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## Frictions or deadlocks? Job polarization with search and matching frictions

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# Frictions or deadlocks? Job polarization with search and matching frictions

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# Frictions or deadlocks? Job polarization with search and matching frictions

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## Abstract

This paper extends Pissarides (1990)'s matching model by considering two sectors (routine and manual) and workers' occupational choices, in the context of skill-biased demand shifts, to the detriment of routine jobs and in favour of manual jobs because of technological changes. The theoretical challenge is to investigate the reallocation process from the middle towards the bottom of the wage distribution. By using this framework, we shed light on the way in which labour market institutions affect the job polarization observed in the United States and Europe. The results of our quantitative experiments suggest that search frictions have non-trivial effects on the reallocation process and transitional dynamics of aggregate employment.

**Keywords:** Search and matching, job polarization, reallocation, labor market institutions.

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**JEL Classification:** E24, J62, J64, O33

## 1 Introduction

For more than 30 years, developed countries have undergone dramatic structural changes driven by rapid technological advances. While technological changes increase the marginal product of skilled workers (skill-biased technological changes hereafter), they affect employment demand for low-skilled workers in a less trivial way: technological changes generate skill-biased demand shifts to the detriment of middle-skilled workers and in favour of the lowest-skilled workers. Technological changes thus lead to job polarization, namely the disappearance of mid-level jobs (requiring a moderate level of skills, such as autoworkers' jobs) relative to both those at the bottom (requiring few skills such as cleaners and salespeople) and those at the top (requiring greater skill levels such as managers and professionals). Autor & Dorn (2013)<sup>1</sup>, by using US data, and Goos & Salomons (2014), for European countries, find empirical evidence of pervasive job polarization. In other words, the automation of tasks in the middle of the wage distribution (in repetitive, 'routine' tasks that can be replaced by machines) requires that workers previously employed to carry out these tasks switch occupations, thereby moving to another labour market where their manual abilities will be used (e.g. in 'manual' non-repetitive jobs in the service sector<sup>2</sup>). This paper develops a multi-sectoral search and matching model with endogenous occupational choice to shed light on the way in which labour market institutions (LMIs) affect the job polarization observed in the United States and Europe in the context of skilled-biased technological changes.

Accounting for reallocations from the middle towards the bottom of the wage distribution has become an important challenge<sup>3</sup>. Indeed, these reallocations contrast with those described in Aghion & Howitt (1994) and Mortensen & Pissarides (1998) where obsolete jobs

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<sup>1</sup>Jaimovich & Siu (2015) show that this phenomenon is magnified in recession.

<sup>2</sup>As in Autor & Dorn (2013), the "service sector" herein includes non-routine manual activities involving assisting others (e.g. janitors, cleaners, childcare) performed by unskilled workers.

<sup>3</sup>Our paper can be viewed as a first step towards developing the following suggestion: "*Further work tractably integrating various forms of labor market imperfections within a framework that incorporates the endogenous allocation of skills to tasks appears to be another fruitful area for research.*" Acemoglu & Autor (2011), p.1160.

are destroyed and displaced workers are reallocated to jobs on the technological frontier<sup>4</sup>. Our work can be viewed as an extension of Mortensen & Pissarides (1999*b*)’s framework to a non-stationary environment where workers can move from a declining sector to an emerging sector. As in Pissarides and Mortensen’s framework, we share the view that employment allocation across tasks depends on LMIs, unemployment benefits (UB), and employment protection laws. We also add a focus on the minimum wage (MW). In addition, our paper relates to research dealing with occupational changes such as Alvarez & Shimer (2011) and Carrillo-Tudela & Visschers (2014). We borrow from these papers the distinction between ‘search’ and ‘rest’ unemployment: a worker in search unemployment moves to better job opportunities, which is a costly activity, while a worker in rest unemployment waits for her current labour market conditions to improve. While these papers study career changes over the business cycle, we extend their work by analyzing occupational changes in a non-stationary environment, with structural technological changes. Workers face long-term changes in productivity across sectors such that workers in routine jobs know that the labour market conditions cannot improve in the future.

The aim of the present paper is to study employment reallocations from jobs at the middle of the wage distribution towards low-paid jobs. We then focus on unskilled workers’ sectoral reallocation. We analyze the transitional dynamics from the old world to a new world, i.e. the path along which structural technological changes remove the competitive advantages of workers in the middle of the wage distribution, leading them to move to new opportunities at the bottom of the wage distribution. By nature, this phenomenon takes time (searching for a job in a new occupation is time consuming), and it can be blocked if redistributive policies, by increasing the outside option of the poorest, cancel the potential profits of new jobs in the service sector.

This approach contrasts with the stylized model proposed by Autor & Dorn (2013) who stress only the long-term effects of the job polarization phenomenon in a frictionless economy. Workers move from the routine sector to the manual sector without search frictions as soon as wages are equalized across sectors. Forward-looking behaviours in occupational choices and sluggish employment adjustments are ignored. For the sake of simplicity, we consider the basic model of Pissarides (1990), which is suitable for a dynamic analysis of the job reallocation of unskilled workers. Beyond the comparison of the initial and final steady states, we also solve the transitional dynamics. Further, our paper goes

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<sup>4</sup>Pissarides & Vallanti (2007) show that technological growth reduces unemployment despite these reallocations.

beyond the traditional analysis of LMIs' effects on labour market outcomes by focusing on their effects on the reallocation from routine to manual tasks. Our stylized model can be summarized as follows: *(i)* there are two sectors (manufacturing and services), with two opposite exogenous productivity processes (declining for routine jobs and increasing for manual jobs); *(ii)* employment allocation is driven by a matching model *à la* Pissarides in each segmented market; *(iii)* as in Autor & Dorn (2013)<sup>5</sup>, an individual worker's ability affects her productivity in the manufacturing sector, unlike in the service sector; *(iv)* each unemployed worker in the routine market chooses the labour market in which to search for a job; and *(v)* if she moves from a routine to a manual job, the occupational change is accompanied by a learning process that transitorily reduces her productivity on manual tasks (compared with experienced workers in the sector), in accordance with Cortes (2015)'s empirical finding.

In an unbalanced growth environment with a flexible labour market, we show that *(i)* search frictions entice workers to anticipate the changes in productivity across sectors and *(ii)* more attractive employment prospects in manual jobs encourage workers to lower their wage in the first stage of the reallocation process. Indeed, since their decisions rely on job prospects, which take into account future job finding rates, unemployed workers can switch occupations before their previous job becomes unprofitable. Workers who just switched occupations (referred to as 'movers', or inexperienced/novice workers in the service sector) can transitorily accept lower wages in manual jobs in anticipation of future improvements in their productivity as experienced manual workers. Hence, the first step of job polarization, at least at the individual level, is characterized by lower wages in the manual sector and longer unemployment spells. Nevertheless, given that these reallocations are voluntary, each individual moves towards those markets in which new opportunities are created and thus search unemployment is the best option. We show that strong downward wage flexibility can accelerate this reallocation process, even if it involves transitory employment costs.

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<sup>5</sup>With respect to their paper, we focus on unskilled labour only, which is at the heart of the labour reallocation involved in job polarization. We also develop in this paper a partial equilibrium approach. Modelling a general equilibrium as in Autor & Dorn (2013) would involve computing the relative price of services with respect to goods, which depends on relative labour demand and supply in each sector. This would involve taking into account other elements in the model such as household demand, capital, skilled workers, and so on, which lies beyond the scope of this paper. This is left for future research. We also argue that the exogenous rise in service productivity could be considered to be a proxy for the rise in the relative price of services found in Autor & Dorn (2013).

