and (32) with expressions for value functions (17) to (24) yields the following continuing (pre-tax) wage equations:

$$\tilde{\omega}_{\tau,i}(k,z) = \gamma(1-\phi)\int y(k,x',z)dG_x(x') + \frac{1-\gamma}{1-\psi}\underline{\omega}_{\tau}(k) + \gamma\big(F_i - \mathcal{I}(\tau < T)\beta\sum_{i'}\mu_e(i'|i)F_{i'}\big); \tag{33}$$

$\tau = 2, ..., T,\ i = 0, 1,\ (k, z) \in \mathcal{K} \times \mathcal{Z}$ for an unrevealed-quality match and

$$\omega_{\tau,i}(k,x,z) = \gamma(1-\phi)y(k,x,z) + \frac{1-\gamma}{1-\psi}\underline{\omega}_{\tau}(k) + \gamma\big(F_i - \mathcal{I}(\tau < T)\beta\sum_{i'}\mu_e(i'|i)F_{i'}\big). \tag{34}$$

$\tau = 2, ..., T$, $i = 0, 1$, $(k, z) \in \mathcal{K} \times \mathcal{X} \times \mathcal{Z}$ for a revealed-quality match. We define:

$$\frac{1}{1-\psi}\,\underline{\omega}_{\tau}(k) \equiv \frac{1}{1-\psi}\left[\overline{V}_{e,\tau}(k) - \mathcal{I}(\tau < T)\,\beta \sum_{k'} \pi_e(k'|k)\overline{V}_{e,\tau+1}(k')\right], \tag{35}$$

which can be interpreted as the pre-tax worker's reservation wage in a continuing match, determined by the current outside option net of the discounted expected unemployment option value for the next period.

Moreover, the same set of conditions implies that the hiring wage equations satisfy:

$$\tilde{\omega}_{\tau,ne,i}(k,z) = \tilde{\omega}_{\tau,0}(k,z) + \frac{1-\gamma}{1-\psi}\big(\underline{\omega}_{\tau,ne,i}(k) - \underline{\omega}_{\tau,0}(k)\big) - \gamma F_0 \tag{36}$$

$$\tilde{\omega}_{\tau,ue,i}(k,z) = \tilde{\omega}_{\tau,0}(k,z) + \frac{1-\gamma}{1-\psi}\big(\underline{\omega}_{\tau,ue,i}(k) - \underline{\omega}_{\tau,0}(k)\big) - \gamma F_0 \tag{37}$$

for $\tau = 2, ..., T$, $i = 0, 1$, $(k, z) \in \mathcal{K} \times \{z_0\}$, where

$$\frac{1}{1-\psi}\,\underline{\omega}_{\tau,je,i}(k) \equiv \frac{1}{1-\psi}\left[\overline{V}_{\tau,j,i}(k) - \mathcal{I}(\tau < T)\,\beta \sum_{k'} \pi_e(k'|k)\overline{V}_{\tau+1,e}(k')\right] \tag{38}$$

for $\tau = 2, ..., T; i = 0, 1; (k, z) \in \mathcal{K} \times \{z_0\}$, and $j \in \{n, u\}$, which is the pre-tax reservation wage of the worker, which explicitly depends on the UI and labor-force status (j, i) that determine the outside option in the negotiation (and negatively on the next-period expected nonemployment option value in the case of hiring).

3.4 Surplus functions

The first-order conditions of the Nash problems enable us to express the decision problem of workers and firms in terms of the gross surplus of a match. As per the above discussion, the surplus of a new match depends on the origin labor-force state of the worker and the UI status. As such, the surplus of a hiring-stage match satisfies the conditions:

$$\tilde{S}_{\tau,ne,i}(k,z) = \tilde{V}_{\tau,ne,i}(k,z) - \overline{V}_{\tau,n,i}(k) + \tilde{\Pi}_{\tau,ne,i}(k,z) \tag{39}$$

$$\tilde{S}_{\tau,ue,i}(k,z) = \tilde{V}_{\tau,ue,i}(k,z) - \overline{V}_{\tau,u,i}(k) + \tilde{\Pi}_{\tau,ue,i}(k,z); \tag{40}$$

$\tau = 2, ..., T$, $i = 0, 1$, and $(k, z) \in \mathcal{K} \times \{z_0\}$. The surplus in a continuing job (with unrevealed and revealed match quality, respectively) is defined as

$$\tilde{S}_{\tau,i}(k,z) = \tilde{V}_{\tau,e,i}(k,z) - \overline{V}_{\tau,e}(k) + \tilde{\Pi}_{\tau,i}(k,z) + F_i; \quad (k,z) \in \mathcal{K} \times \mathcal{Z} \tag{41}$$

$$S_{\tau,i}(k,x,z) = \tilde{V}_{\tau,e,i}(k,x,z) - \overline{V}_{\tau,e}(k) + \Pi_{\tau,i}(k,x,z) + F_i; \quad (k,x,z) \in \mathcal{K} \times \mathcal{X} \times \mathcal{Z}, \tag{42}$$

for $\tau = 2, ..., T$ and $i = 0, 1$. Using the latter with expressions (16) to (28) we obtain the unrevealed-quality continuing surplus function

$$\begin{aligned}\tilde{S}_{\tau,i}(k,z) = (1-\phi)(1-\gamma\psi)\int y(k,x',z)dG_x(x') - \frac{1-\gamma\psi}{1-\psi}\underline{\omega}_{\tau}(k) + (1-\gamma\psi)\big(F_i - \beta\sum_{i'}\mu_e(i'|i)F_{i'}\big)\\ + \beta\sum_{i'}\mu_e(i'|i)\sum_{k'}\pi_e(k'|k)\int\Big\{(1-\alpha)\max(\tilde{S}_{\tau+1,i'}(k',z'),0)\\ + \alpha\int\max(S_{\tau+1,i'}(k',x',z'),0)dG_x(x')\Big\}dG_z(z'|z).\end{aligned} \tag{43}$$

for $\tau = 2, ..., T-1$, $i = 0, 1$, and $(k, z) \in \mathcal{K} \times \mathcal{Z}$, and the revealed-quality surplus

$$\begin{aligned}S_{\tau,i}(k,x,z) = (1-\phi)(1-\gamma\psi)y(k,x,z) - \frac{1-\gamma\psi}{1-\psi}\underline{\omega}_{\tau}(k) + (1-\gamma\psi)\big(F_i - \beta\sum_{i'}\mu_e(i'|i)F_{i'}\big)\\ + \beta\sum_{i'}\mu_e(i'|i)\sum_{k'}\pi_e(k'|k)\int\max(S_{\tau+1,i'}(k',x,z'),0)dG_z(z'|z),\end{aligned} \tag{44}$$

for $\tau = 2, ..., T-1$, $i = 0, 1$, and $(k, x, z) \in \mathcal{K} \times \mathcal{X} \times \mathcal{Z}$. The terminal values satisfy

$$\tilde{S}_{T,i}(k,z) = (1-\phi)(1-\gamma\psi)\int y(k,x',z)dG_x(x') - \frac{1-\gamma\psi}{1-\psi}\overline{V}_{T,e}(k); \quad (k,z) \in \mathcal{K}\times\mathcal{Z} \tag{45}$$

$$S_{T,i}(k,x,z) = (1-\phi)(1-\gamma\psi)y(k,x,z) - \frac{1-\gamma\psi}{1-\psi}\overline{V}_{T,e}(k); \quad (k,x,z) \in \mathcal{K}\times\mathcal{X}\times\mathcal{Z}, \tag{46}$$

for $i = 0, 1$.

Finally, the surplus for a new, hiring-stage match solves

$$\begin{aligned}\tilde{S}_{\tau,ne,i}(k,z) = \tilde{S}_{\tau,0}(k,z) + \frac{1-\gamma\psi}{1-\psi}\big(\underline{\omega}_{\tau,ne,i}(k) - \underline{\omega}_{\tau}(k)\big) - (1-\gamma\psi)F_0\\ \tilde{S}_{\tau,ue,i}(k,z) = \tilde{S}_{\tau,0}(k,z) + \frac{1-\gamma\psi}{1-\psi}\big(\underline{\omega}_{\tau,ue,i}(k) - \underline{\omega}_{\tau}(k)\big) - (1-\gamma\psi)F_0;\end{aligned} \tag{47}$$

$\tau = 2, ..., T$, $i = 0, 1$, and $(k, z) \in \mathcal{K} \times \mathcal{X} \times \mathcal{Z}$.

3.5 Policy functions

Optimal search effort. The optimal search effort, written in terms of the surplus function, is given by

$$s^*_{\tau,j,i}(k) = \min\left\{(1/\chi_j)\left[\beta A\theta^{1-\eta}\frac{\gamma(1-\psi)}{1-\gamma\psi}\sum_{i'}\mu_o(i'|i)\sum_{k'}\pi_o(k'|k)\max\big(\tilde{S}_{\tau+1,je,i'}(k'),0\big)\right]^{\frac{1}{\zeta}},\ 1\right\}, \tag{48}$$

for $\tau = 1, ..., T-1$, $i = 0, 1$, $k \in \mathcal{K}$, and $j \in \{n, u\}$. Moreover, $s^*_{\tau,j,i}(k) = 0$ for $\tau = 0$ (by assumption) and $\tau = T$.

Labor-force participation. The probability of participating (i.e., of choosing unemployment) in $\tau+1$ conditional on being in non-employment in period τ, and conditional on the origin state in $\{n,u,e\}$, next-period skill level k' and UI status i' is:

$$\begin{aligned}\mathcal{P}^{nu}_{\tau+1,i'}(k') &= \frac{\exp\left(V_{\tau+1,u,i'}(k')-\bar{c}_{nu}\right)}{\exp\left(V_{\tau+1,n,i'}(k')\right)+\exp\left(V_{\tau+1,u,i'}(k')-\bar{c}_{nu}\right)}\\ \mathcal{P}^{uu}_{\tau+1,i'}(k') &= \frac{\exp\left(V_{\tau,u,i'}(k')\right)}{\exp\left(V_{\tau+1,n,i'}(k')\right)+\exp\left(V_{\tau+1,u,i'}(k')\right)}\end{aligned} \tag{49}$$

for all $\tau=0,...,T-1$, $i'=0,1$, and $k'\in\mathcal{K}$. Moreover, the probability of participating of an individual who is nonemployed at the end of period τ but coming from employment is:

$$\mathcal{P}^{eu}_{\tau+1}(k') = \frac{\exp\left(V_{\tau+1,u,1}(k')-\bar{c}_{eu}\right)}{\exp\left(V_{\tau+1,n,1}(k')\right)+\exp\left(V_{\tau+1,u,1}(k')-\bar{c}_{eu}\right)}, \tag{50}$$

for all $\tau=0,...,T-1$ and $k'\in\mathcal{K}$. Moreover, $\mathcal{P}^{un}_{\tau+1}=1-\mathcal{P}^{uu}_{\tau+1}$, $\mathcal{P}^{nn}_{\tau+1}=1-\mathcal{P}^{nu}_{\tau+1}$, and $\mathcal{P}^{en}_{\tau+1}=1-\mathcal{P}^{eu}_{\tau+1}$.

Matching. Conditional on a contact between a worker and a firm, hiring takes place under the condition that

$$\tilde{S}_{\tau,je,i}(k)\geq 0. \tag{51}$$

Denote by $\underline{k}_{\tau,j,i}$ the lowest value of $k\in\mathcal{K}$ such that the above condition is satisfied (assuming that such a value exists).

Job separation. There are joint worker-firm decisions on whether a job match is viable or not. These decisions can be expressed as reservation thresholds in terms of match productivity. Separation occurs in two cases: after the revelation of the match quality or after a productivity shock. Define $\tilde{z}_{\tau,i}:\mathcal{K}\to Z$ and $z_{\tau,i}:\mathcal{K}\times\mathcal{X}\to\mathcal{Z}$ by

$$\begin{aligned}&\tilde{S}_{\tau,i}(k,\tilde{z}_{\tau,i}(k))=0\\ &S_{\tau,i}(k,z_{\tau,i}(k,x),x)=0.\end{aligned} \tag{52}$$

In cases that such $\tilde{z}_{\tau,i}(k)$ and $z_{\tau,i}$, it is convenient for the following developments to let $\tilde{z}_{\tau,i}(k)=\inf\mathcal{Z}$ and $z_{\tau,i}(k,x)=\inf\mathcal{Z}$.

