Cross-country Differences in Unemployment: Fiscal Policy, Unions, and Household Preferences in General Equilibrium

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Abstract

We develop a five period overlapping generations model with individuals who differ by ability and an imperfect labour market (union wage setting) for the individuals of lower ability. The model explains human capital formation, hours worked and unemployment within one coherent framework. Its predictions match the differences in the unemployment rate across 12 OECD countries remarkably well. A Shapley decomposition of these differences reveals an almost equal contribution of fiscal policy variables and union preferences. As to fiscal policy, differences in unemployment benefits play a much more important role than tax differences. Differences in households' taste for leisure are unimportant.

Keywords: Low-skilled unemployment, Heterogeneous agents, Union wage setting, Fiscal policy, Shapley decomposition
JEL classification codes: E24, E62, J51, J64

1 Introduction

Labour market performance differs widely across OECD countries. Since about a decade many researchers have built gradually richer general equilibrium models to account for these differences. Initial contributions by Prescott (2004), Rogerson (2007), Dhont and Heylen (2008) and Ohanian et al. (2008) tried to explain differences in aggregate per capita hours worked. Later work introduced a life-cycle dimension in labour supply and employment in order to explain also the huge cross-country differences in employment among persons older than 50 (see Rogerson and Wallenius (2009), Erosa et al. (2012), and Alonso-Ortiz (2014)). Another advantage of introducing a life-cycle dimension is that it became possible to model the time allocation of young people between labour and education, and to explain human capital formation as an endogenous variable (see e.g. Ludwig et al. (2012); Heylen and Van de Kerckhove (2013); Wallenius (2013)).

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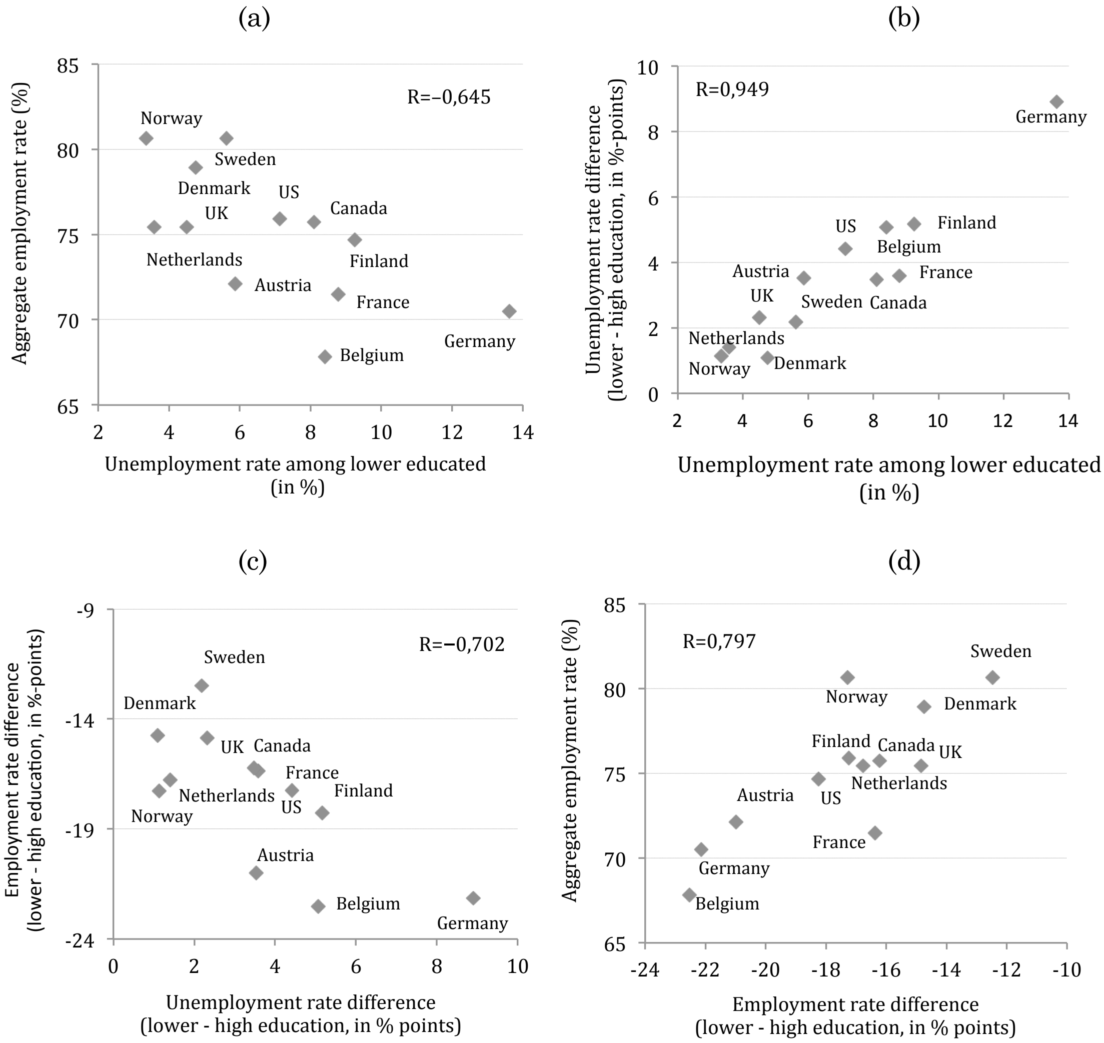
Figure 1: Employment and unemployment in OECD countries, 2001-07.



Notes: We compute the (un)employment rate among lower educated individuals as the average of the (un)employment rates among individuals with less than upper secondary education and among individuals with upper secondary, but no tertiary degree. The (un)employment rate among individuals with higher education relates to those with a tertiary degree. Unless defined differently, all reported employment and unemployment rates concern the age group 25-64. The employment rate indicates the fraction of individuals who have a job. Data sources: Eurostat (LFS series: lfsa_ergaed, lfsa_urgaed) and OECD Labour Force Statistics (Total Employment).

Despite the enormous progress that has been made in this literature, one clear weakness has not been dealt with. A striking observation in all the aforementioned models is their assumption of a perfectly competitive labour market. They cannot explain equilibrium unemployment, let alone the huge and persistent differences in unemployment between for example high and lower educated individuals. Yet, as demonstrated in Figure 1 for 12 OECD countries in 2001-2007, cross-country differences in aggregate employment are strongly related to differences in unemployment, in particular unemployment among lower educated individuals[1]. In panel (a), we observe the highest aggregate employment rates in countries (e.g. Denmark, Norway, and Sweden) that are relatively successful in avoiding unemployment among lower educated individuals. By contrast, countries that fail in fighting unemployment among the lower educated, like Belgium and Germany, also show relatively bad aggregate employment perform-

[1]The focus of this paper is on 2001-2007 as this was the last period of relative stability on the labour market before the financial crisis and the euro crisis. Considering that the analysis in this paper aims at studying equilibrium unemployment, it is clearly more appropriate to use data for a relatively stable period.

ance. The other panels in Figure 1 reveal a number of interesting other regularities, which will guide us later in this paper. Panel (b) establishes the fact that almost all cross-country variation in the gap between the unemployment rates of lower and high educated individuals is due to variation in the unemployment rate among the lower educated. Correlation in this panel is almost 0.95. Countries vary much less when it comes to the labour market situation of the high educated. (Correlation between the unemployment rate among individuals with a tertiary degree and the unemployment gap between the lower and the high educated is only 0.14). Panel (c) shows a strong inverse relationship between the unemployment gap and the employment gap between lower and high educated individuals. Finally, panel (d) reveals that the aggregate employment rate is strongly related to this employment gap. We conclude that if it is the objective of countries to raise aggregate employment, an important challenge will be to fight unemployment among lower educated individuals. The existing (dynamic) general equilibrium models for labour market analysis in the tradition of Prescott (2004) and Rogerson (2007) have no clear answer to deal with this challenge.

Next to excluding a potential role for labour market imperfections, the above mentioned general equilibrium literature also leaves little room for differences in individual preferences across countries to show up. Blanchard (2004) and Alesina et al. (2005) have argued that a key factor behind the lower employment in many European countries compared to the US is a higher taste for leisure. Yet, the general equilibrium literature generally imposes the same preferences upon individuals.

Our contribution in this paper is to extend the dynamic general equilibrium literature studying employment with a labour market imperfection and to use our extended model to quantitatively explore which variables drive cross-country differences in unemployment, in particular unemployment among lower educated individuals. More precisely, we develop a five generations OLG model for a small open economy with two key assumptions. The first one - given the importance of skills and education - is the assumption that individuals are heterogeneous by ability. They enter our model with different human capital stocks and have different capacity to build more human capital. This approach may offer the best match to findings by Huggett et al. (2006), Huggett et al. (2011) and Keane and Wolpin (1997) that heterogeneity in human capital endowment at young age and in learning abilities, rather than shocks to human capital, account for most of the variation in lifetime utility. Our second assumption and key novelty compared to previous work in this tradition is the assumption of a unionised labour market for lower ability (lower educated) individuals[2]. Like Faia and Rossi (2013), we introduce a monopolistic firm-specific trade union that determines the real pre-tax wage for these workers while taking aggregate variables and fiscal policy parameters (e.g. tax rates, unemployment benefits) as given. We specify a Stone-Geary utility function for the union with both wages and employment as arguments, albeit with a different weight. As to wages, the firm-specific union only derives utility from the difference between the after-tax wage and a reference wage. The monopoly union chooses the wage in a first stage. In the next stage, the firm will choose employment (number of workers), while the households of lower ability individuals decide on the supply of hours per employed. Both the firm and the households take the wage set by the union as given.

The union wage setting framework in our model is motivated by the observation that in Europe union

[2] For higher ability workers we assume that wages and employment are determined in a perfectly competitive way. Several authors have provided empirical evidence that the effects of the presence of unions are much stronger for low skilled individuals than for the high skilled, e.g. through a higher union-non union wage premium among the low skilled workers. See e.g. Card et al. (2004), and Checci and García-Peñalosa (2008).

wage bargaining is still the most common way of wage determination. While union membership rates have decreased over time, the coverage of collective bargaining is still at least 80% in most continental European countries and Nordic countries. Also, despite the fact that unions are not that powerful in the US, there exists a form of minimum wage in the US. As such, a union pushing the wage above its perfectly competitive counterpart might be a valid assumption for all countries to introduce unemployment.

Firms in our model act competitively on the goods market. Furthermore, we introduce a government with a rich set of fiscal policy instruments. Government spending on goods and unemployment benefits are financed by taxes on labour, capital and consumption. As to labour taxes, we distinguish between taxes paid by the employer and the employees[3]. Another novelty is the modelling of progressive income taxes paid by the households. We follow the approach used by Guo and Lansing (1998) and Koyuncu (2011). Lump sum transfers balance the budget.

We then use our model to investigate the main drivers of the differences in unemployment across OECD countries. A large range of variables play a role in the model. To find out which of these matter most, our procedure is as follows. First, we calibrate our model and show its empirical relevance for twelve countries belonging to three groups (five continental European countries, four Nordic countries and three Anglo-Saxon countries). More precisely, we simulate our calibrated model for each country imposing common technology on all countries, but country-specific fiscal policy parameters and country group-specific household and union preferences. We find that the predictions of our model match the main facts in most countries. These facts concern hours worked per employed person and the unemployment rate. Having established its empirical reliability, we then use the model to find out what policy or preference parameters account for the cross-country differences in the aggregate unemployment rate. Our objective is similar to the one of Dhont and Heylen (2008), Wallenius (2013) and Alonso-Ortiz (2014) in earlier work. We make progress by also explicitly testing the potential explanatory power of labour market imperfections, different union preferences in particular, and different tastes for leisure of the households. Performing a Shapley decomposition, we find an almost equal role for differences in fiscal policy variables and in union preferences. Each account for about half of the explained variation in unemployment rates across countries. By contrast, any differences in the households' taste for leisure play virtually no role. Our story will then be that the above market-clearing wage chosen by the unions is the source of unemployment, while the fiscal policy variables explain a significant part of the magnitude of unemployment. Going into greater detail on the fiscal side, we find that the key variable driving cross-country differences in unemployment of lower ability individuals is the unemployment benefit replacement rate. In the Nordic countries and (even more) the continental European countries, this has a significant impact on the reference wage of the union. We find no contribution, however, from differences in labour taxes to account for cross-country unemployment variation on an interregional level.