Once equilibrium unemployment is explicitly considered, it allows us to take into account another key dimension of the job reallocation process in interaction with LMIs. We show that if the unemployment value is not perfectly indexed on labour market conditions (existence of a MW or UB incorporating a redistributive component), then the reallocation process can lead to persistent rest unemployment. Indeed, with high wages and strong downward rigidity, we show that endogenous job separations in the routine sector<sup>6</sup> may occur before the moving market is attractive enough to create jobs. In this case, the downward rigidity in wages due to high unemployment and the existence of an MW decreases the aggregate employment rate, at least in the short to medium run and, in some cases, in the long run. This departure from the frictionless labour market *à la* Autor & Dorn (2013) underlines that changes in labour demand (labour shares) within the unskilled labour market can lead to a large divergence across countries in terms of employment levels depending on their LMIs. A relatively high level of welfare state incomes can become an obstacle to employment when polarization is at work. This explains why welfare state reforms have accompanied the polarization process for more than 20 years. Hence, we complement the studies of Ljungqvist & Sargent (1998), Ljungqvist & Sargent (2008) and Hornstein et al. (2007) by providing a framework where the direction of the reallocation is dictated by the shift in sectoral labour demand.

The remainder of the paper is organized as follows. We present the model in Section 2, before contrasting the US and European cases (Section 3). Section 4 concludes.

## 2 The model

### 2.1 Assumptions

The structure is based on a search and matching model with endogenous occupational choice: search, rest and reallocation. It consists of two types of jobs: routine ( $r$ ) and manual ( $s$ ). There is a continuum of workers who differ with respect to their abilities  $\eta$ . As in Autor & Dorn (2013), low-skilled workers have homogeneous (heterogeneous) skills at performing manual (routine) tasks.<sup>7</sup> The model endogenously determines which

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<sup>6</sup>Taking into account downward wage rigidity through the existence of a fixed minimum income may lead to an optimal scrapping time for each task.

<sup>7</sup>This approach is consistent with the view that blue-collar workers in the factory differ in performing their tasks on an assembly line while jobs such as janitors can hardly differ in terms of productivity

workers occupy routine and manual occupations through the endogenous determination of the  $\tilde{\eta}$  below which workers choose to work in manual jobs in the service sector. The mobility cost between activities is modelled as a loss of efficiency, which proxies a learning process on a new occupation<sup>8</sup>. Hence, in the production of services, displaced workers from the routine labour market are novice in service occupations and they thus have lower productivity than experienced manual workers, which introduces heterogeneity among workers in the service sector. Occupational choices, by affecting the number of workers in each unemployment pool, directly alter the unemployment rates in each sector of the economy as well as job finding probabilities.

Labour markets are characterized by search and matching frictions *à la* Pissarides (1990). Search is directed as there is a labour sub-market for each occupation, especially for each ability level  $\eta$  in routine jobs<sup>9</sup>. Within each pool, the meeting process between workers and firms is random. There is no on-the-job search.  $m_t$ , the amount of hiring per period in each segment of the labour market (routine for each ability level  $\eta$  and all manual labour), is determined by a constant returns to scale matching function:

$$m_i = \chi v_i^\psi u_i^{1-\psi}, \quad 0 < \psi < 1 \quad (1)$$

with  $i = r(\eta)$  (routine of ability  $\eta$ ),  $s^0(\eta)$  (displaced routine worker of ability  $\eta$  who just switched to a manual job in the service sector), and  $s$  (experienced worker in manual jobs).  $\chi > 0$  is a scale parameter measuring the efficiency of the matching function,  $v_i$  the number of vacancies and  $u_i$  the number of unemployed workers.  $\psi$  is the elasticity of the matching function with respect to vacancies. A vacancy is filled with probability  $q_i = m_i/v_i$  and the job finding probability per unit of worker search is  $f_i = m_i/u_i$ . Labour market tightness is  $v_i/u_i$ .

A job can be destroyed for exogenous reasons at rate  $s$ . Endogenous separation occurs when profits become negative. This could arise when the job surplus is negative or when a MW exists. In all cases, a firing cost  $d$  is incurred<sup>10</sup>.

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in providing non-routine manual services. The service sector employs only unskilled labour in non-routine manual tasks  $n_s$  (such as janitors, cleaners, etc. occupations involving assisting others). Then, experienced workers in services are identical. As a result, ability  $\eta$  matters (does not matter) in routine (manual) productivity.

<sup>8</sup>For simplicity, we assume that this learning process takes only one period. Obviously, with linear utility functions, only the size of the efficiency loss matters, not its duration.

<sup>9</sup>This assumption is also retained in Mortensen & Pissarides (1999c).

<sup>10</sup>Firing costs are not severance payments but rather the administrative costs of layoff procedures. Hence, they are pure losses.



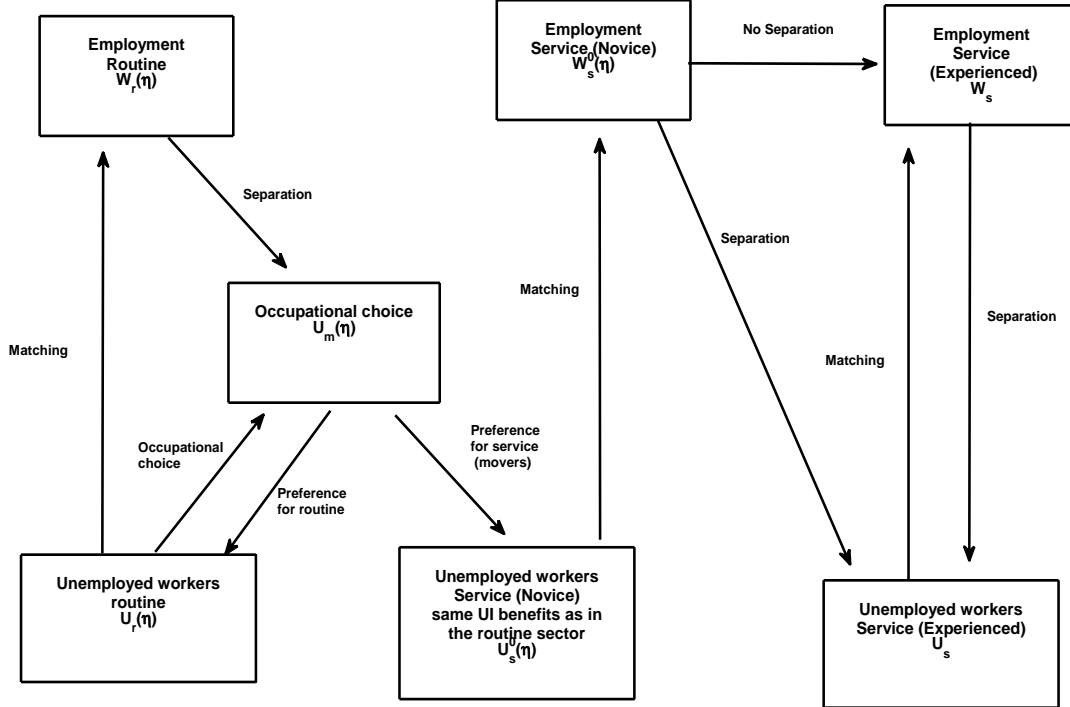


Figure 1: **LABOUR MARKET FLOWS**. Notations are defined in Section 2.2.1

Polarization is triggered by an exogenous fall in productivity in the routine sector and an exogenous increase in productivity in the service sector. The structure of shocks is consistent with Autor & Dorn (2013)'s idea that a decline in the price of technological capital leads to labour substitution and an increase in the price of services<sup>11</sup>. A summary of labour flows is depicted in Figure 1. The timing of events is described in Figure 2. If it exists, endogenous separation happens at the very beginning of the period, before production starts. The same is true for occupational choices. Unemployed workers make their occupational choice at the beginning of the period. Scrapping and quitting is explained in Section 2.2.3. The stock of employed and unemployed workers is determined. Production takes place. Wages and UB are paid. The number of vacant jobs is determined. The number of new employment relationships is determined through the matching process. Newly hired workers enter employment in the next period.

<sup>11</sup>In our partial equilibrium model, we capture the increase in the price of services through the exogenous rise in productivity in the service sector.