State conditional transition probabilities. The UE and NE transition probabilities are given by:

$$\lambda_{\tau,ue,i}(k) = A\theta^{1-\eta} s^*_{\tau,u,i}(k) \sum_{i'} \mu_o(i'|i) \sum_{k'} \pi_o(k'|k)\, \mathcal{I}\big(k' \geq \underline{k}_{\tau+1,n,i'}\big)$$
$$\lambda_{\tau,ne,i}(k) = A\theta^{1-\eta} s^*_{\tau,n,i}(k) \sum_{i'} \mu_o(i'|i) \sum_{k'} \pi_o(k'|k)\, \mathcal{I}\big(k' \geq \underline{k}_{\tau+1,u,i'}\big) \tag{53}$$

for all $k \in \mathcal{K}$, $i = 0, 1$, and $\tau = 1, ..., T-1$. $\mathcal{I}(.)$ is the indicator function. These are defined as the probability of transiting from unemployment and non-participation to employment between age τ and $\tau + 1$ conditional on skill and UI status.

Moreover, the probability of transiting across U and N is:

$$\lambda_{\tau,nu,i}(k) = \sum_{i'} \mu_o(i'|i) \sum_{k'} \pi_o(k'|k) \left[1 - A\theta^{1-\eta} s^*_{\tau,u,i}(k) \mathcal{I}\big(k' \geq \underline{k}_{\tau+1,u,i'}\big)\right] \mathcal{P}^{nu}_{\tau+1,i'}(k')$$
$$\lambda_{\tau,un,i}(k) = \sum_{i'} \mu_o(i'|i) \sum_{k'} \pi_o(k'|k) \left[1 - A\theta^{1-\eta} s^*_{\tau,n,i}(k) \mathcal{I}\big(k' \geq \underline{k}_{\tau+1,n,i'}\big)\right] \mathcal{P}^{un}_{\tau+1,i'}(k'). \tag{54}$$

for all $\tau = 1, ..., T-1$, $i = 0, 1$, and $k \in \mathcal{K}$. In an unrevealed-quality match, the probability of transiting to the out-of-work state $j \in \{n, u\}$ is

$$\tilde{\lambda}_{\tau,ej,i}(k, z)$$
$$= \sum_{i'} \mu_e(i'|i) \sum_{k'} \pi_e(k'|k) \left[(1-\alpha) G_z(\tilde{z}_{\tau+1,i'}(k')|z) + \alpha \int G_z(z_{\tau+1,i'}(k', x')|z) dG_x(x')\right] \mathcal{P}^{ej}_{\tau+1}(k'). \tag{55}$$

for all $\tau = 1, ..., T-1$, $i = 0, 1$, $(k, z) \in \mathcal{K} \times \mathcal{Z}$, and for all destination state $j \in \{u, n\}$.

Considering a revealed-quality match, we have

$$\lambda_{\tau,ej,i}(k, x, z) = \sum_{i'} \mu_e(i'|i) \sum_{k'} \pi_e(k'|k) G_z(z_{\tau+1,i}(k, x)|z) \mathcal{P}^{ej}_{\tau+1}(k'), \tag{56}$$

for all $\tau = 1, ..., T-1$, $i = 0, 1$, $(k, x, z) \in \mathcal{K} \times \mathcal{X} \times \mathcal{Z}$, and all $j \in \{u, n\}$.

Moreover, recall that all workers are born in nonparticipation and choose between nonparticipation and unemployment at the end of age $\tau = 0$. Hence, we have the age $t = 0$ transition probabilities:

$$\lambda_{0,nn,i}(k) = \mathcal{P}^{nn}_{1,i}(k)$$
$$\lambda_{0,nu,i}(k) = \mathcal{P}^{nu}_{1,i}(k), \tag{57}$$

for $k = k_0$, $i = 0$, which, are, by assumptions, values for the state variables at birth.

3.6 Labor-market flows and distributions

See appendix B.1.

3.7 Labor-market tightness

The free-entry condition implies, using the Cobb-Douglas functional form for the matching function:

$$\theta^{\eta} = \frac{\beta A}{c} \frac{1-\gamma}{1-\gamma\psi} \sum_{\tau=1}^{T-1} \sum_{i\in\{0,1\}} \mu_o(i'|i) \sum_{k\in\mathcal{K}} \pi_o(k'|k)$$
$$\times \left\{ \frac{s^*_{\tau,n,i}(k) n_{\tau,i}(k)}{\mathcal{L}^*_n + \mathcal{L}^*_u} \max\left(\tilde{S}_{\tau+1,ne,i'}(k'), 0\right) + \frac{s^*_{\tau,u,i}(k) u_{\tau,i}(k)}{\mathcal{L}^*_n + \mathcal{L}^*_u} \max\left(\tilde{S}_{\tau+1,ue,i'}(k'), 0\right) \right\}, \quad (58)$$

where

$$\mathcal{L}^*_n = \sum_{\tau=1}^{T-1} \sum_{i\in\{0,1\}} \sum_{k\in\mathcal{K}} s^*_{\tau,n,i}(k) n_{\tau,i}(k) \quad (59)$$
$$\mathcal{L}^*_u = \sum_{\tau=1}^{T-1} \sum_{i\in\{0,1\}} \sum_{k\in\mathcal{K}} u^*_{\tau,n,i}(k) u_{\tau,i}(k) \quad (60)$$

represent the effective measure of job seekers in nonparticipation and unemployment, respectively (total number of agents who are out of work in these two states multiplied by their optimal search intensity).

3.8 Equilibrium definition

Definition 1. *A steady-state equilibrium is a list of value functions* $\left\{V_{\tau,n,i}, V_{\tau,u,i} : \tau = 1, ..., T; i = 0, 1\right\}$*, surplus functions* $\left\{\tilde{S}_{\tau,ne,i}, \tilde{S}_{\tau,ue,i}, \tilde{S}_{\tau,i}, S_{\tau,i} : \tau = 2, ..., T; i = 0, 1\right\}$*, policy functions* $\{s^*_{\tau,n,i}, s^*_{\tau,u,i}, \mathcal{P}^{nu}_{\tau,i}, \mathcal{P}^{uu}_{\tau,i}, \mathcal{P}^{eu}_{\tau} : \tau = 0, ..., T; i = 0, 1\}$ *and* $\{\underline{k}_{\tau,n,i}, \underline{k}_{\tau,u,i}, \tilde{z}_{\tau,i}, z_{\tau,i} : \tau = 2, ..., T; i = 0, 1\}$*, wage functions* $\{\tilde{\omega}_{\tau,ne,i}, \tilde{\omega}_{\tau,ue,i}, \tilde{\omega}_{\tau,i}, \omega_{\tau,i} : \tau = 0, ..., T; i = 0, 1\}$*, labor market stocks* $\{n_{\tau,i}(k), u_{\tau,i}(k) : \tau = 0, ..., T; i = 0, 1; k \in \mathcal{K}\}$*, and a labor-market tightness* θ *such that* (10)-(60) *are satisfied and such that labor-market stocks and distributions are time-invariant.*

4 Calibration

We calibrate the model and illustrate some of its key properties. We focus on the following five economies: France, Germany, Italy, Spain, and the U.K. We calibrate the model for men and women. For all economies, there are two sets of parameters: those that are uniform across economies vs. those specific to each economy. We describe these parameters below.

Functional forms, exogenous distributions, stochastic processes. We assume that the match quality x follows a log-normal distribution with parameters denoted μ_x and σ^2_x. We let $\mu_x = -\sigma^2_x/2$ so the match quality distribution has unconditional mean normalized to one, and we calibrate the variance of the log match quality σ^2_x internally (see below). Moreover, we let the stochastic match-output component z, taken in log terms, follow a first-order autoregressive process with mean zero:

$$\ln z' = \rho_z \ln z + \varepsilon'.$$

with $\rho_z \in (0,1)$ the persistence parameter and $\varepsilon' \sim \mathcal{N}(0, \sigma_\varepsilon^2)$ is an i.i.d. innovation term.

Common technology parameters. For the following parameters, we use the same values for all countries and demographic groups. The time unit is set to a quarter. The discount factor β is 0.9902, consistent with an annual discount rate of 4 percent. As is standard in the literature, the vacancy-elasticity of the matching function η and the bargaining power of workers γ are both set to the same value of 0.5. Motivated by the observation that shocks in empirical wage-earnings equations are close to unit-root processes, we set $\rho_z = 0.975$ to make match productivity highly persistent. In addition, we let $\sigma_\varepsilon = (1-\rho_z)^{1/2} = 0.1581$ to let the standard deviation of the log-stochastic output component to be equal to one. Finally, we let the efficiency of matching, A, to be equal across countries. We calibrate the model in partial equilibrium in the sense that we treat $p(\theta)$, the probability of contact per unit of time dedicated to search, as a parameter that is internally calibrated (see below for details). Specifically, we set $A = 0.4$ in all countries and then we compute the equilibrium posting cost c_v consistent with the calibrated value of $p(\theta)$. Finally, we let the human capital grid to have equal spacing between points, mid-point equal to one, and a lower-to-upper bound ratio equal to two. This mimics the fact that in OECD countries, wages roughly double between labor-market entry and prime age (see, for instance, Lagakos et al. [2018]). At first glance, this might be seen as arbitrary but one should keep in mind that agents' decisions are determined by the probability of skill acquisition $\overline{\pi}_e$ conditional on the grid (see Jung and Kuhn [2019]). This parameter will be internally calibrated.

Labor-market policies. We use OECD data on retirement, UI benefits, EPL, and tax wedges to set the policy parameters. The parameters $T, \overline{\mu}_o, \overline{\mu}_e$ are externally calibrated. We use estimates on the effective retirement age by country for men and women in OECD [2021] to set country-specific and gender-specific value for the retirement time horizon T. We set $\overline{\mu}_o = .2212$ in all countries to make eligibility for high UI benefits last one year on average. This is motivated by the observation that in the countries under scrutiny, UI replacement ratios decline sharply after one year of unemployment but display, in comparison, low variation within the first year. Finally, we set $\pi_e = .1175$ to make EPL apply after two years on average. This is motivated by the fact that in many countries, low-tenure workers are in temporary jobs for which the regular EPL rule does not apply, with a typical maximum duration equal to two years.

Country-specific structural/policy-invariant parameters. The remaining parameters are: $c_v, \overline{c}_{eu}, \overline{c}_{nu}, \overline{c}_u, \chi_u, \chi_n, \overline{\pi}_e, \alpha, \sigma_x, y_o, \zeta$. These are policy-invariant parameters that describe technology, skills, and preferences (broadly speaking). We treat these parameters as country specific. We also allow a subset of these parameters to vary across genders. Specifically, the production technology and skill parameters c_v, κ, α and σ_x are common to men and women, but those related to non-work utility and workers' search activities $\chi_u, \chi_n, \zeta, y_o, \overline{c}_{eu}, \overline{c}_{nu}, \overline{c}_u$ are allowed to be different. We interpret these differences as reflecting heterogeneity in home production technologies due to factors such as childcare or family responsibility. All the other parameters are assumed to be the same for men and women (i.e., the preset parameters and the institution parameters).

These parameters are set to match the six aggregate transition rates between the states N, U, and E by gender and the employment rate by age for both men and women. We show the calibrated parameter values in tables 4 and 5. The model fit to targeted institutions and transition rates is shown in table 6 and in figure 3c. Lastly, we show the fit of our model to the non-targeted transition rates by age and gender for each of the five countries under scrutiny in figures 4c to 13c.