Our finding that both policies and institutions should be taken into account for a good explanation of differences in unemployment across OECD countries matches well with the results of many econometric studies, like those of Nickell et al. (2005), Bassanini and Duval (2009), and Nymoen and Sparrman (2015). The generosity of the unemployment benefit system and the characteristics of wage setting are

[3]In a perfect labour market situation, whether labour taxes are levied on workers or firms does not matter for the cost of labour, nor for after-tax wages and employment. However, as Heijdra and Ligthart (2009) argue, it is not immediately clear whether the same result holds in imperfectly competitive labour markets. We therefore choose to distinguish explicitly between the two.

often found among the main drivers of unemployment in these studies. Our focus on unemployment among low educated workers, however, is missing in most econometric studies (despite its importance for the aggregate employment situation that we highlighted in Figure 1). As we have emphasised before, introducing a labour market imperfection and explaining unemployment is also our main contribution to the dynamic general equilibrium analysis of labour market performance in the tradition of Prescott (2004), Rogerson (2007), Rogerson and Wallenius (2009), and Heylen and Van de Kerckhove (2013), among others.

Several earlier contributions have made an attempt to introduce unemployment in dynamic macro models. Daveri and Tabellini (2000), Corneo and Marquardt (2000), and Ono (2010) among others developed OLG models with a unionised labour market, while Ravn and Sørensen (1999), Cahuc and Michel (1996) and Sommacal (2006) introduced minimum wages. Gali et al. (2011) extended the Smets and Wouters New Keynesian DSGE model to allow for involuntary unemployment. In their model, unemployment also results from market power in labor markets, reflected in positive wage markups. Other authors embed a search and matching setup in a life-cycle model, e.g. de la Croix et al. (2013). We also make progress compared to this literature. First, to the best of our knowledge, all the existing OLG models where unions are present are populated by only two generations, which means that they lack a life-cycle dimension of labour supply. The fact that we model the labour market outcome of different generations is clearly different from the DSGE literature on unemployment as well. Second, most of the models incorporating unions in a life-cycle model leave the intensive margin of employment (i.e. hours worked) unexplored. However, hours of work per employed person are substantially lower in most European countries than in the Anglo-Saxon countries. Third, most of these models do not allow for individuals with different ability. The consequence being that these are not suited to explore the labour market situation of lower educated individuals separately. And last, given the rich specification of the model, both in terms of fiscal and institutional variables, we are able to explore the drivers of unemployment in much more detail.

The structure of this paper is as follows. In Section 2, we describe the basic setup of our model. Section 3 discusses optimal behaviour of unions and firms, and how this drives hours worked, unemployment and real output. Section 4 presents our calibration procedure. In Section 5 we test and show the empirical validity of our model for 12 OECD countries as described above. Finally, in Section 6 we investigate the relative importance of institutional and (household and union) preference related variables versus several fiscal policy variables to explain differences across countries in the unemployment rate. Section 7 concludes.

2 The model: setup, preferences and constraints

Time is discrete and runs from 0 to infinity. We assume a small open economy populated by five overlapping generations of households, firms, unions and a fiscal government. Individual members of the household enter the model at the age of 18 and live for five periods j of 12 years. Individuals have either high or low innate ability. Households have only higher or lower ability members, but not both. Both the goods market and the labour market for higher ability individuals are competitive, whereas the labour market for lower ability individuals is unionised. In every period t, wages for lower ability workers are set by a monopoly union at the firm level. The government in our model disposes of a rich set of fiscal

Table 1: Life-cycle of a member of a higher ability household of generation t

Time	t	$t+1$	$t+2$	$t+3$	$t+4$
Hours worked	n^t_{1H}	n^t_{2H}	n^t_{3H}	n^t_{4H}	0
Education	e^t_{1H}	0	0	0	0
Participation rate	1	1	1	1	0
Unemployment rate	0	0	0	0	0
Employment rate	1	1	1	1	0
Leisure time	$1-n^t_{1H}-e^t_{1H}$	$1-n^t_{2H}$	$1-n^t_{3H}$	$1-n^t_{4H}$	1

Table 2: Life-cycle of a member of a lower ability household of generation t

Time	t	$t+1$	$t+2$	$t+3$	$t+4$
Hours worked when employed	n^t_{1L}	n^t_{2L}	n^t_{3L}	n^t_{4L}	0
Education	0	0	0	0	0
Participation rate	1	1	1	1	0
Unemployment rate	$u_{1,t}$	$u_{2,t+1}$	$u_{3,t+2}$	$u_{4,t+3}$	0
Employment rate	$1-u_{1,t}$	$1-u_{2,t+1}$	$1-u_{3,t+2}$	$1-u_{4,t+3}$	0
Leisure time when employed	$1-n^t_{1L}$	$1-n^t_{2L}$	$1-n^t_{3L}$	$1-n^t_{4L}$	1

policy instruments. Government spending on goods and unemployment benefits are financed by taxes on capital, labour and consumption. As to labour taxes, we distinguish between taxes paid by the employer (linear) and by the employees (non-linear). There is no uncertainty.

2.1 Households

In the spirit of Merz (1995) and Andolfatto (1996), we assume a number of households each consisting of a continuum of members of the same age and the same ability. Each household has unitary mass. We normalise the number of households of a given age and ability type to one. Therefore, the economy consists of 10 households in total[4]. All members at working age participate on the labour market and pool their income, meaning that consumption across household members is the same. As such there is perfect insurance within the household against the risk of unemployment. A household that enters the model in period t (a household of generation t) is denoted with a superscript t. Subscripts are reserved for the age $j \in \{1,2,3,4,5\}$ and the ability type $a \in \{H, L\}$. Hence, n^{t+1}_{2H} denotes the fraction of time devoted to labour services by a member of a higher ability family who is in the second period of life and who started active life in period $t+1$. Tables 1 and 2 present a brief overview of the model structure with respect to the households:

– Members of the higher ability household enter the model with a human capital stock h^t_{1H}. They have a time endowment of one in each period which they can devote to work, education when young, or leisure. During four active periods (age $j = 1,2,3,4$), all these individuals are employed on a perfectly competitive labour market. During the fifth period ($j = 5$), they are retired. The household chooses an optimal consumption path, the optimal amount of non-human wealth, the time each individual devotes to education when young and the amount of hours each member supplies labour.

[4]With our assumption of five periods, we are able to isolate the young (18-29) and the elderly (54-65) and look at whether the model correctly predicts the labour market outcome for these generations. Including more generations would not lead to additional insights with respect to the aggregate unemployment rate. Having fewer generations might lead to generations that are too big (especially the young and the older workers).

– Members of the lower ability household enter with a human capital stock $h^t_{1L} < h^t_{1H}$. Just like their higher ability counterparts, they have a time endowment of one. Lower ability individuals do not pursue tertiary education. A fraction $1 - u_{j,t+j-1}$ of all lower ability individuals of generation t at age j will be employed in period $t + j - 1$, the others are (involuntarily) unemployed. Employed members devote time to either work or leisure, unemployed members only have leisure. The household chooses an optimal consumption path, the optimal amount of non-human wealth and the amount of time the employed members supply labour.

2.1.1 Higher ability households

Lifetime utility of the higher ability household of generation t is given by

$$u^t_H = \sum_{j=1}^{5} \beta^{j-1} \left(\ln c^t_{jH} + \gamma_j \frac{\left(1 - e^t_{jH} - n^t_{jH}\right)^{1-\theta}}{1-\theta} \right) \tag{1}$$

with $0 < \beta < 1$, $\gamma_j > 0$, $\theta > 0$ ($\theta \neq 1$), and where $e^t_{2H} = e^t_{3H} = e^t_{4H} = e^t_{5H} = n^t_{5H} = 0$. In this equation, β represents the discount factor, γ_j is an age-specific parameter determining the value of leisure relative to consumption and $\frac{1}{\theta}$ is the intertemporal elasticity of substitution in leisure[5]. The household's budget constraints are given by (2). Income is derived from labour, non-human wealth and lump sum transfers from the government. It is allocated to either consumption or savings.

$$(1 + \tau_c)c^t_{jH} + \Omega^t_{jH} = w_{H,t+j-1}\varepsilon_j h^t_{jH} g(n^t_{jH})(1 - \tau_{jH}) + (1 + r_{t+j-1})\Omega^t_{j-1,H} + z_{t+j-1} \tag{2}$$

for $j \in \{1, 2, 3, 4, 5\}$ and with $\Omega^t_{0H} = \Omega^t_{5H} = n^t_{5H} = 0$. As in Rogerson and Wallenius (2009), $g(n^t_{jH}) = \max\{n^t_{jH} - \bar{n}_H, 0\}$, with n^t_{jH} the chosen fraction of their time endowment that individuals allocate to labour services and $n^t_{jH} - \bar{n}_H$ the effective labour time that individuals supply. We assume that if an individual with human capital stock h^t_{jH} devotes a fraction n^t_{jH} of his/her time to the labour market, this will yield $(n^t_{jH} - \bar{n}_H)h^t_{jH}$ units of effective labour market services if $n^t_{jH} \geq \bar{n}_H$, and 0 otherwise. A fraction $\bar{n}_H$ is not productive due to e.g. commuting and getting setup in a job. Individuals earn an after-tax wage of $w_{H,t+j-1}\varepsilon_j\ h^t_{jH} g(n^t_{jH})(1 - \tau_{jH})$ during their four active periods, where $w_{H,t+j-1}$ is the pre-tax real wage per unit of effective labour, ε_j is an age-specific productivity parameter, and τ_{jH} is the average tax rate on labour. Due to our modelling of a progressive labour income tax system, tax rates depend on individuals' ability and age. We specify the tax system in greater detail below. As to other variables, we denote the lump sum transfer from the government at time t by z_t. The consumption tax rate is τ_c. The households' accumulated non-human wealth at the end of their j-th period of life is Ω^t_{jH}. Households enter the model without wealth and leave no bequests.

2.1.2 Lower ability households

In the spirit of the previous subsection, we again consider a large household, consisting of a continuum of lower ability members. Again, the decision unit is the household. The key difference is that in this household only a fraction $1 - u_{j,t+j-1}$ of the individuals is employed. A fraction $u_{j,t+j-1}$ is unemployed. Hence, $u_{j,t+j-1}$ represents the aggregate unemployment rate among the lower ability individuals of

[5] In the empirical part of our paper (i.e. Sections 4 and 5), we allow γ_j to differ between regions (continental European countries, Nordic countries, and Anglo-Saxon countries). The region-specific values will be calibrated.

generation t at age j and time $t+j-1$. The household derives utility from consumption, while it only enjoys utility from the leisure of each employed member[6]. Thus, lifetime utility of the household of lower ability individuals of generation t is given by

$$u_L^t = \sum_{j=1}^{5} \beta^{j-1} \left(\ln c_{jL}^t + \gamma_j (1 - u_{j,t+j-1}) \left[\frac{(1 - n_{jL}^t)^{1-\theta}}{1-\theta} \right] \right) \tag{3}$$

where $n_{5L}^t = 0$. The household's budget constraints are given by (4). Again, we assume that all members of the household pool their income:

$$(1+\tau_c)c_{jL}^t + \Omega_{jL}^t = w_{L,t+j-1}\varepsilon_j h_{jL}^t (1 - u_{j,t+j-1}) g(n_{jL}^t)(1 - \tau_{jL}) + \widetilde{B}_j + (1 + r_{t+j-1})\Omega_{j-1,L}^t + z_{t+j-1} \tag{4}$$

for $j \in \{1, 2, 3, 4, 5\}$ and with $\Omega_{0L}^t = \Omega_{5L}^t = n_{5L}^t = 0$. For the fraction $u_{j,t+j-1}$ of its members who are unemployed, the household receives an unemployment benefit, equal to a fraction $\widetilde{b}_j$ of the after-tax labour income that these individuals would receive if they were employed. Formally, $\widetilde{B}_j = \widetilde{b}_j w_{L,t+j-1}\varepsilon_j h_{jL}^t g(n_{jL}^t)(1 - \tau_{jL})u_{j,t+j-1}$, where $j \in \{1, 2, 3, 4\}$. The household takes both the unemployment benefit and the unemployment rate as given, when choosing consumption, savings and the supply of working hours. Note that, due to the progressivity of labour income taxes, lower ability households will face a different tax rate than higher ability households ($\tau_{jL} < \tau_{jH}$).