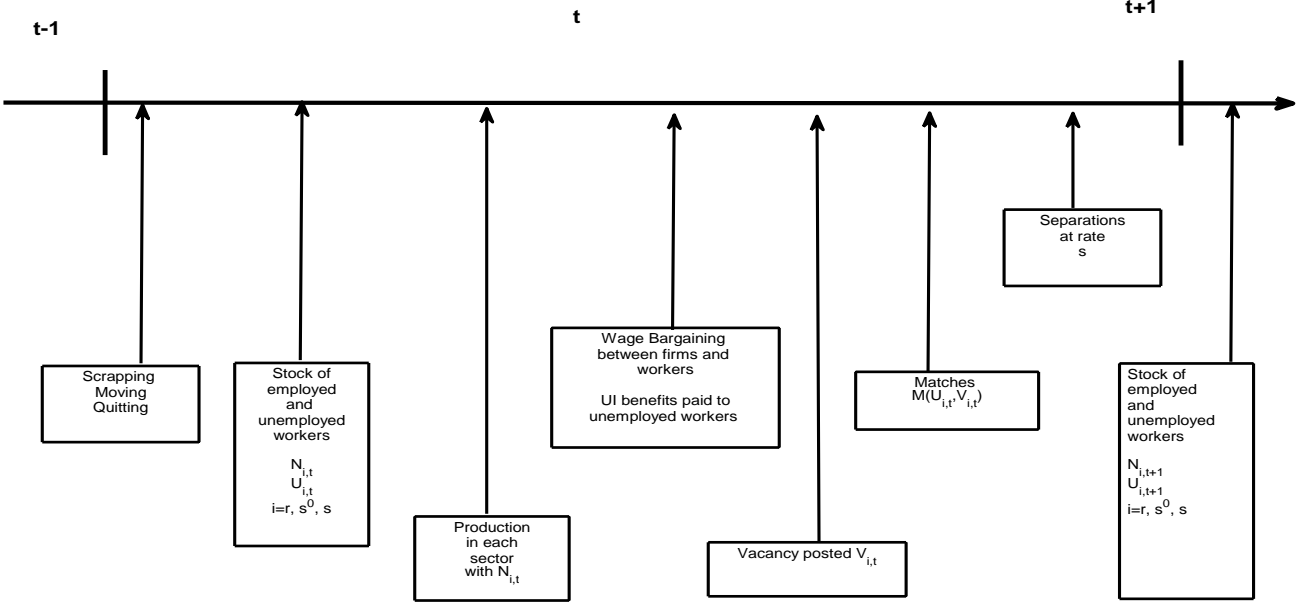


Figure 2: TIMING OF EVENTS.

## 2.2 Bellman equations

### 2.2.1 Workers

We distinguish three types of unemployed workers: workers of ability  $\eta$  looking for routine jobs (with subscript  $r(\eta)$ ), those looking for manual jobs (with subscript  $s$ ), and those previously employed in a routine job but looking for a manual job for inexperienced workers (with subscript  $s^0(\eta)$ ). In the service sector, we distinguish novice from experienced workers. New unemployed workers in the service sector (also referred to as novice or inexperienced) enjoy the same UB as in the routine sector (where they were previously employed), while experienced unemployed workers with past employment experience in the service sector enjoy the UB specific to this sector. The present values for unemployed workers in the routine and service sectors (novice and experienced) are denoted by  $U_r(\eta, t)$ ,  $U_s^0(\eta, t)$ , and  $U_s(t)$ , respectively. The corresponding employment values are  $W_r(\eta, t)$ ,  $W_s^0(\eta, t)$ , and  $W_s(t)$ , respectively.  $U_m(\eta, t)$  defines the occupational choice of an unemployed workers between the two sectors. The workers' value functions reported in

Figure 1 are

$$U_r(\eta, t) = b_r(\eta, t) + \beta[f_r(\eta, t)W_r(\eta, t + 1) + (1 - f_r(\eta, t))U_m(\eta, t + 1)] \quad (2)$$

$$U_m(\eta, t) = \max\{U_r(\eta, t), U_s^0(\eta, t)\} \quad (3)$$

$$U_s^0(\eta, t) = b_r(\eta, t) + \beta[f_s^0(\eta, t)W_s^0(\eta, t + 1) + (1 - f_s^0(\eta, t))U_s^0(\eta, t + 1)] \quad (4)$$

$$U_s(t) = b_s(t) + \beta[f_s(t)W_s(t + 1) + (1 - f_s(t))U_s(t + 1)] \quad (5)$$

$$W_r(\eta, t) = \max\{w_r(\eta, t) + \beta[(1 - s)W_r(\eta, t + 1) + sU_m(\eta, t + 1)], U_m(\eta, t)\} \quad (6)$$

$$W_s^0(\eta, t) = \max\{w_s^0(\eta, t) + \beta[(1 - s)W_s(t + 1) + sU_s(t + 1)], U_s^0(\eta, t)\} \quad (7)$$

$$W_s(t) = \max\{w_s(t) + \beta[(1 - s)W_s(t + 1) + sU_s(t + 1)], U_s(t)\} \quad (8)$$

$\beta$  is the discount factor and  $s$  the exogenous separation rate.  $b_r(\eta, t)$  denotes UB when unemployed in the routine sector or newly unemployed in the service sector, while unemployed workers with employment experience in the service sector enjoy  $b_s(t)$ .  $w_r(\eta, t)$  is the wage rate in the routine sector as a function of the worker's ability  $\eta$ . An unemployed routine worker of ability  $\eta$  at time  $t$  (Equation (2)), with value  $U_r(\eta, t)$ , can find a job with probability  $f_r(\eta, t)$ . If the worker fails to find a job, he can decide to switch occupations, in which case, we refer to him as a "mover". This happens if the expected value from unemployment in the service sector is larger than that in the routine sector. Equation (3) captures the occupational choice. In the service sector, the wage rates are  $w_s^0(\eta, t)$  and  $w_s(t)$  for novice and experienced workers respectively. Unemployed workers find a job with probabilities  $f_s^0(\eta, t)$  and  $f_s(t)$ . Employed workers may become unemployed at rate  $s$ . It should be noted that unemployed workers in the service sector do not have an occupational choice.

Concerning mobility choices, they appear twice: unemployed workers can choose in which market they will search (Equation (3)), and employed workers can choose to quit because firms cannot keep up with the rise in their outside options (Equation (6)). Endogenous separations can occur when  $U_s^0(\eta, t) = \max\{W_r(\eta, t), U_m(\eta, t)\}$ . As a result, in Equation (2), the unemployment value  $U_m(\eta, t + 1) = U_s^0(\eta, t)$  is not indexed on the employment value  $W_r$ .

### 2.2.2 Firms

The continuum of producers in a competitive market use labour as their only input. A job may be either filled and productive or unfilled and unproductive. The values of a filled

job in the routine and service sectors (novice and experienced) are denoted as  $J_r(\eta, t)$ ,  $J_s^0(\eta, t)$ , and  $J_s(t)$ , respectively. The associated values when the job is vacant are  $V_r(\eta, t)$ ,  $V_s^0(\eta, t)$ , and  $V_s(t)$ , respectively

$$J_r(\eta, t) = y_r(t)\eta - w_r(\eta, t) + \beta [(1 - s) \max \{J_r(\eta, t + 1), -d\} + sV_r(\eta, t)] \quad (9)$$

$$J_s^0(\eta, t) = \delta y_s(t) - w_s^0(\eta, t) + \beta [(1 - s) \max \{J_s(t + 1), -d\} + sV_s(t)] \quad (10)$$

$$J_s(t) = y_s(t) - w_s(t) + \beta [(1 - s) \max \{J_s(t + 1), -d\} + sV_s(t)] \quad (11)$$

$$V_r(\eta, t) = -\kappa + \beta [q_r(\eta, t)J_r(\eta, t + 1) + (1 - q_r(\eta, t))V_r(\eta, t + 1)] \quad (12)$$

$$V_s^0(\eta, t) = -\kappa + \beta [q_s^0(\eta, t)(1 - s)J_s^0(\eta, t + 1) + (1 - q_s^0(\eta, t))V_s^0(\eta, t + 1)] \quad (13)$$

$$V_s(t) = -\kappa + \beta [q_s(t)(1 - s)J_s(t + 1) + (1 - q_s(t))V_s(t + 1)] \quad (14)$$