Table 4: Common preset parameter values

β	discount factor	0.9902
γ	bargaining power	0.5
η	elasticity of matching	0.5
A	efficiency of matching	0.4
$\underline{k}$	human capital: lowest level	0.61
$\overline{k}$	human capital: highest level	1.65
ρ_z	match output shocks: persistence	0.97
σ_ε^2	match output shocks: innovation variance	0.03
$\overline{\mu}_o$	UB, regime-change probability	0.22
$\overline{\mu}_e$	EPL, regime-change probability	0.12

Table 5: Country-specific parameters

		France		**Germany**		**Italy**		**Spain**		**U.K.**	
Institutions											
T	retirement age	60		63		62		63		64	
b_0	UB, low level	0.55		0.23		0.12		0.53		0.17	
b_1	UB, high level	0.70		0.65		0.64		0.79		0.34	
F	firing costs	1.60		2.09		2.71		1.99		0.85	
ψ	wage tax rate	0.40		0.30		0.30		0.20		0.10	
ϕ	output tax rate	0.10		0.10		0.10		0.10		0.10	
Technology/skills											
σ_x^2	match quality, variance	0.22		0.64		0.57		0.35		0.53	
α	match quality, revelation prob.	0.33		0.32		0.54		0.46		0.48	
κ	skill accumulation prob.	0.03		0.04		0.07		0.02		0.04	
Search/leisure		*Men*	*Wom.*	*Men*	*Wom.*	*Men*	*Wom.*	*Men*	*Wom.*	*Men*	*Wom.*
ζ	search cost, curvature	1.98		1.71		2.40		1.69		2.24	
y_o	non-work utility	0.27	0.41	0.57	0.84	0.47	0.89	0.73	0.98	0.63	0.90
$\bar{c}_u$	period unemp. cost	0.51	0.51	0.22	0.32	0.17	0.38	0.58	0.61	0.57	0.34
c_{eu}	unemp. entry cost, from emp.	3.15	3.87	4.66	5.00	4.86	4.57	2.82	2.47	4.25	4.20
c_{nu}	unemp. entry cost, from nonpart.	9.11	8.65	7.90	7.62	7.18	6.62	7.34	6.01	6.83	7.03
χ_u	search cost, slope, in unemp.	1.90	2.75	3.63	3.79	5.01	5.78	1.23	1.60	4.66	7.22
χ_n	search cost, slope, in nonpart.	11.54	10.98	8.68	9.62	9.30	19.63	10.67	10.45	13.55	12.29

Table 6: Model fit to targeted moments

	France		**Germany**		**Italy**		**Spain**		**U.K.**	
	Target	*Model*	*Target*	*Model*	*Target*	*Model*	*Target*	*Model*	*Target*	*Model*
Institutions										
$b_0/\overline{w}$	0.55	0.51	0.13	0.13	0.05	0.06	0.50	0.42	0.10	0.10
$b_1/\overline{w}$	0.65	0.64	0.60	0.38	0.60	0.34	0.65	0.63	0.20	0.21
$F/\overline{w}$	1.50	1.48	1.25	1.24	1.50	1.45	1.50	1.58	0.50	0.53
Labor-market transitions, men										
NU	1.92	1.92	1.57	1.65	3.23	3.20	2.78	2.76	2.34	2.41
NE	4.01	4.05	7.93	7.92	6.99	7.48	3.71	3.69	5.94	6.18
UN	1.71	1.72	2.18	2.27	2.76	2.83	1.87	2.62	4.82	4.78
UE	14.26	14.17	16.55	13.44	13.59	12.39	17.25	18.11	20.61	19.19
EN	0.70	0.19	1.20	1.07	1.10	0.92	0.69	0.45	0.89	0.89
EU	1.72	1.60	1.90	1.78	1.76	1.33	3.68	3.18	1.10	0.95
Labor-market transitions, women										
NU	0.90	0.89	0.95	0.98	2.00	2.00	3.55	3.72	0.92	0.92
NE	3.60	3.63	6.75	6.67	2.78	3.19	3.48	3.48	6.35	6.48
UN	2.77	2.76	4.92	4.89	7.01	7.02	4.77	5.20	7.88	7.61
UE	13.86	8.14	15.90	13.18	11.24	10.30	14.98	13.72	22.64	11.35
EN	1.05	1.05	3.06	3.20	2.21	2.23	1.44	1.44	2.34	2.34
EU	1.82	1.87	1.45	1.52	1.98	1.97	4.35	4.77	0.80	0.80

5 Quantitative results

[To be completed.]

5.1 Cross-country employment decomposition

We use the calibrated model to decompose the differences in the aggregate employment rates into three components reflecting differences originating in (i) the technology of production and labor-market search and (ii) policies. We focus on the following five calibrated economies: France, Germany, Italy, Spain, and the U.K. Define the following vector of country-specific parameters:

$$\vartheta = (\sigma_x^2, \alpha, \kappa, \zeta, y_o, \overline{c}_u, c_{eu}, c_{nu}, \chi_u, \chi_n) \tag{61}$$

$$\varphi = (T, b_0, b_1, F, \psi, \phi); \tag{62}$$

the vector $\vartheta \in \Theta \subset \mathbb{R}^{L_\vartheta}$ of size L_ϑ has parameters describing technology, whereas $\varphi \in \Phi \subset \mathbb{R}^{L_\varphi}$ of size L_φ captures policies. Consider $E : \Theta \times \Phi \to [0, 1]$, the employment rate generated by the model as a function of the vector of parameters (ϑ, φ). We consider the following additive decomposition for the aggregate model employment difference between country c and a reference country r:

$$\begin{aligned} E(\vartheta^c, \varphi^c) - E(\vartheta^r, \varphi^r) = & \underbrace{\frac{1}{2}\Big[\big(E(\vartheta^c, \varphi^c) - E(\vartheta^r, \varphi^c)\big) + \big(E(\vartheta^c, \varphi^r) - E(\vartheta^r, \varphi^r)\big)\Big]}_{\text{technology}} \\ & + \underbrace{\frac{1}{2}\Big[\big(E(\vartheta^c, \varphi^c) - E(\vartheta^c, \varphi^r)\big) + \big(E(\vartheta^r, \varphi^c) - E(\vartheta^r, \varphi^r)\big)\Big]}_{\text{policy}}, \end{aligned} \tag{63}$$

for all $\vartheta^c, \vartheta^r \in \Theta$ and $\varphi^c, \varphi^r \in \Phi$, where ϑ^j and φ^j are the parameters specific to country $j \in \{c, r\}$. The two highlighted additive components measure the respective contributions of the technology (production and search) and the policy parameters to the total employment difference between countries c and r. The same decomposition can evidently be applied to any equilibrium outcome of the model, including the participation rate, the unemployment rate, and the aggregate worker flows. [TBC]

6 Conclusion

In this paper, we provide a comprehensive account of the relationship between cross-country differences in aggregate employment and disaggregated differences in worker flows along the life cycle. Overall, our results shed light on the importance of separations when accounting for differences in employment outcomes both aggregate and over the life cycle across Europe. Our result complements the empirical literature on the importance of the worker flows in explaining the dynamics of unemployment. We also go beyond description by developing a model that speaks to the facts we document. Our model features worker flows across employment, unemployment and nonparticipation, that move over the life cycle in ways that are qualitatively and quantitatively in line with the data. We use the model to draw inferences about the role of technology, preferences for work, and labor market institutions in explaining the life-cycle profiles of worker flows.

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Appendices

A Additional Tables

List of Tables

Table 7a: Average transition probabilities: Men

	Aged 16 to 65						Aged 25 to 54					
	EU	*EN*	*UE*	*UN*	*NE*	*NU*	*EU*	*EN*	*UE*	*UN*	*NE*	*NU*
Nordic countries:												
Denmark	1.27	1.58	17.89	8.85	6.20	2.28	1.17	0.80	18.71	5.84	7.62	3.03
Finland	2.57	3.29	16.75	6.39	10.49	2.75	2.34	1.72	18.67	5.11	14.12	4.81
Iceland	1.60	3.78	30.44	7.58	34.20	5.18	1.48	1.98	30.98	6.71	27.49	6.77
Norway	0.51	1.37	17.32	5.94	5.71	1.21	0.51	0.77	15.77	5.68	7.81	1.81
Sweden	1.46	2.62	27.66	13.68	13.96	4.33	1.14	1.16	30.81	8.51	17.07	4.96
Average	**1.48**	**2.53**	**22.01**	**8.49**	**14.11**	**3.15**	**1.33**	**1.29**	**22.99**	**6.37**	**14.82**	**4.28**
Western Europe:												
Austria	2.12	1.34	26.08	4.68	4.46	1.26	1.97	0.57	28.22	3.02	7.70	2.31
Belgium	1.03	1.10	7.61	4.37	3.05	2.05	0.93	0.74	10.82	2.54	5.60	2.61
Switzerland	0.61	1.11	25.49	6.83	7.80	1.24	0.52	0.43	27.51	5.61	11.46	2.58
Germany	0.93	0.82	9.64	4.06	4.65	1.25	0.77	0.29	10.48	2.46	7.04	3.01
France	1.57	0.71	13.82	2.11	1.82	0.90	1.39	0.18	15.55	1.21	3.78	2.02
Ireland	1.77	1.20	9.22	2.71	4.54	1.92	1.68	0.49	10.01	2.13	5.46	2.72
Luxembourg	0.94	0.50	16.35	3.12	1.47	0.63	0.86	0.23	17.62	1.99	4.23	1.57
Netherlands	0.89	1.45	11.56	3.74	6.15	0.79	0.84	0.75	14.20	2.69	11.57	2.27
United Kingdom	1.05	1.10	19.87	5.92	5.02	1.56	0.91	0.54	20.04	4.70	5.39	2.09
Average	**1.21**	**1.04**	**15.52**	**4.17**	**4.33**	**1.29**	**1.10**	**0.47**	**17.16**	**2.93**	**6.91**	**2.35**
Southern Europe:												
Cyprus	3.03	0.66	27.26	3.03	2.57	1.94	2.86	0.23	29.24	2.06	4.88	3.46
Spain	3.60	0.78	16.96	2.12	3.27	1.92	3.49	0.36	18.48	1.43	4.37	3.43
Greece	2.80	0.66	17.49	1.88	1.85	1.80	2.83	0.26	18.64	1.15	2.97	2.86
Italy	1.62	1.00	12.33	3.02	2.83	1.87	1.55	0.60	13.57	2.45	6.97	3.60
Malta	0.70	0.97	11.60	3.12	3.16	0.81	0.64	0.41	11.02	2.06	4.77	1.73
Portugal	2.64	2.21	14.83	3.66	6.73	2.25	2.55	1.97	15.45	3.00	6.91	2.96
Average	**2.40**	**1.05**	**16.75**	**2.81**	**3.40**	**1.76**	**2.32**	**0.64**	**17.73**	**2.03**	**5.14**	**3.01**
Baltic States:												
Estonia	2.06	1.16	16.81	3.81	4.98	1.56	1.95	0.65	17.06	2.46	5.50	1.61
Lithuania	2.30	1.07	14.77	2.57	4.01	1.55	2.22	0.64	15.08	1.75	3.82	2.25
Latvia	3.06	0.98	16.13	2.56	4.07	1.98	2.99	0.52	16.57	1.75	4.93	3.09
Average	**2.47**	**1.07**	**15.90**	**2.98**	**4.35**	**1.69**	**2.39**	**0.60**	**16.24**	**1.98**	**4.75**	**2.32**
Eastern Europe:												
Bulgaria	2.82	0.89	13.18	1.30	3.06	1.44	2.67	0.42	14.05	0.79	4.78	1.52
Czech Republic	1.10	0.47	16.04	2.62	1.91	1.17	0.94	0.12	16.64	1.22	3.25	1.73
Croatia	3.40	1.69	10.36	1.32	5.50	1.72	3.13	0.71	10.73	0.84	5.33	1.51
Hungary	2.63	1.01	23.23	3.45	2.67	1.19	2.51	0.55	25.27	2.61	4.79	1.73
Poland	1.93	1.08	17.89	2.49	3.54	1.49	1.77	0.67	19.27	1.86	4.88	1.58
Romania	0.42	0.51	10.83	2.90	1.65	0.57	0.42	0.34	12.03	2.59	3.29	1.12
Slovenia	1.46	0.50	13.55	8.23	1.82	2.19	1.28	0.18	15.53	6.38	3.75	5.53
Slovakia	1.38	0.93	13.32	2.36	2.98	1.81	1.21	0.62	13.31	1.38	4.72	2.31
Average	**1.89**	**0.89**	**14.80**	**3.08**	**2.89**	**1.45**	**1.74**	**0.45**	**15.85**	**2.21**	**4.35**	**2.13**
European Average	**1.78**	**1.24**	**16.66**	**4.21**	**5.36**	**1.76**	**1.66**	**0.64**	**17.78**	**3.03**	**6.98**	**2.73**

NOTE: The entries in the table are averages of quarterly transition probabilities expressed in percentage point. The last row of each country group reports the (unweighted) average of the numbers in each column.