2.1.3 Human capital

Individuals enter our model at the age of 18 with a predetermined level of human capital. This level is generation-invariant, but higher for individuals with high innate ability. The latter reflects for example higher intelligence and greater capacity to learn and accumulate knowledge at primary and secondary school. We normalise the human capital of a young individual with high ability to h_0. A young individual with low ability enters the model with only a fraction $\epsilon_L h_0$, where $\epsilon_L < 1$. The parameter ϵ_L will be calibrated.

During youth, individuals with high ability will invest a fraction of their time in tertiary education. They accumulate more human capital, making them more productive in later periods. Formally,

$$h_{2H}^t = h_{1H}^t (1 + \phi (e_{1H}^t)^\sigma) \text{ with } 0 < \sigma \leq 1, \phi > 0 \tag{5}$$

We adopt in Equation (5) a human capital production function similar to Lucas (1990) and Bouzahzah et al. (2002). The production of new human capital by these individuals rises in the amount of time they allocate to education (e_{1H}^t) and in their initial human capital (h_{1H}^t). The parameter σ indicates the elasticity of time input, ϕ is an efficiency parameter. Individuals with low innate ability do not study. Their human capital remains constant: $h_{2L}^t = h_{1L}^t$. Finally, we assume that the human capital of all individuals remains unchanged after the second period. A rationale for this assumption is that learning-by-doing in work may counteract depreciation. This means that $h_{4a}^t = h_{3a}^t = h_{2a}^t$, for $a \in \{H, L\}$.

[6] A similar utility function is also used in both business cycle and overlapping generations models with search and matching frictions, e.g. Tomas (2008) and de la Croix et al. (2013). Similar to these contributions, we assume that the leisure of the unemployed members is neutral in terms of utility.

2.2 Firms

Both the goods market and the labour market for higher ability individuals are perfectly competitive, whereas the labour market for lower ability individuals is unionised. All firms are identical. They maximise profits, pay taxes on capital income and social security contributions when hiring labour. Total domestic output is given by the production function (6). Production exhibits constant returns to scale in aggregate physical capital (K_t) and labor in efficiency units (A_tH_t). Given our assumption of perfect competition on the goods market, profits are zero in equilibrium.

$$Y_t = K_t^{\alpha}(A_tH_t)^{1-\alpha} \tag{6}$$

Technology A_t is growing at an exogenous and constant rate x: $A_{t+1} = (1+x)A_t$. As to total effective labour H_t, we assume that higher and lower ability individuals are imperfectly substitutable in production. This framework was pioneered by Katz and Murphy (1992). So,

$$H_t = \left[\eta_H H_{H,t}^{\frac{\iota-1}{\iota}} + \eta_L H_{L,t}^{\frac{\iota-1}{\iota}}\right]^{\frac{\iota}{\iota-1}}, \text{ with } \eta_H + \eta_L = 1 \tag{7}$$

with η_a being a share parameter and ι the elasticity of substitution between higher and lower ability labour. Furthermore, workers of the same ability type but different age are assumed to be perfect substitutes. Formally, this gives respectively for higher and lower ability labour

$$H_{H,t} = \sum_{j=1}^{4}(n_{jH}^{t-j+1} - \bar{n}_H)\varepsilon_j h_{jH}^{t-j+1}, \;\; H_{L,t} = \sum_{j=1}^{4}(1-u_{j,t})(n_{jL}^{t-j+1} - \bar{n}_L)\varepsilon_j h_{jL}^{t-j+1} \tag{8}$$

2.3 Unions

The economy is populated by decentralised trade unions, operating at the firm level. Every single union represents all the lower ability workers in a firm. As such, unions are large compared to the workers. The union will determine the lower ability workers' wage while taking aggregate variables and fiscal policy parameters as given. Just like in e.g. Pencavel (1984) and de la Croix et al. (1996), the objective function of the union follows the Stone-Geary specification,

$$V_t = \sum_{j=1}^{4}\left[\frac{1}{\chi_j}(w_{L,t}(1-\tau_{jL}) - \bar{w}_{j,t})^{\chi_j}(1-u_{j,t})\right] \tag{9}$$

with $\chi_j > 0$. The union derives utility from both wages and employment, albeit to a different degree[7]. As to wages, what matters is the difference between the after-tax wage $w_{L,t}(1-\tau_{jL})$ and a reference wage, $\bar{w}_{j,t}$. The age-specific parameter χ_j measures the concavity with respect to the excess wage gap. The higher χ_j, the higher the preference of the union for wages versus employment for the age group j. Every union has the same reference wage. We define this as a weighted average or combination of the after-tax wage that would prevail if the lower ability labour market were competitive, the after-tax wage of higher ability workers and the unemployment benefit. The respective weights are ρ_1, ρ_2 and ρ_3. They sum up to 1. Formally, the reference wage is given by $\bar{w}_{j,t} = \rho_1 w_{L,t}^c(1-\tau_{jL}^c) + \rho_2 w_{H,t}(1-\tau_{jH}) +$

[7] In our companion paper (Boone and Heylen, 2015), we elaborate more in detail on the Stone-Geary functional form.

$\rho_3 \widetilde{b}_j w_{L,t}(1-\tau_{jL})^8$.

2.4 Government

Unemployment benefits and government spending on goods are financed by taxes on capital, labour (both on employers and employees) and consumption. Lump sum transfers ensure a balanced budget. Formally,

$$G_t + B_{L,t} + Z_t = T_{nH,t} + T_{nL,t} + T_{k,t} + T_{c,t} \tag{10}$$

and

$$G_t = gY_t, \;\; Z_t = 10z_t \tag{11}$$

$$T_{k,t} = \tau_k \alpha Y_t \tag{12}$$

$$T_{c,t} = \tau_c \sum_{j=1}^{5} (c_{jH}^{t+1-j} + c_{jL}^{t+1-j}) \tag{13}$$

$$B_{L,t} = \sum_{j=1}^{4} \widetilde{b}_j w_{L,t} \varepsilon_j h_{jL}^{t+1-j} g(n_{jL}^{t+1-j})(1-\tau_{jL}) u_{j,t} \tag{14}$$

$$T_{nH,t} = \sum_{j=1}^{4} w_{H,t} g(n_{jH}^{t+1-j}) \varepsilon_j h_{j,H}^{t+1-j} (\tau_{jH} + \tau^p) \tag{15}$$

$$T_{nL,t} = \sum_{j=1}^{4} w_{L,t}(1-u_{j,t}) g(n_{jL}^{t+1-j}) \varepsilon_j h_{jL}^{t+1-j} (\tau_{jL} + \tau^p) \tag{16}$$

The government spends a fraction g of output on goods. In Equations (15) and (16), τ_{ja} is the average tax rate that applies to the labour income of an individual of age j and ability a and τ^p is the tax rate paid by the employer. What remains is the specification of progressive income taxes. The tax rates appearing in the budget constraints of the households are average tax rates and given by $\tau_{ja} = \Gamma \left(\frac{y_{ja,t}^{lab}}{\bar{y}_t^{lab}} \right)^{\xi}$, where $\xi \geq 0$ and $0 < \Gamma \leq 1$. Here, $y_{ja,t}^{lab}$ is total pre-tax labour income of the household at time t and $\bar{y}_t^{lab}$ is the average labour income in the economy. Just like in Guo and Lansing (1998) and Koyuncu (2011), the parameters ξ and Γ govern the slope and level of the tax schedule. The average tax rate τ_{ja} increases with the total taxable labour income of the household when $\xi > 0$. Households are aware of the progressive structure of the tax system when making decisions, but take this as given. The marginal tax rate τ_{ja}^m is then simply the rate applied to the last euro earned: $\tau_{ja}^m = (1+\xi)\Gamma \left(\frac{y_{ja,t}^{lab}}{\bar{y}_t^{lab}} \right)^{\xi}$. Rewriting this yields $\frac{\tau_{ja}^m}{\tau_{ja}} = 1 + \xi$. The marginal tax rate is higher than the average tax rate when $\xi > 0$, i.e. the tax schedule is said to be progressive. When $\xi = 0$, the average and marginal tax rates coincide.

[8] Like for the household taste for leisure parameters (γ_j), we also assume for χ_j and ρ_k ($j \in \{1,2,3,4\}$ and $k \in \{1,2,3\}$) that their empirical values may differ across country groups (continental European countries, Nordic countries, and Anglo-Saxon countries).

3 Optimisation and Equilibrium

All households will optimally choose consumption in each period of life and hours worked when employed. Households of higher ability will also choose the fraction of time allocated to education when young. The first order conditions are standard. We report them in Appendix A. Our focus in this section is on the maximisation problem of the firms and the unions. Moreover, we also present a detailed description of how we solve for the subgame perfect equilibrium of the game played between a triplet of a union, a firm and a household. For a description of the general equilibrium of our model, we refer to Appendix B.

3.1 Firms

The representative firm in our model operates in a small open economy with perfect mobility of physical capital. It chooses the optimal capital stock and the amount of effective labour. In terms of production, the firm prefers a combination of few people working more hours over a combination of many people working few hours, as each individual causes a time cost for commuting and getting setup in a job. More precisely, firms maximise profits with respect to the vector $[K_t, H_{1H,t}, H_{2H,t}, H_{3H,t}, H_{4H,t}, (1 - u_{1,t}), (1 - u_{2,t}), (1 - u_{3,t}), (1 - u_{4,t})]$, leading to the following first order conditions,

$$\alpha \left[\frac{A_t H_t}{K_t}\right]^{(1-\alpha)} (1 - \tau_k) = r_t \tag{17}$$

$$(1-\alpha) A_t^{1-\alpha} \left[\frac{K_t}{H_t}\right]^{\alpha} \eta_a \left[\frac{H_t}{H_{a,t}}\right]^{\frac{1}{\iota}} = w_{a,t}(1 + \tau^p), \;\; a \in \{H, L\} \tag{18}$$

where $H_{H,t}$ and $H_{L,t}$ are defined in Equation (8) and $\eta_H = 1 - \eta_L$. Due to the perfect mobility of capital, the firm in Equation (17) will hire capital until its after-tax marginal product equals the exogenous world interest rate, r_t. There is no depreciation of capital. Whenever the net return to investment exceeds the world interest rate, capital will flow into the country until optimality is restored. According to Equation (18), firms hire higher and lower ability labour up to the point where their marginal product equals their real wage cost. On the labour market for higher ability workers, wages are determined competitively. Wage flexibility on this market implies that they will all work. The wage will be such that the total supply of higher ability labour, $H_{H,t}$, in Equation (8) equals the firms' demand in (18). For lower ability workers, however, the wage is controlled by the union. Since hours of work are chosen by the households, in order to satisfy Equation (18) the firm can only choose the fraction of persons it wants to employ, or the unemployment rate.

Our assumptions of constant population and of individuals entering the model with a predetermined and generation-invariant level of human capital imply that in steady state effective labor will be constant. Physical capital, output and real wages by contrast will all grow at the exogenous technology growth rate x.