Productivity in a routine job is characterized by two components:  $y_r(t)$  is a common component and  $\eta$  is the ex-ante skill ability.  $y_s(t)$  denotes the productivity of a manual job.  $y_r(t)$  and  $y_s(t)$  are both exogenously determined. The productivity of novice workers in the service sector is assumed to be lower than that of experienced workers, i.e.  $\delta \leq 1$ . To fill their vacant jobs, firms publish adverts and screen workers, incurring hiring costs  $\kappa$ . A vacant job is filled with probability  $q_i$ . Finally, routine jobs may shut down endogenously when profits are negative or, if dismissal costs exist ( $d$ ), when the firm's profits are lower than dismissal costs. In this case, it is better to terminate employment and pay dismissal costs.<sup>12</sup>

Job creation is driven by the free entry condition. In equilibrium, all gain opportunities generated by a vacant job are equal to zero, i.e.  $V_i = 0$ . From Equations (12) - (14), one gets:

$$\frac{\kappa}{q_i(t)} = \beta J_i(t + 1) \quad i = r(\eta), s^0(\eta), s \quad (15)$$

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<sup>12</sup>Given the exogenous productivity change considered herein, once created, manual jobs are always profitable. Endogenous separation does not occur for manual jobs in the service sector. Endogenous separations affect routine employment.

### 2.2.3 Wages and unemployment benefits

**Wages.** Wages are determined through an individual Nash bargaining process. The optimal sharing rule leads to<sup>13</sup>

$$\xi J_i(t) = (1 - \xi)(W_i(t) - U_i(t)) \quad (16)$$

where  $\xi$  and  $1 - \xi$  denote the bargaining power of firms and workers, respectively. The indexation of the unemployment value to the worker or firm values rules out endogenous separations. This is the case when unemployed workers do not choose to change occupations. By contrast, when they choose to change occupations, employees' outside options become the search value in another labour market, a value not indexed on the job value of the market in which they are employed. If this new unemployment value (the value of the inexperienced unemployed worker in the service sector) remains constant or increases, whereas worker and firm values decrease because of the fall in productivity (as is the case for routine jobs), then the outside option can become the best option after a finite employment spell. Hence, outsiders' occupational change places upward pressure on the routine wage of 'insiders' by introducing a credible alternative that comes from another market. If this outside option leads to a wage that will be outside the bargaining set, then there is a separation. This defines an optimal *quitting rule* given by  $W_i(\hat{T}) - U_i(\hat{T}) = 0$ , where  $W_i(\hat{T})$  is the employment value for a wage that corresponds to the solution of the Nash bargaining process.<sup>14</sup> Before this finite endogenous employment spell, if it exists, wages are given by<sup>15</sup>:

$$\tilde{w}_r(\eta, t) = \xi(y_r(t)\eta + \kappa\theta_r(\eta, t)) + (1 - \xi)b_r(\eta, t) \quad \text{if } U_r(\eta, t) > U_s^0(\eta, t) \quad (17)$$

$$\tilde{w}_r(\eta, t) = \xi(y_r(t)\eta + \kappa\theta_s^0(\eta, t)) + (1 - \xi)b_r(\eta, t) \quad \text{if } U_r(\eta, t) \leq U_s^0(\eta, t) \quad (18)$$

$$\tilde{w}_s^0(\eta, t) = \xi(\delta y_s(t) + \kappa\theta_s^0(\eta, t)) + (1 - \xi)(b_r(\eta, t) + \beta(U_s^0(\eta, t + 1) - U_s(t + 1))) \quad (19)$$

$$\tilde{w}_s(t) = \xi(y_s(t) + \kappa\theta_s(t)) + (1 - \xi)b_s(t) \quad (20)$$

<sup>13</sup>Following Ljungqvist (1999), we assume that the Nash product is  $J_i(t)^\xi(W_i(t) - U_i(t))^{1-\xi}$  each period  $t$ , instead of  $J_i(t)^\xi(W_i(t) - U_i(t))^{1-\xi}$  at the time of the meeting and  $(J_i(t) + d)^\xi(W_i(t) - U_i(t))^{1-\xi}$  after the meeting. Indeed, Ljungqvist (1999) shows that these alternative wage structures only change the wage over the career, but not the employment allocation. Hence, we adopt the simplest contract.

<sup>14</sup>When the outside options can lead the employee to quit, she can ask for a wage that corresponds to her productivity: this case corresponds to the solution of an ultimatum. However, in this case, the firm closes down, and thus the match is also broken. Hence, if we take into account the possibility of this ultimatum, this does not change the employment relationship, only the terminology of the separation: it becomes a "scrap" instead of a "quit".

<sup>15</sup>Wages are reported in Appendix A.

In Equation (17), all components are indexed on the decreasing productivity of routine jobs  $y_r(t)$ . This is not the case in (18), where  $\theta_s^0(\eta, t)$  depends on increasing productivity in the service sector  $y_s(t)$ . The outside option given by an alternative market with increasing productivity can push the wage outside the bargaining set, leading to endogenous separations. How are these outside options perceived by workers? If workers choose to switch occupations, then they target the jobs of experienced employees in the service sector. They accept lowering their reservation wages by an amount proportional to  $\beta(U_s^0(\eta, t+1) - U_s(t+1))$  (Equation (19)) to access more easily the learning process, the prerequisite of being an experienced worker. These low-bargained wages on the first job of movers raise labour market tightness ( $\theta_s^0(\eta, t)$ ) and thus the bargained wage paid for routine jobs (Equation (18)).

**Minimum wage.** LMIs can distort this bargained wage. First, if there is a MW, the wage is:

$$w_i = \max(\tilde{w}_i(t), w_{\min}(t)) \quad (21)$$

If the MW is binding, then the firm has the right to manage. For jobs where the marginal returns are decreasing (routine jobs), it is possible to determine an optimal scrapping time that is not mutually advantageous i.e.  $J_r(\eta, t) - d \leq 0$ , whereas  $W_r(\eta, t) - U_m(\eta, t) \geq 0$ , where the optimal *scrapping rule* is  $J_r(\eta, T^*) - d = 0$ . In addition, the MW can block the creation of service jobs if the labour cost of an inexperienced worker exceeds its marginal return, i.e.  $\delta y_s(t) \leq w_{\min}$  where  $\delta y_s(\tilde{T}) = w_{\min}$  is the *opening rule* for movers.

**Unemployment benefits.** We consider two types of UB. The first stresses the insurance motive in UB with an indexation of UB on current individual wages. The second one emphasizes redistribution. UB are set according to the following rules:

A benefit system purely based the insurance motive ("UB indexed"):

$$b_r(\eta, t) = \rho w_r(\eta, t) \quad (22)$$

$$b_s(t) = \rho w_s(t) \quad (23)$$

A benefit system with a redistributive component ("UB not-indexed"):

$$b_r(\eta, t) = \rho(t) w_r(\eta, 0) \quad (24)$$

$$b_s(t) = \rho(t) w_s(0) \quad (25)$$

In Equations (22) and (23), the replacement rate  $\rho$  is fixed. Hence, along the technological transition, the gap between UB and wages remains constant. UB are indexed on wage changes. In Equations (24) and (25), UB are based on wages at the beginning of the technological changes  $w_r(\eta, 0)$  and  $w_s(0)$ . The polarization process involves displacement of routine workers and employment growth in the service sector. With rules such as in Equations (24) and (25), UB remain generous for routine workers (who lose their jobs during the transition), while they are less generous for workers in the service sector (who are the winners of the technological changes). To that extent, Equations (24) and (25) have a distributive content. Finally, Equations (24) and (25) disconnect UB from wage growth along the technological transition. The non-indexation of UB to the sectoral marginal return can lead to endogenous separations in routine jobs, while it can block the opening of new jobs for inexperienced workers in manual jobs (whose UB are also based on  $b_r$ ). Finally, we also allow  $\rho(t)$  to vary over time.