Table 7b: Average transition probabilities: Women

	Aged 16 to 65						Aged 25 to 54					
	EU	*EN*	*UE*	*UN*	*NE*	*NU*	*EU*	*EN*	*UE*	*UN*	*NE*	*NU*
Nordic countries:												
Denmark	1.17	2.36	17.22	10.04	5.80	2.27	1.18	1.37	18.74	8.37	6.97	4.15
Finland	2.13	4.69	18.32	8.61	11.64	2.15	1.89	3.24	20.74	7.53	14.11	3.03
Iceland	1.28	4.32	28.13	13.84	20.47	3.91	1.32	2.87	30.13	12.35	17.92	4.95
Norway	0.57	2.22	16.92	5.71	5.39	0.69	0.56	1.61	16.90	5.08	7.70	1.20
Sweden	1.21	3.98	25.92	16.49	15.19	3.52	1.04	2.26	26.34	12.63	16.76	4.09
Average	**1.27**	**3.52**	**21.30**	**10.94**	**11.70**	**2.51**	**1.20**	**2.27**	**22.57**	**9.19**	**12.69**	**3.49**
Western Europe:												
Austria	2.00	2.55	21.42	7.11	4.09	0.96	1.93	1.88	22.68	6.16	6.21	1.51
Belgium	1.26	1.67	8.52	4.36	2.95	1.26	1.16	1.40	10.77	3.64	4.89	1.44
Switzerland	0.70	2.19	19.44	7.95	6.51	0.90	0.67	1.54	20.00	7.42	8.31	1.33
Germany	0.89	1.71	8.15	5.31	4.98	1.33	0.79	1.36	8.88	4.54	6.54	1.98
France	1.67	1.04	13.38	3.14	2.17	0.69	1.56	0.57	15.25	2.44	3.81	0.98
Ireland	1.69	2.80	19.44	6.90	3.96	0.84	1.56	2.25	20.57	6.46	4.29	0.98
Luxembourg	1.08	1.32	16.74	6.09	2.02	0.57	1.07	1.18	16.36	5.86	3.75	0.76
Netherlands	0.87	1.79	8.80	3.60	4.66	0.61	0.88	1.19	11.03	3.02	6.50	1.16
United Kingdom	0.75	2.46	21.53	7.88	5.48	0.83	0.67	2.00	21.34	7.32	6.80	0.94
Average	**1.21**	**1.95**	**15.27**	**5.82**	**4.09**	**0.89**	**1.14**	**1.49**	**16.32**	**5.21**	**5.68**	**1.23**
Southern Europe:												
Cyprus	3.67	0.94	28.24	3.49	2.11	1.40	3.45	0.61	29.27	3.03	3.13	1.33
Spain	4.39	1.41	14.88	4.59	2.68	2.52	4.38	1.02	15.68	4.27	3.28	3.85
Greece	3.23	1.63	12.87	2.80	1.73	1.21	3.31	1.28	13.63	2.67	2.40	1.52
Italy	1.88	1.98	10.80	6.62	1.93	1.53	1.90	1.63	11.54	6.60	2.86	2.11
Malta	0.50	2.15	14.47	8.74	2.19	0.28	0.37	1.77	14.34	8.85	2.45	0.24
Portugal	2.89	3.23	14.56	5.35	6.13	2.31	2.86	2.96	14.80	4.93	7.42	2.77
Average	**2.76**	**1.89**	**15.97**	**5.26**	**2.79**	**1.54**	**2.71**	**1.55**	**16.54**	**5.06**	**3.59**	**1.97**
Baltic States:												
Estonia	1.36	2.04	18.52	6.86	5.51	1.11	1.42	1.58	18.55	5.64	8.08	1.55
Lithuania	1.52	1.52	13.38	4.19	3.80	1.11	1.51	1.13	14.24	3.36	5.98	1.92
Latvia	2.11	1.84	16.29	5.19	4.14	2.08	2.11	1.43	16.36	4.38	6.22	3.38
Average	**1.67**	**1.80**	**16.06**	**5.41**	**4.48**	**1.43**	**1.68**	**1.38**	**16.39**	**4.46**	**6.76**	**2.29**
Eastern Europe:												
Bulgaria	2.41	1.44	11.13	2.66	2.51	1.18	2.43	0.90	12.36	1.89	4.80	1.86
Czech Republic	1.26	1.51	13.64	3.78	2.26	1.02	1.21	1.18	14.02	2.66	5.09	1.88
Croatia	3.40	2.04	9.56	2.73	4.02	2.14	3.17	0.74	9.52	2.49	3.25	4.11
Hungary	2.03	1.92	19.79	5.74	2.66	1.04	2.00	1.33	20.97	5.09	4.88	1.62
Poland	1.78	1.83	12.63	4.43	2.77	1.20	1.69	1.29	12.89	4.10	3.91	1.86
Romania	0.22	1.36	7.93	4.32	1.83	0.19	0.22	1.13	8.35	4.28	3.05	0.16
Slovenia	1.65	0.58	12.03	8.38	1.27	1.92	1.55	0.29	13.02	7.01	3.43	6.09
Slovakia	1.29	1.78	11.69	3.70	2.88	1.47	1.25	1.45	11.51	3.09	5.71	2.58
Average	**1.75**	**1.56**	**12.30**	**4.47**	**2.52**	**1.27**	**1.69**	**1.04**	**12.83**	**3.83**	**4.27**	**2.52**
European Average	**1.71**	**2.08**	**15.69**	**6.15**	**4.70**	**1.43**	**1.65**	**1.50**	**16.48**	**5.39**	**6.14**	**2.17**

NOTE: The entries in the table are averages of quarterly transition probabilities expressed in percentage point. The last row of each country group reports the (unweighted) average of the numbers in each column.

Table 8a: Decomposing the employment gap: Men

	Total gap	Demog-raphics	Initial cond.	Transition probab.	Transition probablities					
					EU	*EN*	*UE*	*UN*	*NE*	*NU*
Nordic countries:										
Denmark	1.32	0.27	-0.52	1.57	1.54	-1.86	0.93	-1.32	2.02	0.26
Finland	-5.42	-0.18	-0.14	-5.10	-3.69	-8.36	1.08	-0.66	5.85	0.68
Iceland	9.61	-1.00	0.32	10.30	0.51	-7.11	3.98	-0.52	12.51	0.93
Norway	1.21	-1.60	-1.08	3.89	5.71	-1.54	0.55	-0.93	0.63	-0.53
Sweden	7.04	-0.56	-0.04	7.63	0.92	-3.71	3.49	-0.98	7.08	0.84
Average	**2.75**	**-0.61**	**-0.29**	**3.66**	**1.00**	**-4.52**	**2.00**	**-0.88**	**5.62**	**0.43**
Western Europe:										
Austria	3.10	0.10	0.07	2.93	-1.27	-0.93	3.97	-0.34	1.55	-0.06
Belgium	-5.51	-0.22	0.05	-5.34	3.09	-2.78	-3.86	-0.10	-1.74	0.05
Switzerland	14.73	0.72	1.07	12.93	4.65	2.82	2.47	-0.29	3.52	-0.24
Germany	6.15	-0.03	0.49	5.69	4.10	3.25	-2.75	-0.05	1.06	0.08
France	-2.44	-1.43	-1.21	0.20	0.43	3.35	-1.35	1.29	-3.08	-0.45
Ireland	-7.40	-3.06	-0.39	-3.95	-0.81	0.15	-4.30	0.16	0.72	0.13
Luxembourg	1.13	1.15	-1.20	1.18	3.05	2.03	-0.25	0.31	-3.17	-0.80
Netherlands	4.09	1.28	-0.31	3.12	3.23	-2.92	-0.62	0.45	3.36	-0.39
United Kingdom	5.29	0.35	-0.14	5.08	2.69	0.49	1.58	-0.89	1.31	-0.11
Average	**2.13**	**-0.12**	**-0.17**	**2.43**	**2.13**	**0.61**	**-0.57**	**0.06**	**0.39**	**-0.20**
Southern Europe:										
Cyprus	-3.22	-3.32	-0.19	0.30	-4.87	3.53	4.57	0.63	-3.12	-0.44
Spain	-4.77	1.24	-0.15	-5.87	-7.42	1.88	0.70	1.25	-2.47	0.20
Greece	-5.10	1.12	-0.65	-5.58	-4.64	1.92	1.00	1.20	-4.85	-0.21
Italy	-3.27	1.06	0.08	-4.41	-0.28	-1.08	-2.02	0.25	-1.62	0.33
Malta	3.22	-0.83	0.42	3.63	5.38	1.15	-1.91	0.32	-0.95	-0.38
Portugal	-8.25	-0.79	0.78	-8.24	-3.83	-7.60	0.07	0.14	2.80	0.17
Average	**-3.57**	**-0.25**	**0.05**	**-3.36**	**-2.61**	**-0.03**	**0.40**	**0.63**	**-1.70**	**-0.05**
Baltic States:										
Estonia	-4.77	-1.52	-0.50	-2.75	-1.96	-1.01	0.75	-0.28	0.19	-0.44
Lithuania	-6.85	-1.30	0.15	-5.70	-2.95	-1.23	-0.35	0.60	-1.50	-0.27
Latvia	-5.76	-0.90	0.20	-5.06	-5.84	-0.91	0.51	0.87	0.04	0.28
Average	**-5.79**	**-1.24**	**-0.05**	**-4.50**	**-3.58**	**-1.05**	**0.30**	**0.40**	**-0.42**	**-0.14**
Eastern Europe:										
Bulgaria	-5.74	-0.23	0.13	-5.64	-5.16	1.10	-1.64	1.90	-1.43	-0.42
Czech Republic	3.01	-0.41	-1.18	4.60	2.33	6.30	0.16	1.73	-5.00	-0.91
Croatia	-13.63	-0.44	-0.04	-13.15	-6.81	-4.77	-4.67	1.31	1.79	-0.01
Hungary	-4.86	-0.88	0.09	-4.06	-3.67	-1.15	3.09	0.21	-2.06	-0.48
Poland	-2.62	-0.13	0.26	-2.75	-1.01	-2.06	0.94	0.51	-0.75	-0.38
Romania	7.44	0.21	2.62	4.61	7.23	5.55	-2.80	0.86	-5.03	-1.20
Slovenia	-3.17	0.65	-0.02	-3.80	0.44	2.91	-0.91	-2.07	-5.17	1.00
Slovakia	-3.53	-1.45	0.41	-2.49	1.31	-0.27	-1.79	1.23	-2.46	-0.51
Average	**-2.89**	**-0.34**	**0.28**	**-2.84**	**-0.67**	**0.95**	**-0.95**	**0.71**	**-2.51**	**-0.36**

NOTE: The entries in the table are employment gaps (relative to the population-weighted average of employment across countries) expressed in percentage point. The first column shows the raw employment gap; the second and third columns show the gap explained by differences in demographics and initial conditions, respectively; the fourth column shows the gap explained by differences in transition probabilities. The latter is decomposed into the gap explained by each transition probability in the remaining columns of the table. The last row of each country group reports the (unweighted) average of the numbers in each column.