3.2 Union

The union chooses the wage $w_{L,t}$ to maximise Equation (9) subject to the firm's and the lower ability households' optimal choice of (un)employment and hours of work, i.e.

$$\text{s.t.} \begin{cases} F(n_{jL}^{t-j+1}, 1-u_{j,t}, w_{L,t}) = (1-\alpha)A_t^{1-\alpha}\left[\frac{K_t}{H_t}\right]^{\alpha}\eta_L\left[\frac{H_t}{H_{L,t}}\right]^{\frac{1}{\iota}} - w_{L,t}(1+\tau^p) = 0 \\ G(n_{jL}^{t-j+1}, 1-u_{j,t}, w_{L,t}) = \frac{\gamma_j}{(1-n_{jL}^{t-j+1})^{\theta}} - \frac{w_{L,t}\varepsilon_j h_{jL}^{t-j+1}(1-\tau_{jL}^m)}{(1+\tau_c)c_{jL}^{t-j+1}} = 0 \end{cases}$$

with $j \in \{1,2,3,4\}$. To derive the first order condition, one has to know how the optimal unemployment rate resulting from the second stage of the game changes when the chosen wage changes. From the second stage, we derive a system of two implicit equations in the supply of hours worked, the unemployment rate, and the wage rate.

Using matrix notation, evaluating at the equilibrium values of the supply of hours worked, the unemployment rate, and the wage rate, and taking the total differential yields:

$$\begin{bmatrix} \frac{\partial F}{\partial n_{jL}^{t-j+1}} & \frac{\partial F}{\partial(1-u_{j,t})} \\ \frac{\partial G}{\partial n_{jL}^{t-j+1}} & \frac{\partial G}{\partial(1-u_{j,t})} \end{bmatrix} \begin{bmatrix} dn_{jL}^{t-j+1} \\ d(1-u_{j,t}) \end{bmatrix} = \begin{bmatrix} -\frac{\partial F}{\partial w_{L,t}}dw_{L,t} \\ -\frac{\partial G}{\partial w_{L,t}}dw_{L,t} \end{bmatrix} \tag{19}$$

Under normal parameter values the (2x2)-matrix is non-singular. We can then take the inverse to calculate $\frac{d(1-u_{j,t})}{dw_{L,t}}$, the change in the equilibrium unemployment rate resulting from the second stage of the game, following an increase in the chosen wage rate by the union. Imposing the additional assumption that the union treats every generation equally when it comes to generating union utility, the first order condition for the union is given by[9]:

$$w_{L,t}(1-\tau_{jL}) - \bar{w}_{j,t} = -\frac{\chi_j(1-u_{j,t})}{\frac{\partial(1-u_{j,t})}{\partial w_{L,t}}}(1-\tau_{jL}^m) \tag{20}$$

As the right-hand side of this equation is positive, the left-hand side has to be positive as well. This implies that the after-tax wage determined by the union will exceed the reference wage. The higher χ_j (i.e. the relative weight on wages as opposed to employment for age group j), the higher the ex-ante union wage premium. Ex-post, a rise in χ_j will also be reflected in higher unemployment u_j, though. The reason is that if the union has a higher preference for wages for a particular age group, the firm will in the end replace the workers of this age group by low ability workers of other age. Unemployment among these other age groups might fall. Due to more expensive low ability labour, however, aggregate unemployment among low ability workers will rise.

3.3 Solving for the Subgame Perfect Equilibrium

Within every period t, a dynamic two-stage game is played between a triplet of a firm, a union and a lower ability household. In the first stage, the unions choose the wage for the lower ability workers, whereas in the second stage firms choose the fraction of people they want to employ, and lower ability households choose their labour supply in hours. As such, the second stage is a static game, played between the firm and the lower ability household. We use backward induction to solve for the subgame perfect equilibrium

[9]For details on the derivation of this equation, we refer the reader to Appendix D.

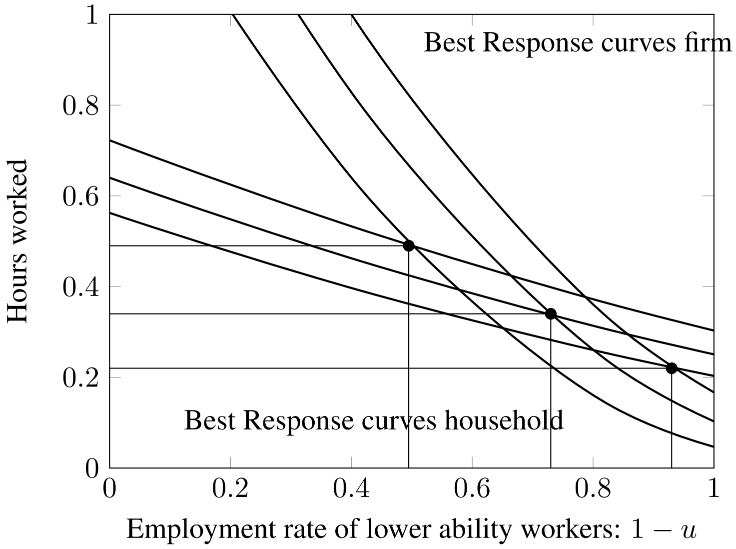
of our game. In the second stage, the firm and the households play simultaneously, taking the union's wage, the fiscal policy variables, and the action of the other player as given. In the previous sections, we already solved for the best responses of the household and the firm. In Graph 1, we show the second stage of the game. The flatter curves are the 'best response'-functions of the households given the real wage rate, the unemployment rate chosen by the firm, tax rates and the unemployment benefit. If the unemployment rate increases, the income and consumption of the household will decrease, implying that the marginal benefit of working increases. Household members will then supply more hours. This argument explains the negative slope of the households' best-response curves. If the wage chosen by the union increases, the best-response curves shift upwards, leading to a higher supply of hours for a given unemployment rate. Intuitively, the substitution effect of a higher wage dominates the income effect. The best-response curves of the firm are calculated using the first-order conditions of the firm. If the households decide to supply more hours for a given wage rate, the firm will employ fewer people. If the wage chosen by the union increases and households maintain their supply of hours, the firm will also employ fewer people, implying that the best-response curves will shift to the left. The intersection of the 'best response'-functions for different wage rates represent the Nash equilibria of the second stage of our game. In Graph 2, an indifference curve of the union has been drawn. The other curve is the collection of Nash equilibria for different wage rates resulting from the second stage of the game. This curve indicates the employment rates which are Nash Equilibria in the second stage given different levels of the real wage rate.

The optimal combination of the wage and the employment rate is found where the indifference curve of the union is tangent to the Nash-function of the second stage. In Graph 2, one optimal point is drawn. From this value for the wage, we can calculate the exact Nash equilibrium in the second stage. The firm chooses the different employment rates such that Equation (18) holds for every age group. The exact composition of employment follows from the second stage of the game. First, notice that Graph 1 only represents one age group. To solve the full game, one needs a similar graph for all age groups (four in total). Then, for a given wage rate chosen by the union, the best-response curves of the firm and the household will be different over the age groups. The workers of an old household react differently to an increase in the wage compared to the members of the youngest household, for example. The same goes for the firm. Given the same wage increase, as there are differences in productivity and the amount of hours worked, the decrease in the employment rate for the oldest workers which is required to restore optimality (Equation 18) will differ from the required decrease for the youngest workers. Thus, the shift in the best-response curves of the household and the firm will be different over all the ages and therefore, for the same wage, one will obtain different employment rates. Finally, as every game is symmetric, the wage will be the same at every firm in the economy.

4 Calibration and empirical relevance of the model

In a first step, we calibrate our model and compare its predictions regarding the main labour market variables to the data for three groups of countries: Anglo-Saxon countries (the US, the UK and Canada), continental European countries (Belgium, France, Germany, the Netherlands, and Austria) and Nordic countries (Denmark, Finland, Norway and Sweden). To make our predictions, we impose common tech-

Graph 1: Second stage of the game



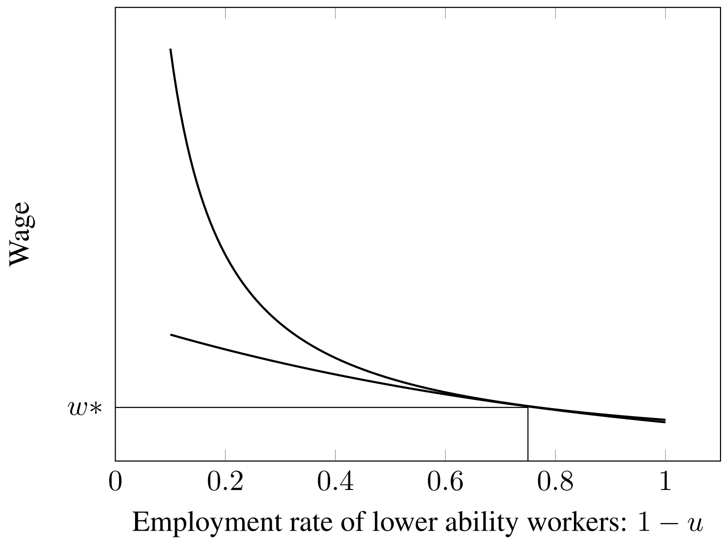
nology and productivity parameters on all countries. Most household and all union preference parameters are assumed to be common for the countries within the same group, but they may differ across groups. The parameters involved are the relative utility of leisure versus consumption for the households (γ_j), the relative weight that the unions assign to wages as opposed to employment (χ_j), and the relative weight of each of the three determinants of the unions' reference wage (ρ_k). To highlight their country group or region-specific character we add a superscript R to these parameters from now on, which gives γ_j^R, χ_j^R and ρ_1^R, ρ_2^R and ρ_3^R respectively, with $j \in \{1, 2, 3, 4\}$ and $R \in \{Eur, Ang, Nor\}$. Last but not least, fiscal policy parameters are all country-specific.

All common and all country group-specific parameters are reported in Table 3 below. So are the country-group averages of the unemployment rate by age, the country-group averages of hours worked per employed person by age, and the overall average education rate and per capita growth rate. These performance indicators play an important role in our calibration, as we will describe in Section 4.2. First, however, we say more about the construction of our main data in Section 4.1. For country-specific data on labour market performance and for the country-specific fiscal policy parameters we refer to Appendix C.

4.1 Data

In our model we have assumed that all individuals (except the retired) of both higher and lower ability participate in the labour market. Those of higher ability will all work. Among those of lower ability, only a fraction $1 - u_{j,t}$ will work. The difference between both employment rates corresponds to the *rate of unemployment* $u_{j,t}$. The data for unemployment that we report in Table 3 reflect this setup. They are the difference in percentage points between the actual employment rate (in persons) among those within a particular age group who enjoyed tertiary education and those who did not. Although consistent with the setup of our model, this proxy for unemployment among the lower educated differs from official unemployment series. Our unemployment rate also captures differences in the labour market participation rate between high and low educated individuals in the data. Lower participation among

Graph 2: First stage of the game



low educated individuals implies higher unemployment in our data. When we account for cross-country differences in unemployment in Section 5, our results will then also capture any impact of household preferences, union preferences, and fiscal policy on participation. This should not affect our main conclusions, though[10]. The (negative) correlation in actual data between the difference in employment rates and the difference in unemployment rates between higher and lower educated individuals is strong (see also Figure 1.c). Depending on the age group considered, it varies between -0.60 and -0.85. Our data for *hours worked per employed n* indicate the fraction of time that employed individuals devote to work relative to their total time endowment on an annual basis. We follow Wallenius (2013) in our computation[11]. The *education rate e* is the fraction of time that higher ability individuals devote to tertiary education. The data reflect the number of students in tertiary education in full-time equivalents divided by (the assumed higher ability) half of the population of age 18-29.

4.2 Calibrated parameters

How well does our model match reality in individual countries? When we impose each country's fiscal policy parameters, how close are the model's predictions to the data? To find out, we first parameterise the model. We discuss our procedure in this section. Table 3 contains an overview of all parameters. Many have been set in line with, or taken from, the existing literature. Others have been calibrated to match key data.

We set the rate of time preference at 2% per year and the (exogenous and constant) world real interest rate at 4.5% per year. Considering that periods in our model last 12 years, this choice implies a discount factor $\beta = 0.788$ and interest rate $r = 0.696$. In the production function for goods, we assume a capital

[10]Balleer et al. (2009) have investigated the determinants of labour force participation in the euro area. They find that labour taxes, union density and unemployment benefits have an impact, but this impact is not robust in sign nor statistical significance across age and gender groups, and countries. Moreover, since the deeper objective of this paper is to contribute to an explanation of labour market performance, and employment in particular (see the introduction to this paper), our approach to compute unemployment rates is even to be considered an advantage.