### 2.3 Stocks and flows

We assume that the mass of employed and unemployed workers is fixed and equal to one. To simplify the notations, we consider the following variables:

$$\begin{aligned} \mathbb{I}^m(\eta, t) &= \begin{cases} 1 & \text{if } U_r(\eta, t) \leq U_s^0(\eta, t) \\ 0 & \text{otherwise} \end{cases} \\ \mathbb{I}^s(\eta, t) &= \begin{cases} 1 & \text{if } J_r(\eta, t) \leq -d \\ 0 & \text{otherwise} \end{cases} \\ \mathbb{I}^q(\eta, t) &= \begin{cases} 1 & \text{if } W_r(\eta, t) \leq U_m(\eta, t) \\ 0 & \text{otherwise} \end{cases} \end{aligned}$$

where  $\mathbb{I}^m(\eta, t)$  is an indicator function defining whether the routine worker moves to the service sector.  $\mathbb{I}^s(\eta, t)$  and  $\mathbb{I}^q(\eta, t)$  correspond to indicator functions describing whether the match is dissolved from the initiative of the firm alone or from a mutual agreement, respectively. Without any real wage rigidities (no MW and UB indexed on wages), we always have  $\mathbb{I}^s(\eta, t) = \mathbb{I}^q(\eta, t) = 0, \forall \eta, t$ . By contrast, the MW can lead to  $\mathbb{I}^s(\eta, t) = 1$  but  $\mathbb{I}^q(\eta, t) = 0$ , whereas non-indexed UB can lead to  $\mathbb{I}^s(\eta, t) = \mathbb{I}^q(\eta, t) = 1$ .

**Property 1.** *The existence of constant real wage rigidity (MW or UB constant over time) is a sufficient condition to have endogenous destructions among routine jobs, i.e.*

$\mathbb{I}^s(\eta, t) = 1$  or  $\mathbb{I}^s(\eta, t) = \mathbb{I}^q(\eta, t) = 1$ . Over time, the rise in the marginal returns of a job in the service sector allows the economy to generate reallocations, i.e.  $\mathbb{I}^m(\eta, t) = 1$ . The existence of increasing real wage rigidities (MW or UB increasing over time) is a sufficient condition to block the reallocation process, i.e.  $\mathbb{I}^m(\eta, t) = 0, \forall \eta, t$ , even if there are endogenous separations,  $\mathbb{I}^s(\eta, t) = 1$  or  $\mathbb{I}^s(\eta, t) = \mathbb{I}^q(\eta, t) = 1$ .

Tightness is:

$$\theta_r(\eta, t) = \begin{cases} \text{Equations (9) and (15)} & \text{if } \mathbb{I}^m(\eta, t) = 0 \ \& \ \mathbb{I}^s(\eta, t) = 0 \ \& \ \mathbb{I}^q(\eta, t) = 0 \\ 0 & \text{otherwise} \end{cases}$$

Given the decision rules of firms and workers, employment in period  $t + 1$  has two components: novice and experienced workers. New employment relationships are formed through the matching process. Matches formed in period  $t$  contribute to period  $t$  employment. At the beginning of period  $t + 1$ ,  $n_i(t)(1 - s)$  jobs are inherited from the previous period. The laws of motion on the labour market of routine jobs are as follows:

$$\begin{aligned} n_r(\eta, t + 1) &= [n_r(\eta, t)(1 - s) + u_r(\eta, t)f_r(\eta, t)](1 - \mathbb{I}^s(\eta, t + 1))(1 - \mathbb{I}^q(\eta, t + 1)) \quad (26) \\ u_r(\eta, t + 1) &= [u_r(\eta, t)(1 - f_r(\eta, t)) + sn_r(\eta, t)(1 - \mathbb{I}^s(\eta, t + 1))(1 - \mathbb{I}^q(\eta, t + 1)) \\ &\quad + n_r(\eta, t) \max(\mathbb{I}^s(\eta, t + 1), \mathbb{I}^q(\eta, t + 1))](1 - \mathbb{I}^m(\eta, t + 1)) \quad (27) \end{aligned}$$

where  $n_r(\eta)$  and  $u_r(\eta)$  denote the number of employed and unemployed workers in the routine sector, respectively. The employment dynamics in each labour market are more complex than those in the basic Pissarides (1990) model. Before the structural change, we have  $\mathbb{I}^s(\eta, t + 1) = \mathbb{I}^q(\eta, t + 1) = 0$ : Equation (26) is the same as in the basic Pissarides (1990) model with exogenous separations. In this case, the market remains segmented if  $\mathbb{I}^m(\eta, t + 1) = 0$ , and unemployment dynamics are also the same as in the basic Pissarides (1990) model with exogenous separations (Equation (27)). However, during the structural change, there are reallocations. Hence, even if there is no endogenous separation (scraping or quit) at time  $t$ , i.e.  $\mathbb{I}^s(\eta, t + 1) = \mathbb{I}^q(\eta, t + 1) = 0$ , unemployed routine workers can move to the more attractive market of manual jobs  $\mathbb{I}^m(\eta, t + 1) = 1$ . In this case, no unemployed workers are in the segment of  $\eta$ -type workers, and employment declines at the rate of the exogenous separation. Finally, whatever the reason for the separation, the jobs disappear and workers become unemployed, leading them to choose between search and rest unemployment (to move or not to move to a new occupation). The opportunity to switch occupations gives rise to a new market: that of inexperienced workers carrying



out manual tasks. The laws of motion in this labour market are as follows:

$$u_s^0(\eta, t+1) = u_s^0(\eta, t)(1 - f_s^0(\eta, t)) + u_r(\eta, t)\mathbb{I}^m(\eta, t+1) + n_r(\eta, t) \max(\mathbb{I}^s(\eta, t+1), \mathbb{I}^q(\eta, t+1))\mathbb{I}^m(\eta, t+1) \quad (28)$$

$$n_s(\eta, t) = u_s^0(\eta, t)f_s^0(\eta, t) \quad (29)$$

where  $u_s^0(\eta)$  and  $n_s^0(\eta)$  denote the number of newly unemployed and employed workers in the service sector, respectively. Equation (28) shows that this market exists only if there are some entries, of an amount  $u_r(\eta, t) + n_r(\eta, t) \max(\mathbb{I}^s(\eta, t+1), \mathbb{I}^q(\eta, t+1))$  if routine unemployed workers choose to move to manual occupations, i.e.  $\mathbb{I}^m(\eta, t+1) = 1$ . Thus, these new entries are larger when there are endogenous separations (i.e. when  $\mathbb{I}^s(\eta, t+1) = 1$  and/or when  $\mathbb{I}^q(\eta, t+1) = 1$ ). Equation (29) defines the transitional stock of inexperienced workers on manual tasks, who have learned their jobs after one quarter. The laws of motion in the labour market of experienced manual workers are as follows:

$$u_s(t+1) = u_s(t)(1 - f_s(t)) + s(n_s(t) + \sum_{\eta} n_s^0(\eta, t)) \quad (30)$$

$$n_s(t) = 1 - u_s(t) - \sum_{\eta} u_r(\eta, t) - \sum_{\eta} n_r(\eta, t) \quad (31)$$

where  $u_s$  and  $n_s$  denote the number of unemployed and employed experienced workers, respectively. The stock of unemployed workers in the service sector falls with hirings and increases with separations and the number of workers who change occupations. The latter includes workers already unemployed who decide to move to the service sector and employed workers experiencing endogenous job destructions who choose to switch directly to the service sector. Finally, because of the unit mass of the labour force, employment in the service sector, in Equation (31), is pinned down by subtracting all other stocks from the unit mass of the labour force.