Table 8b: Decomposing the employment gap: Women

	Total gap	Demog-raphics	Initial cond.	Transition probab.	*EU*	*EN*	*UE*	*UN*	*NE*	*NU*
					Transition probablities					
Nordic countries:										
Denmark	4.81	-0.36	-0.53	5.70	1.72	-0.45	1.46	-1.02	2.86	1.12
Finland	3.41	-0.55	-0.14	4.10	-1.75	-8.89	2.45	-0.65	11.98	0.95
Iceland	17.14	-0.44	0.43	17.16	1.42	-5.81	4.08	-1.12	17.23	1.36
Norway	3.65	-1.75	-1.08	6.47	4.81	-0.52	0.95	-0.10	2.26	-0.93
Sweden	14.96	-0.38	0.01	15.33	1.89	-3.25	3.15	-0.92	13.35	1.12
Average	**8.79**	**-0.70**	**-0.26**	**9.75**	**1.62**	**-3.78**	**2.42**	**-0.76**	**9.54**	**0.72**
Western Europe:										
Austria	-1.56	0.52	-0.77	-1.31	-1.03	-4.21	3.06	-0.42	1.70	-0.41
Belgium	-2.91	-0.58	-0.06	-2.26	2.14	-0.16	-2.90	0.36	-1.45	-0.25
Switzerland	14.69	0.08	1.43	13.18	4.17	0.88	1.58	-0.15	7.07	-0.38
Germany	7.40	0.64	0.35	6.40	4.08	2.63	-2.93	0.29	2.37	-0.04
France	2.70	-0.82	-0.67	4.19	-0.20	8.06	-0.30	1.82	-4.11	-1.07
Ireland	-6.38	-0.73	-0.40	-5.25	-0.17	-5.50	2.28	-0.65	-0.11	-1.11
Luxembourg	0.00	1.04	-2.16	1.12	2.83	3.28	0.66	-0.03	-4.25	-1.38
Netherlands	6.51	0.93	-0.12	5.69	3.56	0.56	-1.86	0.49	3.57	-0.62
United Kingdom	6.97	0.47	0.07	6.44	3.65	-2.51	2.18	-0.65	4.57	-0.79
Average	**3.05**	**0.17**	**-0.26**	**3.13**	**2.11**	**0.34**	**0.20**	**0.12**	**1.04**	**-0.67**
Southern Europe:										
Cyprus	0.18	-1.79	-0.82	2.79	-6.65	7.45	6.16	1.71	-5.37	-0.52
Spain	-6.20	0.92	0.05	-7.17	-9.43	2.74	0.40	0.56	-3.55	2.11
Greece	-12.32	0.41	-0.06	-12.67	-5.12	0.40	-0.95	1.56	-8.31	-0.27
Italy	-13.21	0.47	-0.08	-13.60	-0.97	-2.13	-2.21	-0.72	-7.95	0.38
Malta	-7.18	-0.92	0.21	-6.48	6.06	-1.99	0.35	-0.96	-7.27	-2.67
Portugal	-3.55	-0.62	0.39	-3.31	-4.28	-7.27	0.38	0.48	6.35	1.03
Average	**-7.05**	**-0.25**	**-0.05**	**-6.74**	**-3.40**	**-0.13**	**0.69**	**0.44**	**-4.35**	**0.01**
Baltic States:										
Estonia	3.92	-1.87	-0.08	5.87	0.78	0.25	1.67	-0.40	3.98	-0.43
Lithuania	1.68	-1.46	-0.10	3.24	0.23	2.29	-0.08	0.40	0.52	-0.12
Latvia	1.61	-1.30	-0.04	2.96	-2.32	1.41	1.46	0.25	0.84	1.32
Average	**2.40**	**-1.55**	**-0.07**	**4.02**	**-0.44**	**1.32**	**1.02**	**0.09**	**1.78**	**0.26**
Eastern Europe:										
Bulgaria	-3.25	-1.02	-0.03	-2.21	-3.58	3.62	-1.70	2.06	-2.44	-0.17
Czech Republic	-0.82	-1.31	-1.30	1.79	1.50	3.98	-0.52	1.70	-4.61	-0.26
Croatia	-9.71	-1.16	-0.04	-8.51	-6.24	0.23	-4.69	1.75	-1.43	1.88
Hungary	-4.88	-1.70	-0.02	-3.17	-1.52	-0.88	2.18	-0.06	-2.59	-0.29
Poland	-5.98	-1.12	0.02	-4.89	-0.14	-0.86	-1.13	0.45	-3.15	-0.04
Romania	-1.93	-0.60	0.73	-2.07	8.27	3.80	-3.30	0.48	-8.74	-2.56
Slovenia	-1.00	-0.54	-0.30	-0.16	-0.14	7.94	-2.22	-1.25	-7.19	2.70
Slovakia	-1.39	-1.48	-0.41	0.50	1.54	0.16	-1.82	1.44	-1.13	0.31
Average	**-3.62**	**-1.11**	**-0.17**	**-2.34**	**-0.04**	**2.25**	**-1.65**	**0.82**	**-3.91**	**0.20**

NOTE: The entries in the table are employment gaps (relative to the population-weighted average of employment across countries) expressed in percentage point. The first column shows the raw employment gap; the second and third columns show the gap explained by differences in demographics and initial conditions, respectively; the fourth column shows the gap explained by differences in transition probabilities. The latter is decomposed into the gap explained by each transition probability in the remaining columns of the table. The last row of each country group reports the (unweighted) average of the numbers in each column.

B Model Appendix

B.1 Labor-market flows and distributions

- Let $n_{\tau,i}(k)$, $u_{\tau,i}(k)$, $\tau = 0,...,T$ and $i \in \{0,1\}$ represent measures of individuals in non-participation and unemployment, age τ, UI status i. Let $e_{\tau,i}$ $\tau = 0,...,T$ and $i \in \{0,1\}$ be the measure of employed individuals with age τ, EPL status i. In addition, $\tilde{\alpha}_{\tau,i} \in [0,1]$ $\tau = 0,...,T$, $i \in \{0,1\}$ is the employment share of matches with revealed quality (given age τ and EPL status i).

- Let $\tilde{\mathcal{H}}_{z,\tau,i}(z|k)$, $k \in \mathcal{K}$, $\tau = 0,...,T$, and $i \in \{0,1\}$ be the fraction of unrevealed-quality matches with stochastic match-output component $\tilde{z} \leq z$, $z \in \mathcal{Z}$, conditional on human capital k, age τ, and EPL status i. Moreover, $\mathcal{H}_{z,\tau,i}(z|\,k,x)$ is the same fraction, but considering the revealed-quality matches and conditioning on match quality $x \in \mathcal{X}$.

- In addition, $\mathcal{H}_{x,\tau,i}(x|\,k)$ is the fraction of matches with (revealed) quality $\tilde{x} \leq x \in \mathcal{X}$ conditional on age and EPL status.

- Lastly, let $\tilde{h}_{z,\tau,i}(.\,|\,k)$, $h_{z,\tau,i}(.\,|\,k,x)$ and $h_{x,\tau,i}(.\,|\,k)$ be the equilibrium density functions associated with the above defined c.d.f.

- Define $\lambda_{\tau,nn,i} \equiv 1-\lambda_{\tau,nu,i}-\lambda_{\tau,ne,i}$, $\lambda_{\tau,uu,i} \equiv 1-\lambda_{\tau,un,i}-\lambda_{\tau,ue,i}$, and $\lambda_{\tau,ee,i} \equiv 1-\lambda_{\tau,en,i}-\lambda_{\tau,eu,i}$ for $i \in \{0,1\}$ and $\tau = 0,...,T-1$.

Aggregate labor market flows. *Non-participation outflow rates:*

$$\Lambda_{nj} = \sum_{\tau=0}^{T-1} \sum_{i\in\{0,1\}} \sum_{k\in\mathcal{K}} \frac{n_{\tau,i}(k)}{\mathcal{L}_n} \lambda_{\tau,nj,i}(k) \tag{64}$$

for all destination state $j \in \{u, e\}$ (flows into unemployment and employment).

Unemployment outflow rates:

$$\Lambda_{uj} = \sum_{\tau=0}^{T-1} \sum_{i\in\{0,1\}} \sum_{k\in\mathcal{K}} \frac{u_{\tau,i}(k)}{\mathcal{L}_u} \lambda_{\tau,uj,i}(k) \tag{65}$$

for all destination state $j \in \{n, e\}$ (flows into nonparticipation and employment).

Employment:

$$\Lambda_{ej} = \sum_{\tau=0}^{T-1} \sum_{i\in\{0,1\}} \sum_{k\in\mathcal{K}} \Bigg[\frac{\tilde{\alpha}_{\tau,i} e_{\tau,i}(k)}{\mathcal{L}_e} \int_{x\in\mathcal{X}} \bigg(\int_{z\in\mathcal{Z}} \lambda_{\tau,ej,i}(k,x,z) d\mathcal{H}_{z,\tau,i}(z|k,x) \bigg) d\mathcal{H}_{x,\tau,i}(x|k)$$

$$+ \frac{(1-\tilde{\alpha}_{\tau,i}) e_{\tau,i}(k)}{\mathcal{L}_e} \int_{z\in\mathcal{Z}} \tilde{\lambda}_{\tau,ej,i}(k,z) d\tilde{\mathcal{H}}_{z,\tau,i}(z|k) \Bigg] \tag{66}$$

$$\tag{67}$$

for all destination state $j \in \{n, u\}$ (flows into nonparticipation and unemployment).

Distributions. Probability of transiting from $j \in \{n, u\}$, $i \in \{0, 1\}$, $k \in \mathcal{K}$ to $l \in \{n, u\}$, $i' \in (0, 1)$, $k' \in \mathcal{K}$ between age τ and $\tau + 1$:

$$\xi_{\tau,jl,ii'}(k'|k) = \mu_o(i'|i)\pi_o(k'|k)\left[1 - s^*_{j,\tau,i}(k)p(\theta)\mathcal{I}(k' \geq \underline{k}_{\tau+1,j,i'})\right]\mathcal{P}^{jl}_{\tau+1,i'}(k') \tag{68}$$

Probability of transiting from $j \in \{n, u\}$, $i \in \{0, 1\}$, $k \in \mathcal{K}$ to e (unrevealed), $(k', z', i') \in \mathcal{K} \times \{z_0\} \times \{0\}$ between age τ and $\tau + 1$:

$$\xi_{\tau,je,ii'}(k', z'|k) = \pi_o(k'|k)s^*_{j,\tau,i}(k)p(\theta) \sum_{i'' \in \{0,1\}} \mu_o(i''|i)\mathcal{I}\big(\, k' \geq \underline{k}_{j,\tau+1,i''}\,\big). \tag{69}$$

The probability of transiting to revealed-quality employment from nonemployment is zero by assumption (match are experience goods). Similarly, the probability of transiting to $(z', i') \in \big(\mathcal{Z} \setminus \{z_0\}\big) \times \{1\}$ is zero (z_0 is the starting match productivity and new match start with EPL regime $i = 0$).

Probability of transiting from e (unrevealed), state $(k, z, i) \in \mathcal{K} \times \mathcal{Z} \times \{0, 1\}$ to $j \in \{n, u\}$, $(k', i') \in \mathcal{K} \times \{0\}$:

$$\tilde{\xi}_{\tau,ej,ii'}(k'|k, z) =$$
$$\pi_e(k'|k) \sum_{i'' \in \{0,1\}} \mu_e(i''|i)\left[(1 - \alpha)G_z\big(\underline{\tilde{z}}_{\tau+1,i''}(k')|z\big) + \alpha \int_{x' \in \mathcal{X}} G_z\big(\underline{z}_{\tau+1,i''}(k', x')|z\big)dG_x(x')\right]\mathcal{P}^{ej}_{\tau+1}(k') \tag{70}$$

Note that the probability of transiting to UI state $i' = 0$ is zero (newly nonemployed workers start with high UI benefits indexed by $i' = 1$).