[11]We assume that the total time endowment of each individual is 14 hours a day, 7 days a week and 52 weeks per year. This time can be allocated to work, leisure or (for young higher ability individuals) education.

share coefficient α equal to 1/3. Following Caselli and Coleman (2006), who state that the empirical labour literature consistently estimates values between 1 and 2, we set the elasticity of substitution ι between the two ability types in effective labour equal to 1.5. We set $\theta = 4$. Rogerson (2007) considers a value for the inverse of the intertemporal elasticity of substitution in leisure θ between 1 and 3 as reasonable. We do not have an endogenous participation decision, however. Therefore, we adopt a value for θ that is somewhat higher. Two other sets of parameters that we took directly from the literature are the age-specific productivity parameters ε_j and the time cost of commuting and being set-up in a job $\bar{n}$. For the former we follow the hump-shaped pattern imposed by Miles (1999). For the latter we impose a value of 0.05, in line with Wallenius (2013). We impose the same ϵ_j and $\bar{n}$ for both ability types.

Three parameters relate to the production of human capital and to the level of human capital with which individuals enter the model. For the elasticity with respect to education time (σ) we choose a conservative value of 0.3. This value is within the range considered by Bouzahzah et al. (2002), but much lower than the value imposed by Lucas (1990). To determine the relative initial human capital of lower ability individuals (relative to the initial human capital of high ability individuals, ϵ_L) we follow Buyse et al. (2017) who rely on PISA science scores. We use the average of the test scores of students at the 17th and the 50th percentile as representative for lower ability individuals in our model, and the test score of students at the 83th percentile as representative for high ability individuals. The data are remarkably robust across countries. The science test scores of students at the 17th percentile and students at the 50th percentile are always very close to 67% and 85% of the test score of students at the 83th percentile[12]. The differences across countries being so small, we take these relative scores as objective indicators of the relative cognitive capacity of lower and high ability individuals, and will correspondingly set ϵ_L equal to 0.755 (= the average of 0.67 and 0.85). Last but not least, the efficiency parameter ϕ in the human capital production function of the individuals with high ability has been determined by a calibration procedure that we discuss now.

We determined 36 parameters by calibration. Next to the efficiency parameter in human capital production (ϕ), these are the exogenous technology growth rate (x), the share parameter in aggregate effective labor (η_H), the four household taste for leisure parameters ($\gamma_1^R, \gamma_2^R, \gamma_3^R, \gamma_4^R$), the four union 'preference for wage' parameters ($\chi_1^R, \chi_2^R, \chi_3^R, \chi_4^R$), and the three weights in the unions' reference wage ($\rho_1^R, \rho_2^R, \rho_3^R$). The former three parameters (ϕ, η_H, x) are assumed to be the same for all countries. The 11 household and union preference parameters may differ by country group. The efficiency parameter in human capital production (ϕ) is determined to correctly predict the average fraction of time allocated to tertiary education (e) by individuals of age 18-29 in all twelve countries in our sample. The parameter turns out to be 3.53. The exogenous growth rate of technology (x) is calibrated to match actual per capita growth. The underlying target for the annual growth rate is 1.91%, being the average annual per capita growth in our sample of twelve countries in 2001-2007. Following Buyse et al. (2017), we calibrate the share parameter in aggregate effective labor (η_H) to match the relative wage of young workers without a tertiary degree versus young workers with tertiary degree in the US. This relative wage is 0.53[13]. As shown by Equation (18), the share parameter η_H is an important determinant of the relative productivity of labour and relative wages. Actual wages are informative if a close link can be assumed between wages

[12] The data that we report are averages of the PISA results for the years 2000, 2003 and 2006. The available data concern students aged 15.

[13] OECD data (Education at a Glance, 2009, table A7.1a) show a relative wage of 0.43 for workers of age 25-34 without upper secondary education versus workers of this age with a tertiary degree. The relative wage of workers of age 25-34 with upper secondary degree is 0.63. On average this is 0.53.

Table 3: Basic parameterisation of the model

Parameters imposed on all countries - Values		
Discount factor in utility	β	0.788
World real interest rate	r	0.696
Capital share parameter in goods production	α	0.33
Elasticity of substitution between different ability types of labour	ι	1.5
Inverse of the intertemporal elasticity of substitution in leisure	θ	4
Age-specific productivity parameters	ε_1,ε_2,ε_3,ε_4	2.325, 2.770, 2.776, 2.341
Time cost for e.g. commuting	$\bar{n}$	0.05
Relative initial human capital of lower ability individuals (to h_0)	ϵ_L	0.755
Elasticity of human capital with respect to education time	σ	0.3
Efficiency parameter in human capital production	ϕ	3.53
Share parameter of higher ability individuals in effective labour	η_H	0.594
Exogenous technology growth	x	0.255

Calibrated region-specific parameters			
	cont. European	Nordic	Anglo-Saxon
γ_1^R	0.195	0.216	0.106
γ_2^R	0.481	0.391	0.355
γ_3^R	0.356	0.289	0.262
γ_4^R	0.239	0.204	0.187
χ_1^R	2.513	1.740	1.792
χ_2^R	4.013	2.355	2.913
χ_3^R	4.017	2.366	2.888
χ_4^R	4.280	2.598	2.960
ρ_1^R	0.8	0.9	0.9
ρ_2^R	0.05	0	0.1
ρ_3^R	0.15	0.1	0

Target values for the calibrated parameters ϕ, x, and η_H (2001-07)	
Education rate (e) (average over 12 countries)	23.4%
Per capita annual growth (average over 12 countries)	1.91%
Relative gross wage of young low versus high educated workers US	0.53

Region-specific targets: unemployment and hours worked by age (2001-07)			
	cont. European	Nordic	Anglo-Saxon
u_1	14.0%	8.7%	16.9%
u_2	14.9%	11.8%	14.8%
u_3	15.5%	12.7%	14.7%
u_4	20.3%	18.7%	17.2%
n_1	0.295	0.293	0.331
n_2	0.313	0.343	0.371
n_3	0.313	0.343	0.371
n_4	0.306	0.331	0.355

and productivity. This condition is much more likely fulfilled in the US than in Europe, which explains the introduction here of US relative wages. The value for η_H that emerges is 0.59.

Finally, we calibrated the four taste for leisure parameters of the households (γ_j^R), the four union preference for wage parameters (χ_j^R), and the weights in the reference wage of the union for the hypothetical competitive wage of lower ability workers (ρ_1^R), the wage of higher ability workers (ρ_2^R), and the unemployment benefit ($\rho_3^R = 1 - \rho_1^R - \rho_2^R$) for each of the three country groups. That is a total of 33 parameters. To do this, we used a procedure in line with Heylen and Van de Kerckhove (2013). Basically, this procedure comes down to (i) exactly matching the 24 country-group averages of the unemployment rates and hours worked by age reported in Table 3, and (ii) to minimise the deviation of our model's predictions for the aggregate unemployment rate (over all age and both ability groups) from the data in the twelve individual countries in our sample. More precisely, in a first step we imposed 9 values for ρ_1^R, ρ_2^R and ρ_3^R ($R \in \{Eur, Nor, Ang\}$). With these imposed values we calibrated the 12 parameters χ_j^R and the 12 parameters γ_j^R with $j = \{1, 2, 3, 4\}$ and $R \in \{Eur, Nor, Ang\}$ to exactly match the country-group averages of actual unemployment rates u in four generations and the country-group averages of actual hours worked n per generation (over both ability types). The obtained set of household taste for leisure and union preference parameters for each of the three country groups - together with all other calibrated parameters - would then allow us to compute the predictions of our model for all unemployment rates and all hours worked in all generations in each of the twelve countries in our sample separately. We repeated this procedures many times, each time starting from different values for ρ_1^R, ρ_2^R and ρ_3^R. Our guideline to pin down our final values for these parameters and the corresponding values for γ_j^R and χ_j^R was to minimise the deviation of our model's predictions from the actual data for the aggregate unemployment rate (over all age and ability groups)[14].

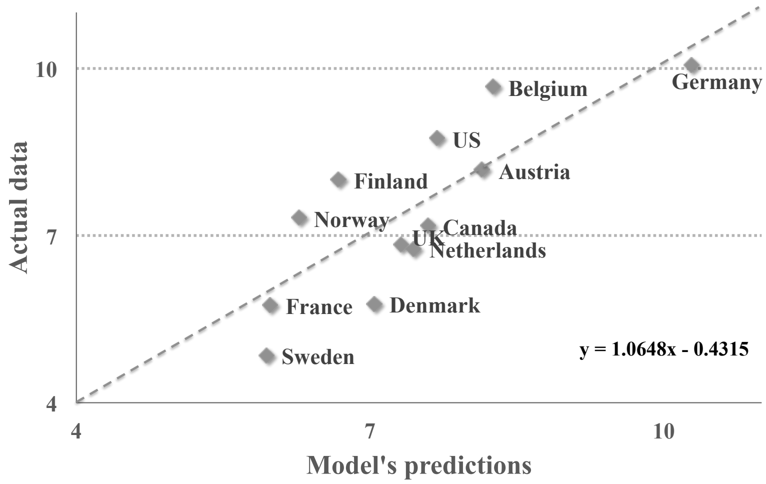
The results in Table 3 reveal by far the highest values for χ_j^{EUR} in continental Europe, which implies that in these countries union indifference curves are flatter, wages are more rigid and the union wage mark-up is higher. Given the dominance of sectoral wage bargaining in these countries, this result matches well with the famous Calmfors and Driffill (1988) hypothesis. Furthermore, we observe that in each country group χ_j^R rises in the age of the workers involved. Wages are therefore the most (least) rigid and the highest (lowest) for the oldest (youngest) workers. Seniority pay systems and the insider-outsider theory may provide an explanation for this result. As to the specific weights in the unions' reference wage, we notice in each country group a major role for the competitive wage of lower ability individuals ($\rho_1^R \geq 0.8$). In the Anglo-Saxon countries the only other variable that matters in the unions' reference wage is the wage of the high skilled. In the Nordic countries, it is the unemployment benefit. In continental Europe, both these other variables have an impact on union wage setting, with unemployment benefits being more important. For the household taste for leisure parameters γ_j^R, we observe the lowest values in the Anglo-Saxon countries, which would confirm Blanchard (2004). Except among the youngest households, however, cross-country differences in γ_j^R are fairly small.

4.3 Evaluation and empirical relevance of the model

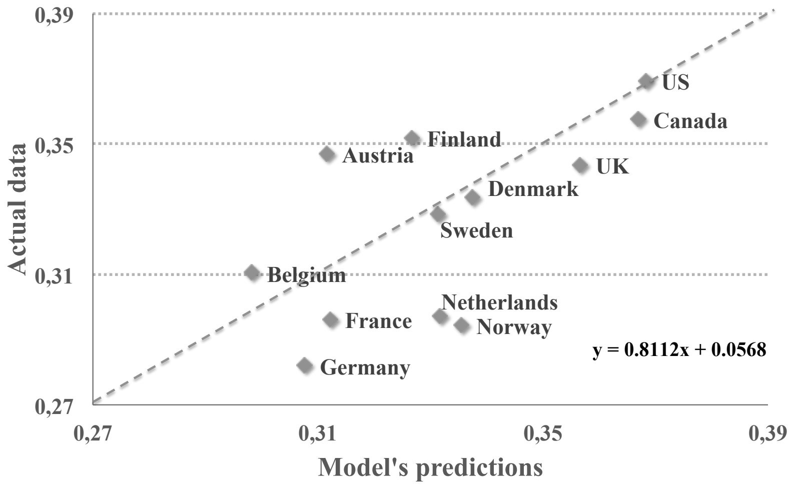
In Figures 2-4, we evaluate the empirical relevance of the model regarding the cross-country variation in unemployment and hours worked. The interrupted line in each figure is the 45º-line. In each figure, we

[14]From the predictions of our model and the data for 12 countries we computed each time for the aggregate unemployment rate the root mean squared error normalised to the mean. We minimised the average normalised RMSE.