**Property 2.** *The model displays two potential types of unemployment in the routine sector:*

- *Search unemployment if  $\mathbb{I}^m(\eta) = 1$  and  $\forall \mathbb{I}^s(\eta)$ .*
- *Rest unemployment if  $\mathbb{I}^m(\eta) = 0$  and  $\forall \mathbb{I}^s(\eta), \mathbb{I}^q(\eta)$ .*

### 3 Reallocations and employment dynamics

This section analyzes the transitory impact of technological bias *à la* Autor & Dorn (2013) on the reallocation process. The analytical comparison of steady states is insufficient because the jobs occupied by workers who learn their new tasks do not necessarily exist at the steady state. This leads us to solve the transitional dynamics of the model numerically. We do not propose a calibration exercise based on empirical targets in particular countries, but a numerical exercise allowing us to disentangle the main mechanisms at work in a reallocation process at the bottom of the wage distribution. Hence, all the structural parameters are maintained constant over all the simulations, while the LMI parameters can vary over time. By doing so, we isolate the impact of the structural change for different LMIs. Our benchmark case is a flexible economy: there is no MW, UB are low and indexed on previous wages, and dismissal costs are nil (an economy reminiscent of that in the United States). By contrast, we consider two types of European economies characterized by several labour market rigidities in order to contain income inequalities. By nature, redistribution introduces some incomes that are not indexed on labour marginal returns in a specific firm. Hence, when productivity growth is unbalanced across sectors, these policies can weaken those that decline or prevent the creation of new jobs for novice workers. Two models have emerged since the end of WWII in Europe. The first relies on generous social programmes and UB as powerful redistributive tools (referred to as Nordic Europe) and the second has an MW set by the state (referred to as Continental Europe). If these two models introduce strong downward real wage rigidities, they are also characterized by the existence of dismissal costs: these are low when the social programmes are generous, but high where the MW is high. We show that these two types of European economies do not share the same properties even though their LMIs could lead to the same deadlocks: the tools aiming at containing inequalities may actually block the reallocation process. As underlined by Ljungqvist & Sargent (1998) and Ljungqvist & Sargent (2008), in tranquil times, namely when transitions between homogeneous jobs are costless, the European system can be viewed as a good arbitration between economic performance and inequality. We point out that this claim no longer holds true in turbulent times, namely in periods when reallocation is costly (human capital losses and learning periods). With respect to these papers, we focus on the reallocation process across sectors<sup>16</sup>.

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<sup>16</sup>From this point of view, we also depart from Hornstein et al. (2007) who focus on how labour demand responses depend on LMIs in the context of rapid technological changes, without any identification of the direction of the structural change.

### 3.1 Calibration

We assume quarterly frequencies and consider three types of calibrations: *(i)* a flexible labour market (as in the United States), *(ii)* a rigid labour market (as in Continental Europe), and *(iii)* a stylized Nordic labour market.

**Common parameters.** We set the discount factor to 0.99, which gives an annual real rate of 4%. Following Mortensen & Pissarides (1999*a*), we impose the Hosios condition  $\xi = 1 - \psi$  (workers' bargaining power is equal to the elasticity of the matching function with respect to unemployment). By using the information provided by Petrongolo & Pissarides (2001), the elasticity of the matching function is set to 0.5. We assume that the cost of posting a vacancy is 0.15, implying a ratio of vacancy cost over productivity of 6% in the flexible economy. For the separation rate, we set an intermediate value between the highest inflow rate into unemployment and its lowest values estimated by Elsby et al. (2013):  $s = 0.07$ . Concerning matching efficiency, OECD statistics show that the average unemployment duration is about 5.7 months in the United States and 14.3 months in France over the same period; therefore,  $\chi$  is set to match the intermediate value of 9.5 months. The aggregate component of routine productivity  $y_r$  is normalized to 1. The initial productivity value in services is set to match the initial share of routine jobs in the United States, which is about 60% (OECD and Albertini et al. (2015))<sup>17</sup>. The productivity loss incurred by newly displaced routine workers who just start working in manual jobs is captured by  $\delta$  in Equation (10). This value is chosen to mimic the range of wage losses after changing from the routine to the service sector, as estimated by Cortes (2015) using US data.

**Country-specific parameters.** The LMIs are : the binding MW, the replacement rate, and dismissal costs. For the MW, we take the "French case" as a representative target.<sup>18</sup> Two measures summarize the importance of the MW: (1) the proportion of workers at the MW which is around 14.5%, and (2) the Kaitz index (ratio of MW over gross full-time mean earnings) of about 55% according to the OECD. However, these statistics take into account skilled and unskilled workers. Given that the model accounts only for unskilled workers, we recompute these two statistics over unskilled workers and obtain a

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<sup>17</sup>This choice implies that the share of routine jobs among low-skilled jobs is 90%. We prefer to keep  $y_s$  the same in the two economies and argue that this stylized calibration may correspond to a case where job polarization arrives later in France.

<sup>18</sup>As discussed below, the group of European countries with a national MW is not restricted to France.

Variables	Symbol	Value	Source
Discount factor	$\beta$	0.99	4% annual real rate
Vacancy posting costs	$\kappa$	0.15	Target $\kappa v \simeq 0.06y$
Matching frictions	$\psi$	0.5	Petrongolo & Pissarides (2001)
Worker bargaining power	$\xi$	0.5	Hosios imposed
Matching efficiency	$\chi$	0.3	Employment rate = 90%
Separation rate	$s$	0.06	Elsby et al. (2013)
Routine aggregate productivity	$y_r$	1	Normalization
Service aggregate productivity	$y_s$	0.71	Albertini et al. (2015)
Productivity loss	$\delta$	0.9	Cortes (2015)

Table 1: **COMMON PARAMETERS FOR THE UNITED STATES AND EUROPE.**

proportion of workers at the MW of 20% and a Kaitz index of 86%.  $w_{\min} = 0.7$  matches these targets. According to the OECD, the average net replacement rates over 60 months of unemployment for families that qualify for cash housing and social assistance<sup>19</sup> (overall average over family status) are given in Table 2. We divide European countries into two groups: "Continental Europe" is the group of countries where there is a national MW in 2004,<sup>20</sup> whereas, there is no national MW in 2004 in "Nordic Europe"<sup>21</sup>. The UB rules in Continental Europe are given by Equations (22)-(23), whereas in Nordic Europe, they are given by Equations (24)-(25). The rationale for this choice is based on the comparison of replacement rates for families who qualify for cash housing and social assistance and those who do not. Based on OECD data, in Nordic countries, the replacement rate for families who qualify for cash housing and social assistance is 22 points higher than that for families who do not. By contrast, the gap in replacement ratios falls to 10 points for countries in Continental Europe. This fact suggests that, in Nordic Europe, unemployment is a strong marker for redistribution, which is not the case for Continental Europe. In the benchmark calibration, replacement ratios for Nordic Europe are constant in Equations (24)-(25). The values are given in Table 2.

The distinction between Continental and Nordic Europe is also based on dismissal costs. Table 2 shows that the OECD summary indicator of the stringency of employment pro-

<sup>19</sup>We look at this statistic because we want to account for social programmes targeted at inactive workers.

<sup>20</sup>For these countries, the monthly MW as a proportion of average monthly earnings is 47.3% in Belgium, 46.5% in France, 44.2% in Portugal, and 37.6% in Spain (Source Eurostat).

<sup>21</sup>Thus, for these countries, Eurostat cannot provide any information on a Kaitz index based on a national MW.