Density transiting from e (revealed), state $(k, x, z, i) \in \mathcal{K} \times \mathcal{X} \times \mathcal{Z} \times \{0, 1\}$ to $j \in \{n, u\}$, $(k', i') \in \mathcal{K} \times \{0\}$:

$$\xi_{\tau,ej,ii'}(k'|k, x, z) = \pi_e(k'|k) \sum_{i' \in \{0,1\}} \mu_e(i'|i)G_z\big(\underline{z}_{\tau+1,i'}(k', x)|z\big)\mathcal{P}^{ej}_{\tau+1}(k') \tag{71}$$

Density transiting from e (unrevealed), state (k, z, i) to e (unrevealed), state (k', z', i'):

$$\tilde{\tilde{\xi}}_{\tau,ee,ii'}(k', z'|k, z) = (1 - \alpha)\pi_e(k'|k)\mu_e(i'|i)\mathcal{I}(z' \geq \underline{\tilde{z}}_{\tau+1,i'}(k'))g_z(z'|z) \tag{72}$$

Density transiting from e (unrevealed) to e (revealed):

$$\tilde{\xi}_{\tau,ee,ii'}(k', x', z'|k, z) = \alpha g_x(x')\pi_e(k'|k)\mu_e(i'|i)\mathcal{I}(z' \geq \underline{z}_{\tau+1,i'}(k', x'))g_z(z'|z) \tag{73}$$

Density transiting from e (revealed) to e (revealed):

$$\xi_{\tau,ee,ii'}(k', x', z'|k, x, z) = \mathcal{I}(x' = x)\pi_e(k'|k)\mu_e(i'|i)\mathcal{I}(z' \geq \underline{z}_{\tau+1,i'}(k', x'))g_z(z'|z). \tag{74}$$

Nonparticipation stock, by age and skill:

$$n_{\tau+1,i'}(k') = \sum_i \sum_k \Big(\xi_{\tau,nn,ii'}(k'|k) n_{\tau,i}(k) + \xi_{\tau,un,ii'}(k'|k) u_{\tau,i}(k) \Big)$$
$$+ \mathcal{I}(i'=1) \sum_i \sum_k \Bigg[(1-\tilde{\alpha}_{\tau,i}) \int_z \tilde{\xi}_{\tau,en,ii'}(k'|k,z) d\tilde{\mathcal{H}}_{z,\tau,i}(z|k)$$
$$+ \tilde{\alpha}_{\tau,i} \int_x \int_z \xi_{\tau,en,ii'}(k'|k,x,z) d\mathcal{H}_{z,\tau,i}(z|k,x) d\mathcal{H}_{x,\tau,i}(x|k) \Bigg] e_{\tau,i}(k) \tag{75}$$

for all $k' \in \mathcal{K}$, $i' = 0,1$, and $\tau = 2, ..., T-1$. Unemployment:

$$u_{\tau+1,i'}(k') = \sum_i \sum_k \Big(\xi_{\tau,nu,ii'}(k'|k) n_{\tau,i}(k) + \xi_{\tau,uu,ii'}(k'|k) u_{\tau,i}(k) \Big)$$
$$+ \mathcal{I}(i'=1) \sum_i \sum_k \Bigg[(1-\tilde{\alpha}_{\tau,i}) \int_z \tilde{\xi}_{\tau,eu,ii'}(k'|k,z) d\tilde{\mathcal{H}}_{z,\tau,i}(z|k)$$
$$+ \tilde{\alpha}_{\tau,i} \int_x \int_z \xi_{\tau,eu,ii'}(k'|k,x,z) d\mathcal{H}_{z,\tau,i}(z|k,x) d\mathcal{H}_{x,\tau,i}(x|k) \Bigg] e_{\tau,i}(k) \tag{76}$$

for all $k' \in \mathcal{K}$, $i' = 0,1$, and $\tau = 2, ..., T-1$.

Employment stocks. Density of individuals of age $\tau+1$, employed in a job with unrevealed match quality, and with state (k', z', i'):

$$(1-\tilde{\alpha}_{\tau+1,i'}) e_{\tau+1,i'}(k') \tilde{h}_{z,\tau+1,i'}(z'|k') = \tilde{\tilde{\xi}}_{\tau,ee,ii'}(k',z'|k,z)(1-\tilde{\alpha}_{\tau,i}) e_{\tau,i}(k) \tilde{h}_{z,\tau,i}(z|k)$$
$$+ \mathcal{I}(z'=z_0, i'=0) \sum_i \Big(\xi_{\tau,ne,i}(k'|k) n_{\tau,i}(k) + \xi_{\tau,ue,i}(k'|k) u_{\tau,i}(k) \Big) \tag{77}$$

for $(k', z') \in \mathcal{K} \times \mathcal{Z}$, $i' = 0,1$, and $\tau = 2, ..., T-1$. Density of individuals of age $\tau+1$, employed in a job with revealed match quality, and with state (k', x', z', i'):

$$\tilde{\alpha}_{\tau+1,i'} e_{\tau+1,i'}(k') h_{z,\tau+1,i'}(z'|k',x') h_{x,\tau+1,i'}(x'|k') =$$
$$\Big(\xi_{\tau,ee,ii'}(k',x',z'|k,x,z) \tilde{\alpha}_{\tau,i} h_{z,\tau,i}(z|k,x) h_{x,\tau,i}(x|k) + \tilde{\xi}_{\tau,ee,ii'}(k',x',z'|k,z)(1-\tilde{\alpha}_{\tau,i}) \tilde{h}_{z,\tau}(z|k) \Big) e_{\tau,i}(k). \tag{78}$$

for $(k', x', z') \in \mathcal{K} \times \mathcal{Z} \times \mathcal{X}$, $i' = 0,1$, and $\tau = 2, ..., T-1$. Initial conditions:

$$\begin{aligned} n_0(k) &= \frac{1}{T+1} \mathcal{I}(k=k_0); & n_1(k') &= \pi_o(k'|k)\, \mathcal{P}^{nn}_{1,0}(k') \\ u_0(k) &= 0; & u_1(k') &= \pi_o(k'|k)\, \mathcal{P}^{nu}_{1,0}(k') \\ e_0(k) &= 0; & e_1(k') &= 0, \end{aligned} \tag{79}$$

for all $k, k' \in \mathcal{K}$.

B.2 Numerical resolution

- Consider discretized sets approximating $\mathcal{Z}$ and $\mathcal{X}$. Denote these sets by $\hat{\mathcal{Z}}$ and $\hat{\mathcal{X}}$. Let I_k, I_x, I_z be the size/cardinality of sets $\mathcal{K}$, $\hat{\mathcal{X}}$, and $\hat{\mathcal{Z}}$.

- Define the vectors with elements equal to age-specific nonemployment measures across states:

$$\begin{aligned}\mathbf{n}_\tau &= \left\{ n_{\tau,i}(k) \,:\, (k,i) \in \mathcal{K} \times \{0,1\} \right\} \\ \mathbf{u}_\tau &= \left\{ u_{\tau,i}(k) \,:\, (k,i) \in \mathcal{K} \times \{0,1\} \right\}\end{aligned} \tag{80}$$

for $\tau = 0, ..., T$.

- With an abuse of notation, define the age-specific employment measure vectors:

$$\begin{aligned}\tilde{\mathbf{e}}_\tau &= \left\{ (1-\tilde{\alpha}_{\tau,i}) e_{\tau,i}(k) \tilde{h}_{z,\tau}(z|k) \,:\, (k,z,i) \in \times \mathcal{K} \times \hat{\mathcal{Z}} \times \{0,1\} \right\} \\ \mathbf{e}_\tau &= \left\{ \tilde{\alpha}_{\tau,i} e_{\tau,i}(k) h_{z,\tau}(z|k,x) h_{x,\tau}(x|k) \,:\, (k,x,z,i) \in \times \mathcal{K} \times \hat{\mathcal{X}} \times \hat{\mathcal{Z}} \times \{0,1\} \right\}.\end{aligned} \tag{81}$$

for $\tau = 0, ..., T$.

- Define the nonemployment-to-nonemployment transition matrices:

$$\boldsymbol{\Gamma}_{\tau,jl} = \left\{ \xi_{\tau,jl,ii'}(k'|k) \,:\, (k,i) \in \mathcal{K} \times \{0,1\}; (k',i') \in \mathcal{K} \times \{0,1\} \right\} \tag{82}$$

for all $j, l \in \{n, u\}$ and $\tau = 0, ..., T-1$.

- Nonemployment to employment (unrevealed quality):

$$\boldsymbol{\Gamma}_{\tau,je} = \left\{ \xi_{\tau,jl,ii'}(k',z'|k) \,:\, (k,i) \in \mathcal{K} \times \{0,1\}; (k',z',i') \in \mathcal{K} \times \hat{\mathcal{Z}} \times \{0,1\} \right\} \tag{83}$$

for all $j \in \{n, u\}$ and $\tau = 0, ..., T-1$

- Employment to nonemployment (from unrevealed- and revealed-quality, respectively):

$$\begin{aligned}\tilde{\boldsymbol{\Gamma}}_{\tau,ej} &= \left\{ \tilde{\xi}_{\tau,ej,ii'}(k'|k,z) \,:\, (k,z,i) \in \mathcal{K} \times \hat{\mathcal{Z}} \times \{0,1\}; (k',i') \in \mathcal{K} \times \{0,1\} \right\} \\ \boldsymbol{\Gamma}_{\tau,ej} &= \left\{ \tilde{\xi}_{\tau,ej,ii'}(k'|k,x,z) \,:\, (i,k,x,z) \in \mathcal{K} \times \{0,1\} \times \hat{\mathcal{X}} \times \hat{\mathcal{Z}}; (k',i') \in \mathcal{K} \times \{0,1\} \right\}\end{aligned} \tag{84}$$

for all $j \in \{n, u\}$ and $\tau = 2, ..., T-1$.

- Employment to employment:

$$\tilde{\tilde{\mathbf{\Gamma}}}_{\tau,ee} = \left\{ \tilde{\tilde{\xi}}_{\tau,ee,ii'}(k',z'|k,z) \,:\, (k,z,i) \in \mathcal{K} \times \hat{\mathcal{Z}} \times \{0,1\}; (k',z',i') \in\in \mathcal{K} \times \hat{\mathcal{Z}} \times \{0,1\} \right\}$$
$$\tilde{\mathbf{\Gamma}}_{\tau,ee} = \left\{ \tilde{\xi}_{\tau,ee,ii'}(k',x',z'|k,z) \,:\, (k,z,i) \in \mathcal{K} \times \hat{\mathcal{Z}} \times \{0,1\}; (k',x',z',i') \in \mathcal{K} \times \hat{\mathcal{X}} \times \hat{\mathcal{Z}} \times \{0,1\} \right\}$$
$$\mathbf{\Gamma}_{\tau,ee} = \left\{ \tilde{\xi}_{\tau,ee,ii'}(k',x',z'|k,x,z) \,:\, (k,x,z,i),\, (k',x',z',i') \in \mathcal{K} \times \hat{\mathcal{X}} \times \hat{\mathcal{Z}} \times \{0,1\} \right\} \tag{85}$$

  for all $\tau = 2, ..., T-1$. These represent, respectively, transition matrices from unrevealed-quality employment to unrevealed-quality, unrevealed to revealed and revealed to revealed.