Figure 2: Aggregate labour market performance in individual countries (2001-07)



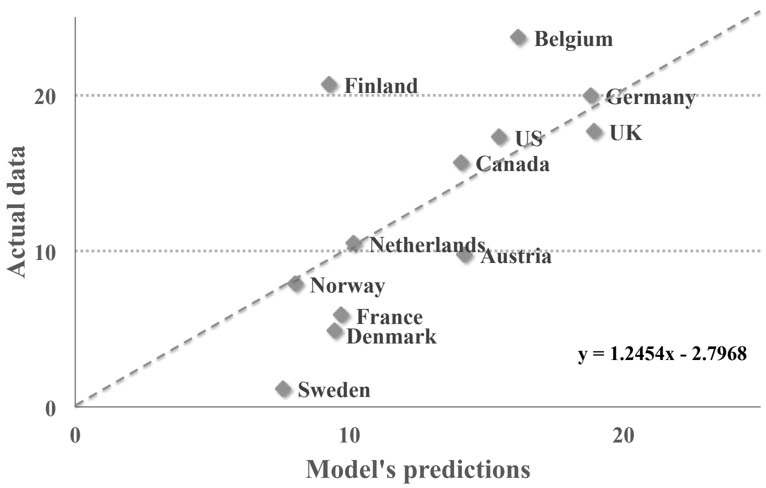
(a) Unemployment rate (in %) - Correlation: 0.804



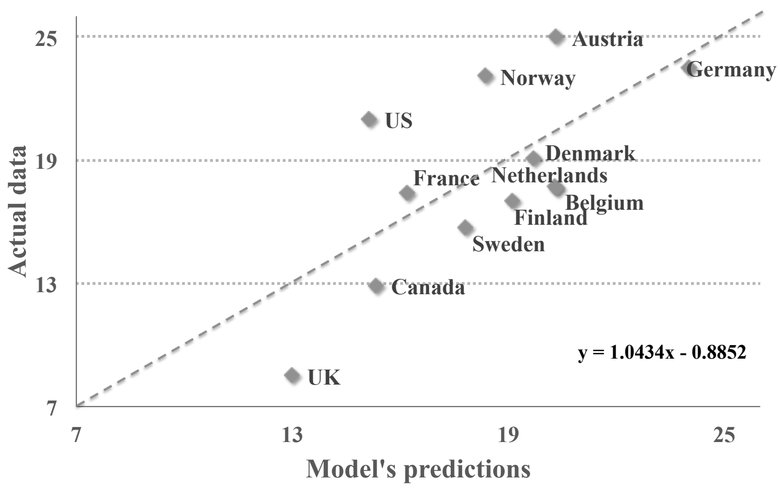
(b) Hours worked per employed - Correlation: 0.64

also report the slope of the regression line (not shown). Plugging each country's policy parameters into our calibrated model, it matches the facts for the aggregate unemployment rate very well. Correlation between the predictions of the model and the facts in Figure 2.a is over 80%, with a slope of the regression line very close to 1. Our model also captures the cross-country differences in the unemployment rates of different age groups quite well. Figure 3 shows this for the youngest and the oldest age groups. Last but not least, in Figures 2.b and 4 our model explains an important fraction of cross-country differences in hours worked per employed. The reported slope of the regression line in these figures remains below one, though, suggesting that our model somewhat exaggerates the effect of policy differences on hours worked.

Figure 3: Unemployment rate (%) among lower ability individuals

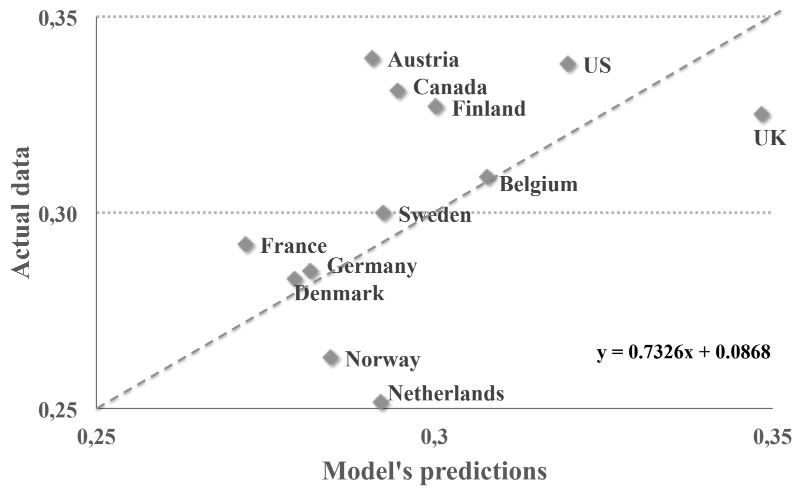


(a) Young (age 18-29) - Correlation: 0.713

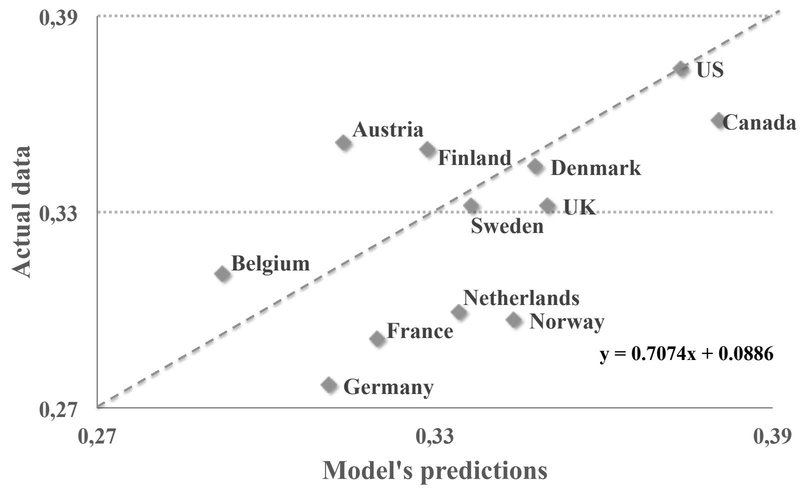


(b) Older (age 54-65) - Correlation: 0.674

Figure 4: Hours worked by age over both ability types



(a) Young (age 18-29) - Correlation: 0.515



(b) Older (age 54-65) - Correlation: 0.590

5 Accounting for cross-country variation in unemployment

Figure 2.a showed large differences across OECD countries in the unemployment rate. From Figure 1 we know that these differences explain an important fraction of cross-country differences in aggregate employment and labour market performance. The final step in this research is to account for these unemployment differences. What exactly causes higher unemployment in some countries compared to other countries?

5.1 Description of the experiment

We find a correlation of 0.804 between the predictions of our model for the aggregate unemployment rate and the unemployment data. From this, we derive a R^2 of 0.646. Following Israeli (2006), we perform a Shapley decomposition of the R^2-coefficient in order to evaluate the relative importance of the different fiscal policy variables, union wage setting and household preferences in generating cross-country unemployment differences. More specifically, according to a Shapley decomposition, the contribution of each of our variables equals its marginal effect measured by the change in the R^2-coefficient after eliminating the cross-country differences in this variable. This change in R^2 is computed for every subset S of other explanatory variables. For example, if we had four explanatory variables, x_1, x_2, x_3, and x_4, the marginal effect of x_1 on R^2 would be $M_1 = R^2[x_1, S \subseteq \{x_2, x_3, x_4\}] - R^2[S \subseteq \{x_2, x_3, x_4\}]$ for every subset S. Next, we take a weighted average over all these marginal effects where the weight is respectively $\frac{s!(n-s-1)!}{n!}$, with s the number of elements in the subset and n the total number of explanatory variables. Hence, for each of our variables in the Shapley decomposition, we successively replace their country-specific values by the average value over all countries in our sample, implying that we shut down the influence of these specific variables in generating cross-country differences in the unemployment rate. These variables are (i) the labour tax imposed on employers; (ii) the labour tax imposed on employees; (iii) the replacement rate in the unemployment benefit formula; (iv) the tax rate on capital; (v) the tax rate on consumption; (vi) government spending on goods; (vii) the union preference parameters, and (viii) the taste for leisure of the households.

Our model generates cross-country variation in aggregate unemployment due to these country-specific and region-specific variables. The Shapley decomposition makes it possible to formally explore the contribution of the variation in each of those variables to the predicted variation in the aggregate unemployment rate. While the decomposition can be applied to any model independent of the underlying theory, we believe that there are a few features of our model and our results that make the Shapley decomposition highly relevant. First, the richer the model, the more explanatory variables contribute to the R^2-coefficient and the more relevant is a decomposition of R^2 into its contributing variables. Second, the R^2-coefficient between the model's predictions and the actual data for the aggregate unemployment rate is quite high. Thus, the variation in the exogenous variables and parameters is highly informative about the cross-country variation in the aggregate unemployment rate.

5.2 Fiscal policy, union preferences, or households' taste for leisure?

Is the cross-country variation in unemployment rates due to differences in union behaviour, household preferences or fiscal policy variables. Blanchard (2004) and Alesina et al. (2005) emphasise the role of union behaviour and differences in the taste for leisure of households. Other authors such as Prescott

Table 4: Shapley decomposition of u_t

Variables		Contribution to R^2	
Preferences/Institutions		**Absolute**	**Relative**
Wage preference of union	χ^R	0.217	33.6%
Weights in union reference wage	$\rho_1^R, \rho_2^R, \rho_3^R$	0.121	18.7%
Household taste for leisure	γ_j^R	-0.009	-1.4%
Total preferences/institutions		0.329	50.9%
Fiscal policy		**Absolute**	**Relative**
Tax on employers, employees, consumption	$\tau^p, \xi, \Gamma, \tau_c$	-0.057	-8.8%
Net unemployment benefit replacement rate	$\tilde{b}_j$	0.198	30.6%
Tax on capital income	τ_k	0.049	7.6%
Fraction of output spent on goods	g	0.128	19.7%
Total fiscal policy		0.318	49.1%
Total		0.647	100%

(2004), Ohanian et al. (2008) and Dhont and Heylen (2008) conclude that differences in fiscal policy are superior. Looking at Table 4, the conclusion is that both fiscal policy variables and union preferences and wage setting matter. They account each for about half of the unemployment variation across countries. A correct diagnosis of the unemployment problem and analysis of cross-country differences clearly seems to require both components. On the other hand, any differences in households' taste for leisure can safely be ignored. Integrating these findings, our interpretation is that while the above market-clearing wage chosen by the unions is the source of unemployment, the fiscal policy variables explain a large part of the magnitude of the unemployment rate.

If we explore the impact of the union parameters into more detail, we notice that the contribution of the variation in χ_j^R (i.e. the relative weight on wages as opposed to employment for age group j) is superior to that of the variation in ρ_1^R and ρ_2^R (i.e. the weights in the specification for the reference wage of the unions).

Looking at the different components of fiscal policy, a surprising result is that - despite huge cross-country variation in ξ, Γ, τ^p, and τ_c - these tax rates and parameters have no role to play when it comes to explaining unemployment differences across countries. Countries with higher average tax rates and a higher degree of progressivity in labour taxes are not necessarily the countries with the highest aggregate unemployment rate. Ambiguous effects from higher taxes may explain this. A rise in τ^p for example will imply higher unemployment because it raises the cost of low skilled labour for the firms. On the other hand, it also generates effects that may lead to lower unemployment. One is the negative effect of a rise in τ^p on competitive gross wages, which will imply more moderate wage claims from the unions. Another is that higher taxes may feed through into higher lump sum transfers in our model. The negative effect of higher transfers on the supply of hours per worker will induce firms to hire more people. Similar ambiguity follows after a rise in Γ. On the one hand, this negatively affects labour supply, pushing wages up and making low skilled workers more expensive. Firms will then hire fewer workers, and unemployment rises. On the other hand, the fact that individuals supply fewer hours because of higher taxes (and an expected increase of lump sum transfers), will induce firms to hire more people.