	US	Continental Europe				Nordic Europe			
		Bel	Fra	Prt	Spa	Den	Fin	Ger	Swe
OECD replacement rates (2004)	0.31	0.63	0.63	0.69	0.49	0.84	0.74	0.66	0.74
OECD employment protection (2003)	0.2	2.2	3	3.7	3.1	1.4	2	2.3	2.2
$\rho$ : calibrated value	0.3	0.6				0.75			
$d$ : calibrated value	0	1.7				0			

Table 2: **REPLACEMENT RATES AND DISMISSAL COSTS.**

tection legislation is larger in Continental Europe than in Nordic Europe. In our stylized representation of LMIs, we simplify in the following way: only Continental Europe has dismissal costs, while the other countries (the United States and Nordic Europe) do not. Dismissal costs correspond to the costs associated with layoff procedures as well as legal and administrative costs. By using French administrative data, Abowd & Kramarz (2003) estimate that the cost of employment protection legislation is about one sixth of the annual wage in France. We then set  $d = 1.7$  such that  $d/\bar{w} = 2$  on a quarterly basis, where  $\bar{w}$  is the average wage.<sup>22</sup>

**Technological structural change and workers' ability distribution.** The structural change is captured by a decline in the productivity of routine jobs by 10% and, at the same time, an increase in the productivity of manual jobs by 10%. For simplicity, we consider a linear adjustment of the shock of 50 periods (12 years). The shocks are unanticipated. However, following the economic disturbances, agents have perfect foresight over future trajectories and know the terminal conditions. Our objective is to compute the transitional dynamics between the initial and final steady states. In addition, we assume that ability  $\eta$  follows a Uniform distribution with support  $U(0.6; 1)$ . We consider 10 ability levels between 0.6 and 1. The quantitative impact of technological trends on job polarization also depend on the ability distribution, as the latter determines the mass of workers in each ability level that is affected by scrapping, quit and occupational switch. These values, while arbitrary, mimic the direction of the structural change discussed by Autor & Dorn (2013). The paper is a first step towards the understanding of job polarization in a search and matching setting. The paper offers a first illustration of the economic mechanisms at work.

The calibration is such that occupational change is unprofitable for workers in the routine

<sup>22</sup>Mortensen & Pissarides (1999a) estimate this cost to be about three times as large as the cost of keeping an open vacancy.

sector at the initial steady state. This strategy allows us to evaluate the role of LMIs on the propagation of the structural change. Furthermore, the shocks are likely to impact the binding of the MW, occupational choices, quits, and plant shutdowns. Therefore, solving the model involves dealing with a non-stationary non-linear environment to capture structural changes in the economy. Standard solution methods that approximate the dynamics around a unique steady state are not implementable here. We thus use the block-recursive property of the Diamond-Mortensen-Pissarides model to solve the paths of the forward variables independent of the block that governs the dynamics of the backward variables. An overview of the algorithm is described in B.

### 3.2 The US case

The structural change modifies occupational choices: *(i)* unemployed workers can choose to move into more valuable markets, *(ii)* workers can choose to quit their firms, *(iii)* manufacturing firms can decide to scrap obsolete jobs, or *(iv)* services firm can choose to open new positions.

Panel c. of Figure 3 displays the value functions of unemployed workers in routine and manual jobs at the beginning and the end of the technological changes. At the initial steady state, all workers with  $\eta \geq \eta(4)$  are such that their unemployment value in the routine sector is larger than that in the service sector. These workers are located in the routine sector, while low type workers, with  $\eta \leq \eta(3)$ , are employed in manual jobs. In the final steady state, all workers with  $\eta \leq \eta(7)$  are employed in the service sector. This means that four types of workers choose to switch occupations during the structural change, i.e. 40% of the workers are displaced during the structural change. Panels d. and e. of Figure 3 show that workers employed in routine jobs ( $\eta > \eta(7)$ ) do not voluntarily quit and are employed in firms where it is not optimal to scrap jobs: the structural change does not lead to suboptimal separations. Panel f. of Figure 3 shows that these choices to move into manual jobs are supported by positive profits for the firms that hire these inexperienced workers,  $\forall \eta$ . The indexation of UB on the previous wage makes profits a decreasing function of ability  $\eta$ . Indeed, while a higher worker's ability gives more UB, ability does not change productivity in manual tasks, resulting in a decrease in profits.

For the initial steady state, i.e. before the structural change, panel a. of Figure 3 shows that tightness in the service sector is larger than that in routine jobs for  $\eta \leq \eta(3)$ . This finding is consistent with the occupational choices summarized in panel c. Further,

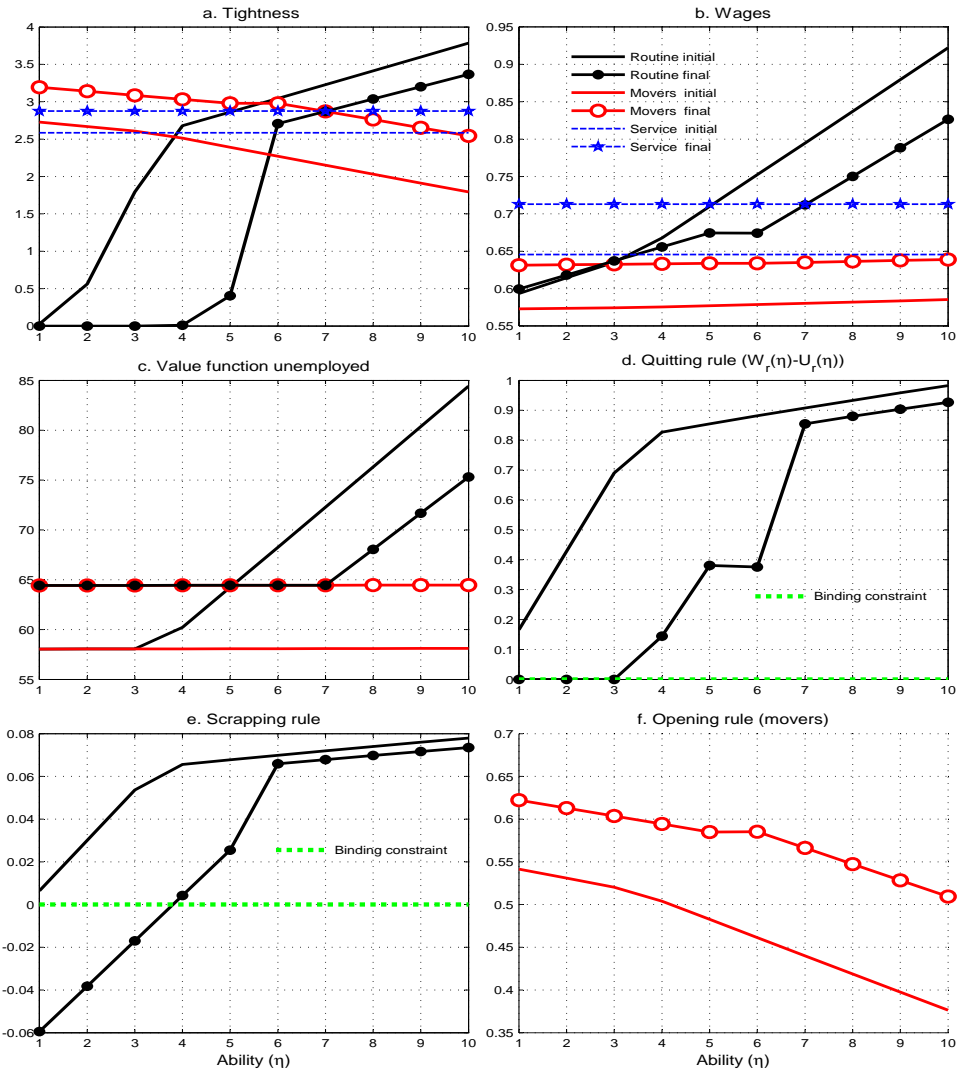


Figure 3: **STEADY STATE: DECISION RULES IN THE UNITED STATES.** "initial" : at the beginning of the technological changes. "final" at the end of the technological changes. Panels d. e. f. quitting, scrapping and opening rules as explained in Section 2.2.3.

the downward sloping shape of profits for movers (panel f.) reduces their tightness as ability level increases (panel a.) while tightness for experienced manual workers remains independent of ability level (in panel a. flat dashed lines). This figure also shows that the structural change shifts the curve of labour market tightness for routine  $\theta_R$  (manual  $\theta_S$ ) jobs downward (upward). The sharp increase in  $\theta_S$  compensates for the negative response of  $\theta_R$  resulting from the structural change. In the United States, market adjustments through changes in  $\theta$ , provide strong signals for low-to- middle-ability routine workers to switch occupations. Unemployed workers in the routine sector with high abilities enjoy generous UB, which deters them from changing occupations and accessing service jobs. Furthermore, as shown by panel b., the bargained wages for movers are low because these individuals accept a reduction in their reservation wage today to enjoy better market conditions once experienced in the service sector. This fact explains why the labour market tightness in these jobs is the highest until  $\eta = \eta(7)$ . The implied low unemployment duration and expectation of career progression, are then able to attract new workers, from  $\eta = \eta(3)$  to  $\eta = \eta(7)$ , despite the losses in instantaneous wages. These wage losses are reported in panel b. of Figure 3: they range from 3% to 10%. This finding is consistent with the range of wage losses after changing from routine to service occupations, as estimated by Cortes (2015) using US data. The Nash bargaining rule leads to enough wage flexibility to allow for wage cuts. These wage cuts prevent endogenous job destructions and create new jobs at the bottom of the wage distribution.