- In matrix form, the discretized equilibrium distributions satisfy the system:

$$\begin{aligned}
\mathbf{n}_\tau &= \mathbf{\Gamma}_{\tau-1,nn}\,\mathbf{n}_{\tau-1} + \mathbf{\Gamma}_{\tau-1,un}\,\mathbf{u}_{\tau-1} + \tilde{\mathbf{\Gamma}}_{\tau-1,en}\,\tilde{\mathbf{e}}_{\tau-1} + \mathbf{\Gamma}_{\tau-1,en}\,\mathbf{e}_{\tau-1} \\
\mathbf{u}_\tau &= \mathbf{\Gamma}_{\tau-1,nu}\,\mathbf{n}_{\tau-1} + \mathbf{\Gamma}_{\tau-1,uu}\,\mathbf{u}_{\tau-1} + \tilde{\mathbf{\Gamma}}_{\tau-1,eu}\,\tilde{\mathbf{e}}_{\tau-1} + \mathbf{\Gamma}_{\tau-1,eu}\,\mathbf{e}_{\tau-1} \\
\tilde{\mathbf{e}}_\tau &= \mathbf{\Gamma}_{\tau-1,ne}\,\mathbf{n}_{\tau-1} + \mathbf{\Gamma}_{\tau-1,ue}\,\mathbf{u}_{\tau-1} + \tilde{\tilde{\mathbf{\Gamma}}}_{\tau-1,ee}\,\tilde{\mathbf{e}}_{\tau-1} \\
\mathbf{e}_\tau &= \tilde{\mathbf{\Gamma}}_{\tau-1,ee}\,\mathbf{e}_{\tau-1} + \mathbf{\Gamma}_{\tau-1,ee}\,\mathbf{e}_{\tau-1},
\end{aligned} \tag{86}$$

  for $\tau = 2, ..., T$, with initial values given by conditions (79).

- The critical task for numerical implementation is to construct the transition matrices. Ideally, this construction should be "vectorized" for faster computation (i.e., expressed in terms of vector and matrix operations). With an abuse of notation, let μ_o, μ_e, π_o, and π_e represent transition matrices for the UI regime, the EPL regime, the out-of-work and employed skill dynamics, respectively. Define the policy-function vectors:

$$\begin{aligned}
&\mathbf{s}_{\tau,j,i} = \big\{ s_{\tau,j,i}(k) \,:\, k \in \mathcal{K} \big\}; && j \in \{n,u\} \\
&\mathbf{P}^{jl}_{\tau,i} = \big\{ \mathcal{P}^{jl}_{\tau,i}(k) \,:\, k \in \mathcal{K} \big\}; && j,l \in \{n,u\} \\
&\mathbf{P}^{ej}_{\tau} = \big\{ \mathcal{P}^{ej}_{\tau}(k) \,:\, k \in \mathcal{K} \big\}; && j \in \{n,u\} \\
&\gamma_{\tau,je,i} = \big\{ \mathcal{I}\big(k \geq \underline{k}_{\tau,j,i}\big) \,:\, k \in \mathcal{K} \big\}; && j \in \{n,u\} \\
&\tilde{\gamma}_{\tau,i} = \big\{ \mathcal{I}\big(z \geq \tilde{\underline{z}}_{\tau,i}(k)\big) \,:\, (k,z) \in \mathcal{K} \times \mathcal{Z} \big\} \\
&\gamma_{\tau,i} = \big\{ \mathcal{I}\big(z \geq \underline{z}_{\tau,i}(k,x)\big) \,:\, (k,x,z) \in \mathcal{K} \times \mathcal{X} \times \mathcal{Z} \big\}
\end{aligned} \tag{87}$$

  for all $\tau = 1, ..., T$, $i \in \{0,1\}$. In addition, let $\hat{g}_x$ represent the p.m.f. associated with discretized match quality $x \in \hat{X}$ and let $\hat{P}_z$ be the transition matrix associated with the stochastic match-output component. Finally, $\hat{g}_z$ is a vector of size I_z with zeros everywhere and with a one when $z = z_0$ (i.e., the entry level match quality). [TBC]

C Model fit to empirical moments

C.1 Model fit to employment rates by age and country

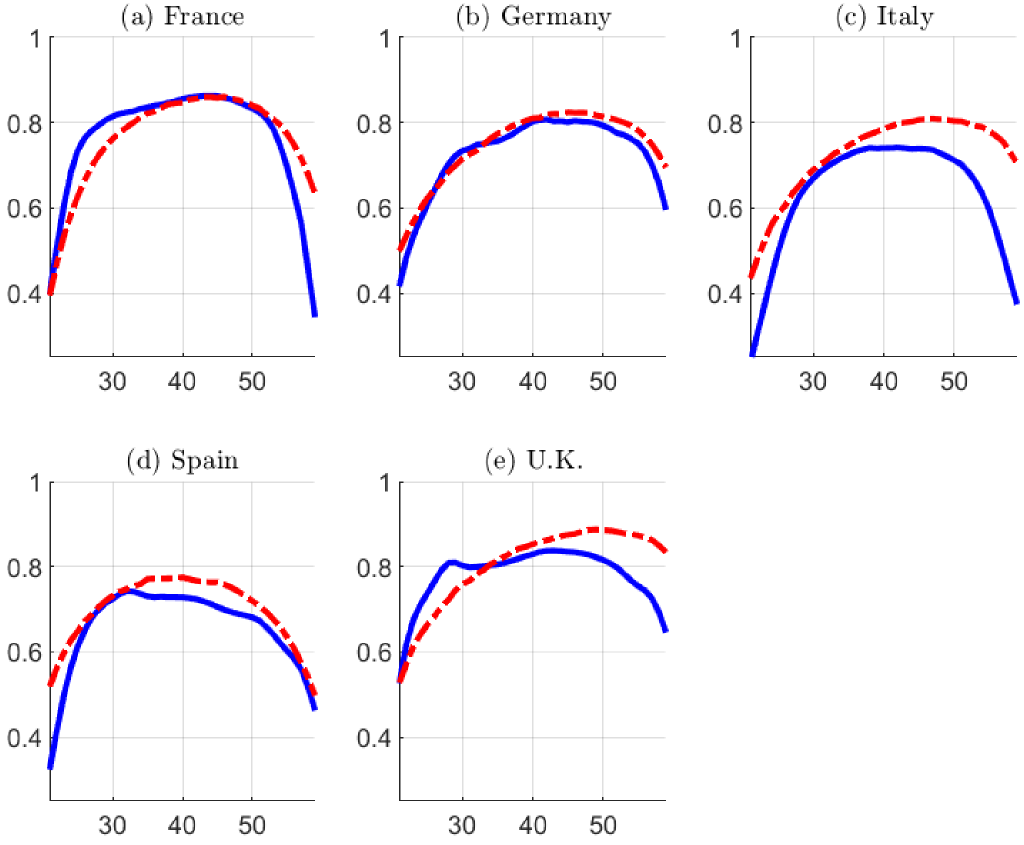

Figure 3c: Employment rate by age, data and model

C.2 Model fit to non-targeted transition probabilities by age, gender and country

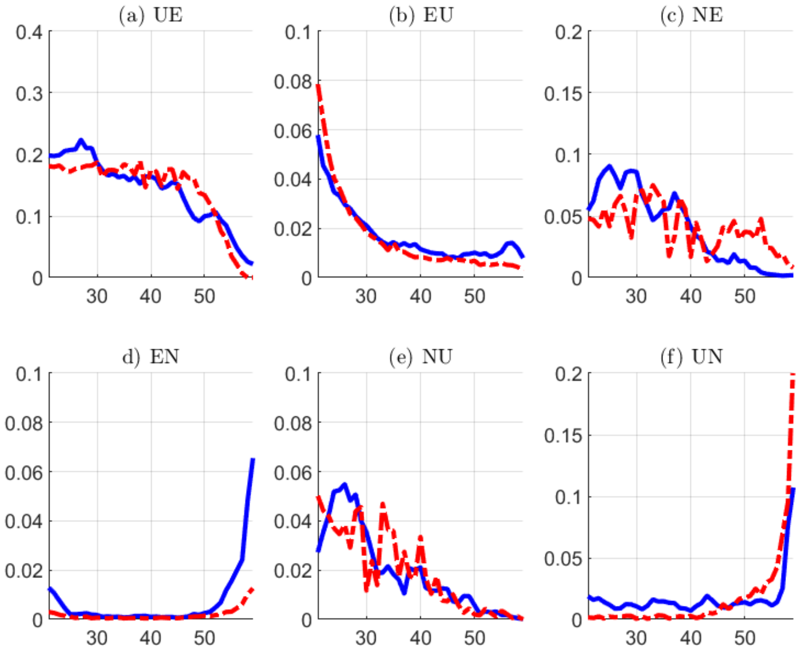

Figure 4c: Transition probabilities: data and model simulation for France, men

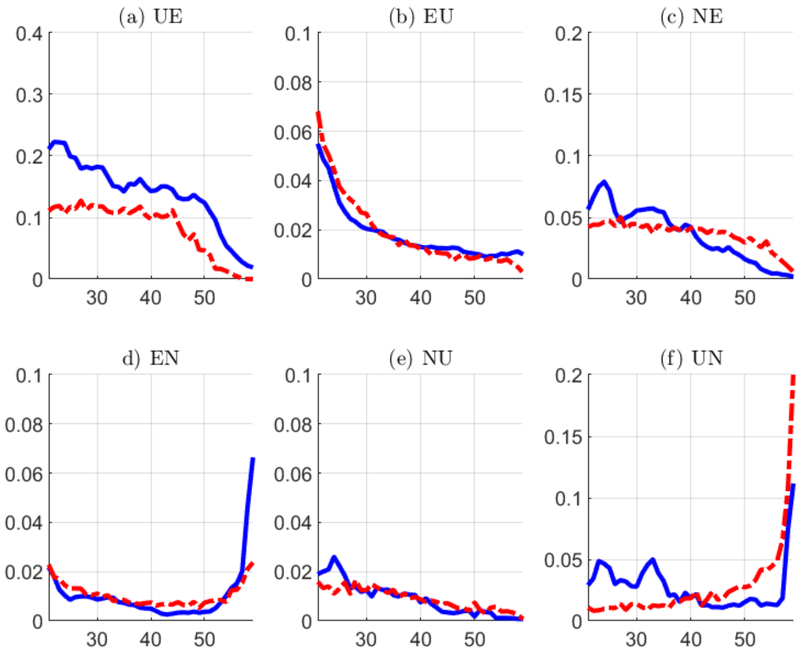

Figure 5c: Transition probabilities: data and model simulation for France, women

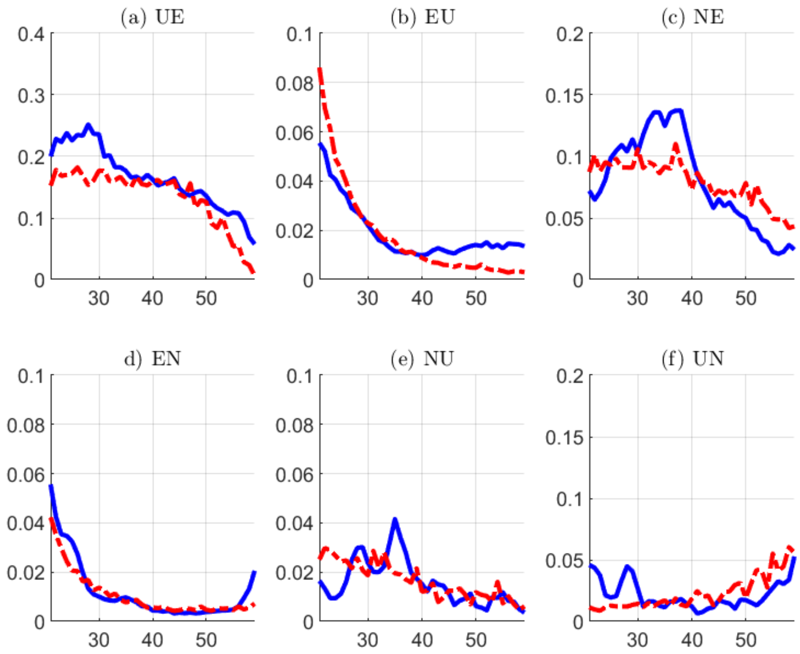

Figure 6c: Transition probabilities: data and model simulation for Germany, men

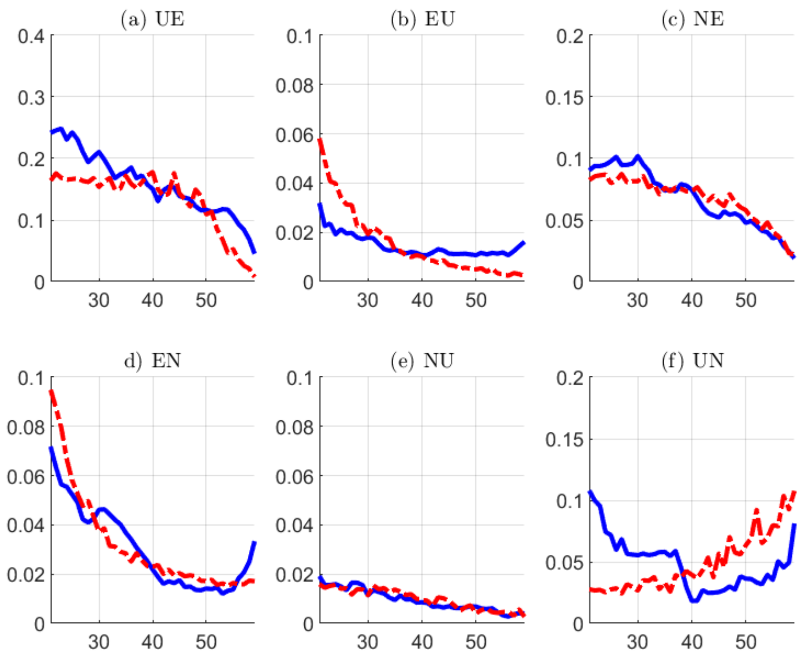

Figure 7c: Transition probabilities: data and model simulation for Germany, women