The major role of the replacement rate $\widetilde{b}_j$ is not a surprising result, however. From the results of the calibration in Table 3, it is clear that unions in both continental Europe and Nordic countries attach a positive weight ρ_3^R to the level of these benefits. This weight is the largest in continental Europe. Benefit changes will therefore affect the cost of low educated labour most in these countries, and therefore firms' willingness to hire. Important differences in benefits as exist for example between France and Germany can then be expected to explain a significant fraction of unemployment differences in the period studied. The contribution of $\widetilde{b}_j$ might even be an underestimation, as it is the combined impact of the net replacement rate and the region-specific union preferences that drive the Shapley results for the union preferences.

The variation in the capital tax rate has a small positive contribution to the R^2. Its influence runs via the first order condition of the firm with respect to capital, and has an impact on the variation in labour demand over countries. This effect dominates the indirect effect on the lump sum transfers. Thus, a decrease in τ_k leads to a decrease in u due to the higher labour demand. Government spending affects u via the lump sum transfers. An increase of g leads to a decrease in lump sum transfers. Households will consume less and supply more hours. Therefore, the firm will hire fewer individuals (u increases).

6 Conclusion

Huge differences in labour market performance across OECD countries have attracted the attention of many researchers during the last decade. One strand of the literature has emphasised the major role of the composition of fiscal policy, i.e. the level and structure of taxes and government expenditures (e.g. Prescott (2004), Rogerson (2007), Dhont and Heylen (2008), Wallenius (2013), Alonso-Ortiz (2014)). The focus of these studies is mainly on explaining employment (hours worked). All assume perfect competition and as such disregard any role for labour market imperfections. Unemployment is not an issue in these studies. A second tradition in the literature also recognises the role of labour taxes and unemployment benefits, but this tradition has put much more emphasis on the role of unions (e.g. union power and wage bargaining) and labour and product market institutions (e.g. Daveri and Tabellini (2000), Nickell et al. (2005), Alesina et al. (2005)). Last but not least, some other authors (e.g. Blanchard (2004)) have pointed to the key role of household preferences. In their view, a major element behind the weaker employment performance in many European countries compared to the US is a higher taste for leisure in Europe. Alesina et al. (2005) explain that stronger unions may have contributed to this higher taste for leisure in Europe.

This paper is complementary to the first strand of the literature. We also develop a general equilibrium model (OLG model) to study cross-country differences in labour market performance. While we somewhat simplify the approach by assuming exogenous participation, our main contribution is to extend this literature so that it can also explain equilibrium unemployment among lower educated individuals. This extension is important given that differences in employment rates among OECD countries are strongly related to countries' success or failure in avoiding unemployment among the lower educated. Two assumptions are key in our model. The first one is the assumption that individuals are heterogeneous by ability. They enter the model with different human capital stocks and have different capacity to build more human capital. A second assumption and key novelty compared to previous work in this tradition is the assumption of a unionised labour market and union wage setting for lower ability (lower educated) individuals. For higher ability individuals we assume that wages and employment are determined in a perfectly competitive way.

Calibrating and simulating this richer model for twelve OECD countries, we are able to assess the relative importance of a whole range of explanatory variables for cross-country differences in unemployment. What is the contribution of (progressive) tax rates on labour, tax rates on consumption, unemployment benefits, etc.? What is the contribution of union preferences and wage setting? What is the contribution of differences in households' taste for leisure? Performing a Shapley decomposition we find an almost equal role for differences in fiscal policy variables and in union preferences. Each account for about half of the cross-country variation in unemployment rates explained by our model. By contrast, any differences in the households' taste for leisure play no role. Integrating our findings, our interpretation will then be that the above market-clearing wage chosen by the unions is the source of unemployment, while the fiscal policy variables explain the major share of its magnitude. Going into greater detail on the fiscal side, we find that differences in unemployment benefit generosity play a much more important role than tax differences. In the Nordic countries and (even more) the continental European countries, the unemployment benefit replacement rate has a significant impact on union wage setting.

Our results highlight the relevance of integrating heterogeneity in individuals' ability and labour market imperfections into dynamic general equilibrium analyses of labour market performance. Imposing perfect competition seems to imply that an important fraction of reality is unfortunately ignored. By contrast, cross-country differences in households' taste for leisure seem insignificant for unemployment, and can safely be disregarded.

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A First-order conditions of the household

A.1 Higher ability households

The maximisation problem of the higher ability households boils down to:

$$\max_{\Upsilon_H} \quad u_H^t = \sum_{j=1}^{5} \beta^{j-1} \left[\ln c_{jH}^t + \gamma_j \frac{\left(1 - e_{jH}^t - n_{jH}^t\right)^{1-\theta}}{1-\theta} \right]$$

s.t. the household budget constraints and the human capital accumulation process, while taking fiscal policy variables, the wage and the interest rate as given. The vector Υ_H of household decision variables $\left[\Omega_{1H}^t, \Omega_{2H}^t, \Omega_{3H}^t, \Omega_{4H}^t, n_{1H}^t, n_{2H}^t, n_{3H}^t, n_{4H}^t, e_{1H}^t\right]$. Optimisation yields the following first order conditions guiding the optimal consumption path (21), the labour-leisure choice (22, 23) and the optimal time allocation to education (24):

$$\frac{c_{j+1,H}^t}{c_{jH}^t} = \beta(1 + r_{t+j}), \ \ j \in \{1,2,3,4\} \tag{21}$$

$$\frac{\gamma_1}{(1 - n_{1H}^t - e_{1H}^t)^\theta} = \frac{w_{H,t}\varepsilon_1 h_{1H}^t (1 - \tau_{1H}^m)}{(1+\tau_c)c_{1H}^t} \tag{22}$$

$$\frac{\gamma_j}{(1 - n_{jH}^t)^\theta} = \frac{w_{H,t+j-1}\varepsilon_j (1 + \phi(e_{1H}^t)^\sigma) h_{1H}^t (1 - \tau_{jH}^m)}{(1+\tau_c)c_{jH}^t}, \ \ j \in \{2,3,4\} \tag{23}$$

$$\frac{\gamma_1}{(1 - n_{1H}^t - e_{1H}^t)^\theta} = \beta \frac{1}{c_{2H}^t}\frac{\partial c_{2H}^t}{\partial e_{1H}^t} + \beta^2 \frac{1}{c_{3H}^t}\frac{\partial c_{3H}^t}{\partial e_{1H}^t} + \beta^3 \frac{1}{c_{4H}^t}\frac{\partial c_{4H}^t}{\partial e_{1H}^t} \tag{24}$$

$$\text{with: } \frac{\partial c_{jH}^t}{\partial e_{1H}^t} = \sigma\phi(e_{1H}^t)^{\sigma-1} \frac{w_{H,t+j-1}\varepsilon_j h_{1H}^t (1 - \tau_{jH}^m)\left(n_{jH}^t - \bar{n}_H\right)}{(1+\tau_c)}, \ \ j \in \{2,3,4\} \tag{25}$$

A.2 Lower ability households

For the lower ability individuals, the objective is to

$$\max_{\Upsilon_L} \quad u_L^t = \sum_{j=1}^{5} \beta^{j-1} \left[\ln c_{jL}^t + (1 - u_{j,t+j-1})\gamma_j \frac{\left(1 - n_{jH}^t\right)^{1-\theta}}{1-\theta} \right]$$

s.t. the household budget constraints and the human capital accumulation process, while taking the unemployment rate, wages, the interest rate, taxes and the unemployment benefit as given. The vector Υ_L of decision variables is $\left[\Omega_{1L}^t, \Omega_{2L}^t, \Omega_{3L}^t, \Omega_{4L}^t, n_{1L}^t, n_{2L}^t, n_{3L}^t, n_{4L}^t\right]$. Optimisation yields the following first order conditions:

$$\frac{c_{j+1,L}^t}{c_{jL}^t} = \beta(1 + r_{t+j}), \;\; j \in \{1, 2, 3, 4\} \tag{26}$$

$$\frac{\gamma_j}{(1 - n_{jL}^t)^\theta} = \frac{w_{L,t+j-1}\varepsilon_j h_{jL}^t(1 - \tau_{jL}^m)}{(1 + \tau_c)c_{jL}^t}, \; j \in \{1, 2, 3, 4\} \tag{27}$$

B Description of the equilibrium of the model

Definition 1 *Given an initial value for the technology stock A_0 and a value for the predetermined human capital stock of young higher ability individuals h_0, a vector of exogenous fiscal policy variables $\{\tau_c, \tau_k, \tau^p, \Gamma, \xi, g, \widetilde{b}_j\}_{j=1}^4$ and the exogenous world interest rate, an intertemporal equilibrium consists of sequences of decision rules $\{c_{1a}^t, c_{2a}^t, c_{3a}^t, c_{4a}^t, c_{5a}^t, \Omega_{1a}^t, \Omega_{2a}^t, \Omega_{3a}^t, \Omega_{4a}^t, e_{1H}^t, n_{1a}^t, n_{2a}^t, n_{3a}^t, n_{4a}^t\}_{t=0}^\infty$ of the household, sequences of prices $\{w_{a,t}\}_{t=0}^\infty$, human capital stocks $\{h_{1a}^t, h_{2a}^t, h_{3a}^t, h_{4a}^t\}_{t=1}^\infty$, lump sum transfers $\{Z_t\}_{t=0}^\infty$, tax rates $\{\{\tau_{ja}, \tau_{ja}^m\}_{j=0}^4\}_{t=0}^\infty$, unemployment rates $\{u_{1,t}, u_{2,t}, u_{3,t}, u_{4,t}\}_{t=0}^\infty$ and aggregate variables $\{Y_t, K_t, H_t, A_t\}_{t=0}^\infty$ for $a \in \{H, L\}$ such that*

1. *Decision rules of the higher ability households maximise the intertemporal utility function (1) subject to the budget constraints (2) and the human capital accumulation process (5), whereas decision rules of the lower ability households maximise the intertemporal utility function (3) subject to the budget constraints (4) and the human capital accumulation process described in Section 2.1.3.*

2. *Firms' choices $\{K_t, H_{1H,t}, H_{2H,t}, H_{3H,t}, H_{4H,t}, (1 - u_{1,t}), (1 - u_{2,t}), (1 - u_{3,t}), (1 - u_{4,t})\}$ maximise profits. These choices are determined via the optimality conditions of the firm in (17) and (18).*

3. *The wage $\{w_{H,t}\}$ is determined via (18) and is such that the labour market for higher ability individuals clears.*

4. *Given the wages chosen by the union using (20), each couple $\{n_{jL}^t, 1 - u_{j,t}\}$ forms a Nash equilibrium in the second stage of the dynamic game played between the household, the firm and the union. The union chooses $\{w_{L,t}\}$ to maximise its utility (9) subject to the optimal responses of the household and the firm (19). These actions form a subgame perfect equilibrium.*

5. *Human capital of the individuals evolves according to the human capital accumulation process described in Section 2.1.3.*

6. *Lump sum transfers ensure that the government budget (10) is balanced.*

7. *Government aggregates are determined via the equations described in (11-16). Average tax rates follow $\tau_{ja} = \Gamma\left(\frac{y_{ja,t}^{lab}}{\bar{y}_t^{lab}}\right)^\xi$, whereas marginal tax rates are determined via $\tau_{ja}^m = (1+\xi)\Gamma\left(\frac{y_{ja,t}^{lab}}{\bar{y}_t^{lab}}\right)^\xi$.*

8. *Y_t follows from the production function (6) and the values for K_t and A_tH_t (7-8).*

C Details on data construction and sources

In this Appendix, we provide details on the construction and sources of our data.

C.1 Individuals of high and low ability

Individuals of high ability pursue tertiary education when they enter our model at the age of 18. Individuals of lower ability do not: they achieve at most an upper secondary degree, but no tertiary degree. These assumptions explain why we use existing data for individuals with a tertiary degree as proxy for variables (e.g. wages, employment) relating to higher ability individuals in our model, and the average of existing data for individuals with a lower secondary degree and individuals with an upper secondary degree (but no tertiary degree) as proxy for variables relating to lower ability individuals. According to ISCED classification, data for high ability individuals therefore relate to education levels 5-6. Data for lower ability individuals are constructed as the average for education levels 0-2 and 3-4.