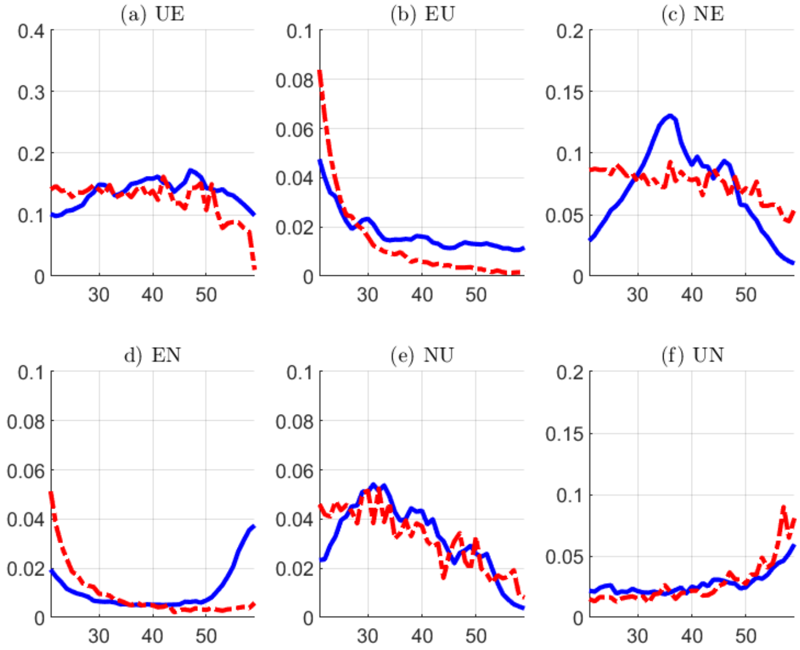

Figure 8c: Transition probabilities: data and model simulation for Italy, men

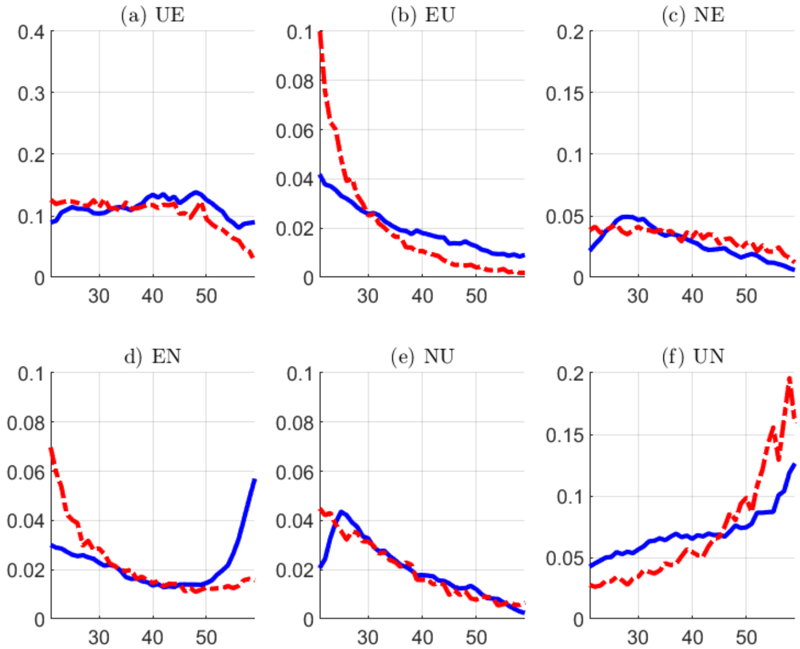

Figure 9c: Transition probabilities: data and model simulation for Italy, women

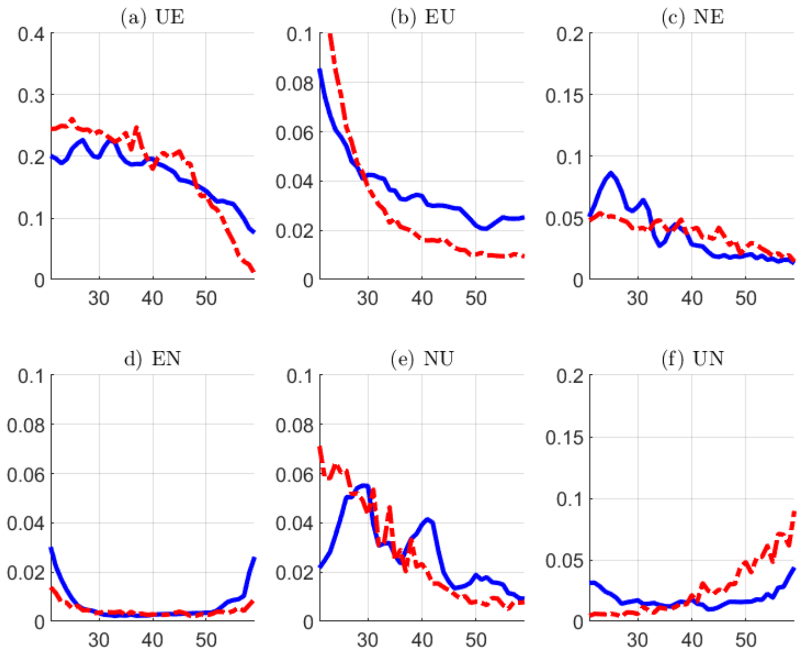

Figure 10c: Transition probabilities: data and model simulation for Spain, men

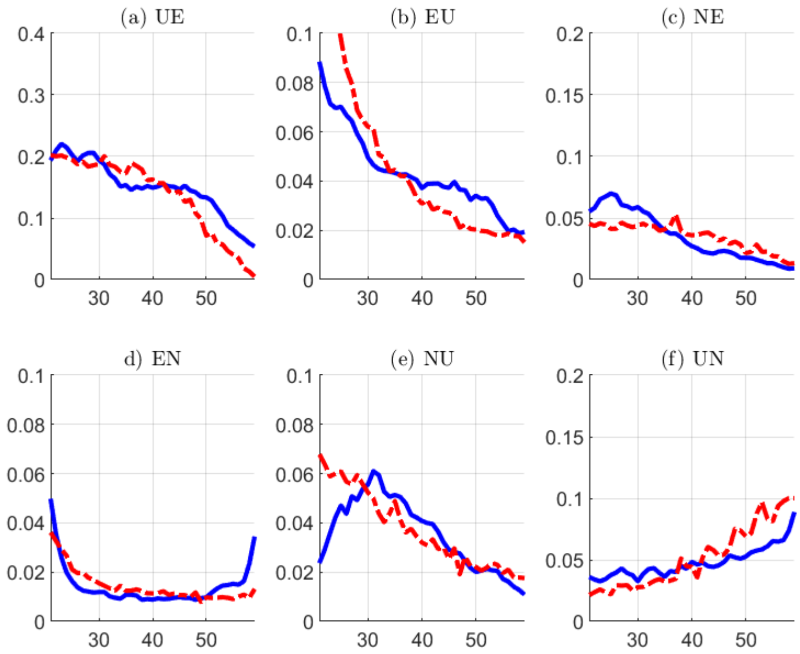

Figure 11c: Transition probabilities: data and model simulation for Spain, women

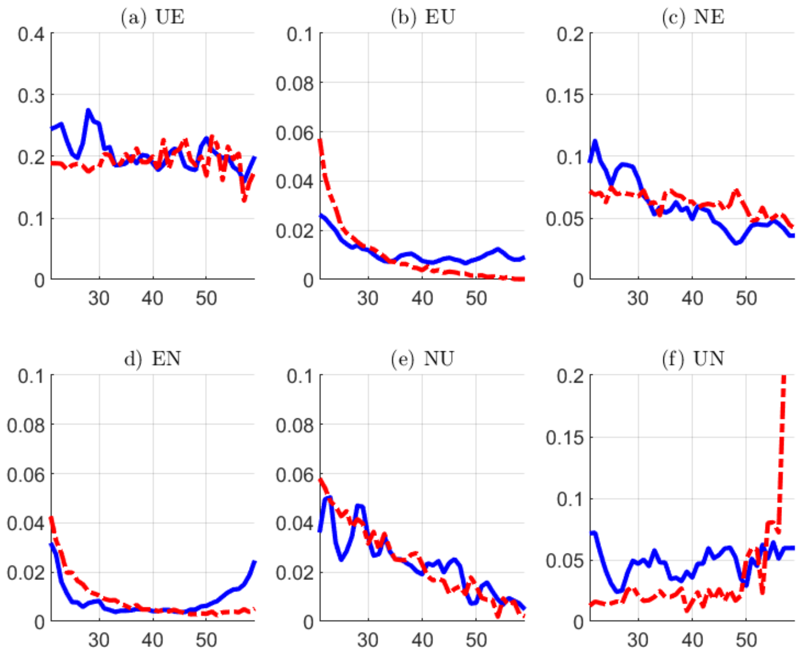

Figure 12c: Transition probabilities: data and model simulation for the U.K., men

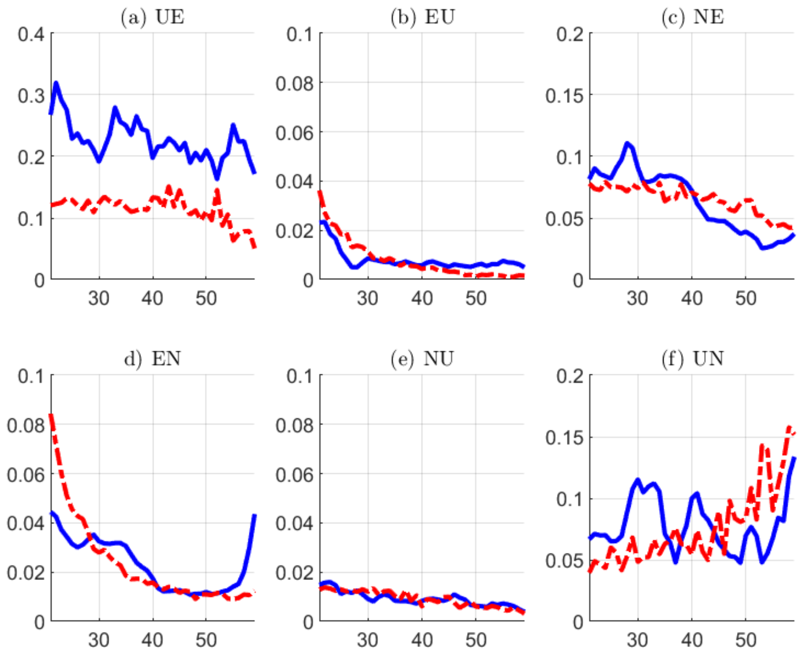

Figure 13c: Transition probabilities: data and model simulation for the U.K., women