C.2 Unemployment

In our model, all individuals participate in the labour market during four periods of working age (18-29, 30-41, 42-53, 54-65). A fraction of lower ability individuals becomes unemployed. High ability individuals are always employed. Since we do not model participation as an endogenous variable, our setup implies that the unemployment rate among lower ability individuals in a particular age group is the same as the gap in percentage points between the employment rate among higher ability individuals and the employment rate among lower ability individuals in that age group. In line with our explanation in C.1, as a proxy for the former we use data for individuals with a tertiary degree. As a proxy for the latter, we compute the average of data for individuals with a below upper secondary degree and individuals with an upper secondary degree, but no tertiary degree.

Data sources: Eurostat (Employment rates by sex, age and highest level of education attained (%) [lfsa_ergaed]) provides employment rates in persons by level of educational attainment and by age for all EU15 countries and Norway since 1995 at the latest. Data are available for the age groups 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59 and 60-64, among others. We compute the data for our four larger age groups as weighted averages of the Eurostat data. The data that we report and employ are for 2001-2007. For the United States and Canada we use data provided by OECD Education at a Glance. Data by educational attainment are available for the age groups 25-34, 35-44, 45-54, 55-64.

C.3 Hours worked

For hours worked, we proceed as follows. First, we gather available OECD (Labour Force Statistics) data on the usual weekly number of hours that individuals work. These data are available for the age groups 15-24, 25-54 and 55-64. We compute the data for our four age groups as weighted averages of the OECD data. Second, we compute how many weeks individuals work per year. We divide OECD data on total annual hours worked per employee by the average number of hours worked per week. Data on total annual hours are only available at the level of the aggregate labour force. As such, we obtain a proxy for the number of weeks individuals work per year, also at the level of the aggregate labour force. Multiplying the first variable (usual hours per week) by the second (weeks per year), we obtain our proxy for total annual hours worked per employee in each generation. We express this number as a fraction

Table 5: Unemployment rates among four generations of lower educated individuals (2001-2007), in %

Unemployment rates	18-29	$30-41$	$42-53$	$54-65$
Belgium	23.7	17.1	18.9	17.6
France	5.9	12.5	10.2	17.4
Germany	20.0	18.5	18.5	23.5
Austria	9.8	14.1	16.4	25.0
Netherlands	10.5	12.4	13.5	17.7
Denmark	4.9	10.2	11.4	19.1
Finland	20.7	12.5	13.8	17.0
Norway	7.9	13.5	14.2	23.1
Sweden	1.2	11.1	10.9	15.7
United States	17.3	15.7	15.8	21.0
United Kingdom	17.7	14.5	13.9	8.5
Canada	15.7	14.3	14.5	12.9
Average	13.5	14.0	14.3	18.2

of the total time endowment. Like Wallenius (2013), we assume that the total time endowment of each individual is 14 hours a day, 7 days a week and 52 weeks per year. This time can be allocated to work, leisure or (for young higher ability individuals) education.

C.4 Education rate of the young higher ability individuals

The education rate indicates the fraction of their total time endowment that high ability individuals allocate to schooling. Considering that in countries like Canada and Norway almost (or even more than) 50% of the 25-34 year-olds succeed in obtaining a tertiary degree, it will be our assumption that 50% of the population in each country has high ability, and therefore the potential to succeed at high level. The extent to which this potential is fully exploited may however differ across countries. Differences may show up in the fraction of individuals that effectively succeed in tertiary education and in the level of the tertiary degree that these individuals eventually achieve. We expect that the latter will be reflected in the number of years that is studied. Building on this assumption and these considerations, our empirical proxy for the education rate is the number of students in tertiary education in full-time equivalents divided by 50% of size of the population of age 18-29. Data on the number of students is obtained from Eurostat (Students by ISCED level, study intensity (full-time, part-time) and sex [educ_enrl1ad]). Population data are from the OECD database (Total Population by sex and age). The education rates that we report are averages for 2001-2007.

C.5 Growth rate of real per capita output

To compute the growth rate of real per capita output, which we need for the calibration of the exogenous rate of technical progress (x), we use data on real potential GDP and on population at working age (15-64). The former are available from OECD Economic Outlook (supply block), the latter from OECD Labour Force Statistics. In line with all other data we compute average growth rates over 2001-2007.

Table 6: Hours worked per person employed (fraction of time) - average for tertiary and non-tertiary educated individuals (2001-2007)

Hours worked	18-29	$30-41$	$42-53$	$54-65$
Belgium	0.309	0.311	0.311	0.311
France	0.292	0.301	0.301	0.291
Germany	0.285	0.283	0.283	0.277
Austria	0.339	0.349	0.349	0.351
Netherlands	0.252	0.319	0.319	0.299
Denmark	0.283	0.354	0.354	0.344
Finland	0.327	0.366	0.366	0.349
Norway	0.263	0.309	0.309	0.297
Sweden	0.300	0.341	0.341	0.332
United States	0.338	0.383	0.383	0.374
United Kingdom	0.325	0.359	0.359	0.332
Canada	0.331	0.371	0.371	0.358
Average	0.305	0.338	0.338	0.323

Table 7: Fraction of time allocated to education by young high ability individuals (2001-2007)

	Education
Belgium	0.450
France	0.450
Germany	0.386
Austria	0.434
Netherlands	0.442
Denmark	0.522
Finland	0.564
Norway	0.512
Sweden	0.444
United States	0.574
United Kingdom	0.366
Canada	0.474
Average	0.468

Table 8: Labour tax rates on employees and employers (2000-2007) and unemployment benefit replacement rates (2001-2004), in %

	ξ	Γ	τ^p	$\widetilde{b}_j$
Belgium	0.343	33.4	29.1	59.6
France	0.296	21.7	38.7	46.0
Germany	0.245	30.2	19.9	64.7
Austria	0.311	27.3	28.6	56.3
Netherlands	0.391	25.2	11.2	55.0
Denmark	0.233	35.3	0	61.9
Finland	0.424	28.9	24.1	61.3
Norway	0.392	25.1	12.7	56.9
Sweden	0.376	28.9	32.2	55.4
United States	0.330	17.1	7.7	30.5
United Kingdom	0.383	24.0	9.8	51.1
Canada	0.331	17.9	11.1	44.4
Average	0.337	26.3	18.8	53.4

Table 9: Tax rates on consumption and capital (in %), and government spending on goods (in % of GDP), (1995-2001)

	τ_c	τ_k	g
Belgium	13.4	27.1	24.8
France	17.1	21.7	28.5
Germany	11.1	34.4	23.2
Austria	13.2	17.3	23.4
Netherlands	12.2	24.3	27.3
Denmark	18.9	22.5	29.8
Finland	15.2	17.2	26.8
Norway	16.4	22.1	26.3
Sweden	17.9	16.1	32.6
United States	7.2	23.6	19.5
United Kingdom	14.5	21.2	21.4
Canada	14.5	24.8	23.6
Average	14.3	22.1	25.7

C.6 Fiscal policy variables

The government in our model finances spending on goods and unemployment benefits from taxes on labour (on both employers and employees), consumption, and capital. Lump sum transfers ensure a balanced budget. For the tax rates τ_k and τ_c, we use the same data as Heylen and Van de Kerckhove (2013). Regarding labour tax rates, we distinguish between social security contributions paid by employers and taxes and social security contributions on labour income paid by employees. Our data source is OECD (Taxation, Tax Database, Tables I.4, I.5, I.6). More specifically, we use the OECD's average rate of employer social security contributions for τ^p (Table I.5). We calibrate the level parameter Γ in the workers' income tax rate using the OECD data for all-in average personal income tax rates at average wage. The all-in tax rate is calculated as the combined central and sub-central government income tax plus employee social security contribution, as a percentage of gross wage earnings. The OECD provides these tax rates for four family types (Table I.6). We computed the average over these types. A novelty compared to previous work is the inclusion of progressive income taxation. Just like Koyuncu (2011), we calibrate the country-specific degree of progressivity ξ according to our description in Section 2.4. as the ratio (minus 1) of the marginal tax rate on workers' gross wage to the average tax rate, both including social security contributions. The OECD provides these marginal and average tax rates for a single person without dependent at four different income levels (Tables I.4 and I.5). Our proxy for ξ reflects the average of the results over these four income levels. All computed and reported tax data in our Table 8 are averages over the period 2000-2007. For government spending on goods in percent of GDP (g) we compute the sum of their data for government consumption and productive government spending. For details on the construction of these fiscal policy variables, we refer to Heylen & Van de Kerckhove (2013, their Appendix 1).

For the unemployment benefit replacement rate ($\widetilde{b}$) we make use of data provided by the OECD (Tax-Benefit Models). Since in our model unemployment is a structural or equilibrium phenomenon, the data that we use concern net transfers received by structurally or long-term unemployed people. They include social assistance, family benefits and housing benefits in the 60th month of benefit receipt. They also include unemployment insurance or unemployment assistance benefits if these benefits are still paid, i.e. if workers can be structurally unemployed for more than five years without losing benefit eligibility. The OECD provides net replacement rates for six family situations and three earnings levels. Our data in Table 8 are the averages of these 18 cases. Data are for 2001-2004.

D Derivation of the first-order condition of the union

The union maximises Equation (9) with respect to $w_{L,t}$. In this derivation, we use the structure of average and marginal tax rates as discussed in Section 2.4. So,

$$\frac{\partial V_t}{\partial w_{L,t}} = 0 \iff \sum_j [\frac{1}{\chi_j} \left(w_{L,t}(1-\tau_{jL}) - \bar{w}_{j,t}\right)^{\chi_j} \frac{\partial(1-u_{j,t})}{\partial w_{L,t}} +$$
$$(1-u_{j,t}) \left(w_{L,t}(1-\tau_{jL}) - \bar{w}_{j,t}\right)^{\chi_j - 1} \left[(1-\tau_{jL}) + w_{L,t}\left(-\frac{\partial \tau_{j,L}}{\partial w_{L,t}}\right)\right]] = 0$$

$$\iff \sum_j [\frac{1}{\chi_j} \left(w_{L,t}(1-\tau_{jL}) - \bar{w}_{j,t}\right)^{\chi_j} \frac{\partial(1-u_{j,t})}{\partial w_{L,t}} +$$
$$(1-u_{j,t}) \left(w_{L,t}(1-\tau_{jL}) - \bar{w}_{j,t}\right)^{\chi_j - 1} *$$
$$\left[(1-\tau_{jL}) + w_{L,t}\left(-\left[\xi\Gamma\left(\frac{y^{lab}_{jL,t}}{\bar{y}^{lab}_t}\right)^{\xi-1}\left(\frac{g(n^{t-j+1}_{jL})h^{t-j+1}_{jL}\varepsilon_j(1-u_{j,t})}{\bar{y}^{lab}_t}\right)\right]\right)\right]] = 0$$

$$\iff \sum_j [\frac{1}{\chi_j} \left(w_{L,t}(1-\tau_{jL}) - \bar{w}_{j,t}\right)^{\chi_j} \frac{\partial(1-u_{j,t})}{\partial w_{L,t}} +$$
$$(1-u_{j,t}) \left(w_{L,t}(1-\tau_{jL}) - \bar{w}_{j,t}\right)^{\chi_j - 1} \left[1 - (\tau_{jL} + \xi\Gamma\left(\frac{y^{lab}_{jL,t}}{\bar{y}^{lab}_t}\right)^{\xi})\right]] = 0$$

$$\iff \sum_j [\frac{1}{\chi_j} \left(w_{L,t}(1-\tau_{jL}) - \bar{w}_{j,t}\right)^{\chi_j} \frac{\partial(1-u_{j,t})}{\partial w_{L,t}} +$$
$$(1-u_{j,t}) \left(w_{L,t}(1-\tau_{jL}) - \bar{w}_{j,t}\right)^{\chi_j - 1} \left[1 - \tau^m_{jL}\right]] = 0$$

The union's first order condition (Equation 20) follows if we impose the additional assumption that the union treats every generation equally when it comes to producing utility. Each part of the above sum must then be equal. Given that the sum itself must be zero, each part will then also be zero. For each generation, the excess wage gap is now related to the corresponding response of the household within that generation and the firm.