The results of these workforce movements on (un)employment stocks are reported in Figure 4: the aggregate dynamics of (un)employment in routine and manual jobs are displayed on the right (panels c. and f.), whereas the dynamics per worker-ability  $\eta$  are reported in panels a. b. d. and e. Two important features, linked to the intertemporal nature of the Pissarides model, must be noted. First, for the labour market directed to workers that will decide to move, the decline in routine employment is sluggish: in panel a. of Figure 4, stocks fall as workers switch occupation to manual jobs ( $\eta \in \{\eta(4), \eta(5), \eta(6), \eta(7)\}$ ). As only unemployed workers can switch occupations, in the absence of binding scrapping times, the pace of occupational changes is given by the exogenous separation rate  $s$ . The extinction of old activities takes time. This does not imply a large increase in unemployment in these labour markets. Panel b. of Figure 4 shows that, for each  $\eta$ -type worker, for  $\eta \in \{\eta(4), \eta(5), \eta(6), \eta(7)\}$ , the number of unemployed workers searching for a routine job, falls instantaneously to zero. The immediate counterpart of this workforce movement is a jump in the number of unemployed workers searching for a manual job (panel d. of



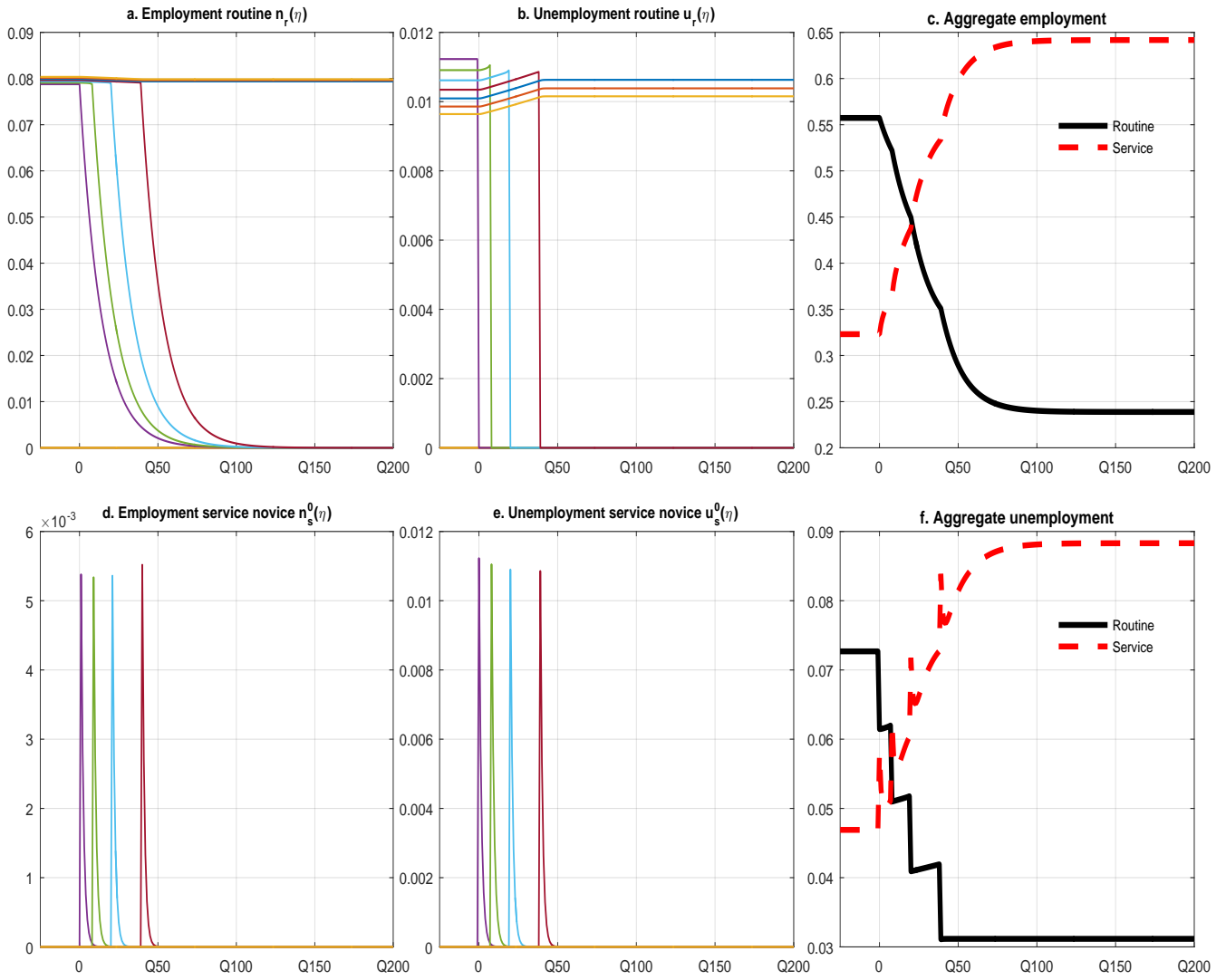


Figure 4: **EVOLUTION OF EMPLOYMENT STOCKS IN THE UNITED STATES.** In all graphs, time (in quarters) is on the horizontal axis, where 0 denotes the beginning of the structural change. Panels a. b. d. and e.: one line for each ability level. Panels c. and f.: aggregation over all ability levels.

Figure 4): "search unemployment" increases during the structural change. Second, the forward behaviours of unemployed workers lead them to move before a decline in the job finding probability in the labour markets of routine tasks. Hence, when productivity in the service sector rises, a proportion of newly created jobs in the service sector is already matched. In the United States where the job filling rate is fairly high, the arrival of newly unemployed workers in the service sector is absorbed very quickly (panel f. of Figure 4). Panel e. of Figure 4 shows that the stock of movers briefly remains in this state. Indeed, these stocks are 0 at the beginning and at the end of the technological changes. If 40% of the workforce moves towards services through "bridge" jobs (jobs for novice workers in the service sector), the stock of these low-paid jobs is small because the duration of the learning process is short, as workers rapidly gain experience in manual tasks.

### 3.3 The European cases

In the same context, we show that the existence of a MW/high UB can block the reallocation process by making these jobs unprofitable.

#### 3.3.1 Continental Europe

We distinguish several cases depending on the evolution of the MW along the transition path.

**Constant MW along the transition path.** Panel a. of Figure 5 shows the importance of labour costs in countries characterized by a high MW. For  $\eta \leq \eta(4)$ , the MW is binding for routine jobs (panel b. of Figure 5). Before the structural change, workers of type  $\eta \leq \eta(3)$  cannot be employed in routine jobs because their labour costs are higher than their productivities, leading to zero labour market tightness and thus no hirings (Panel a. of Figure 5). Panel f. of Figure 5 indicates that workers of type  $\eta \leq \eta(3)$  cannot be employed in the labour market of inexperienced workers in manual jobs either. The opening rule is not satisfied because inexperienced workers cost more than they produce. Given that the initial condition is exogenous, if any  $\eta$ -type workers, with  $\eta \leq \eta(3)$ , had been oriented towards routine jobs, after leaving education, they would have remained unemployed until the beginning of the structural changes since the jobs of inexperienced manual workers, incorporating a learning process, are not open before

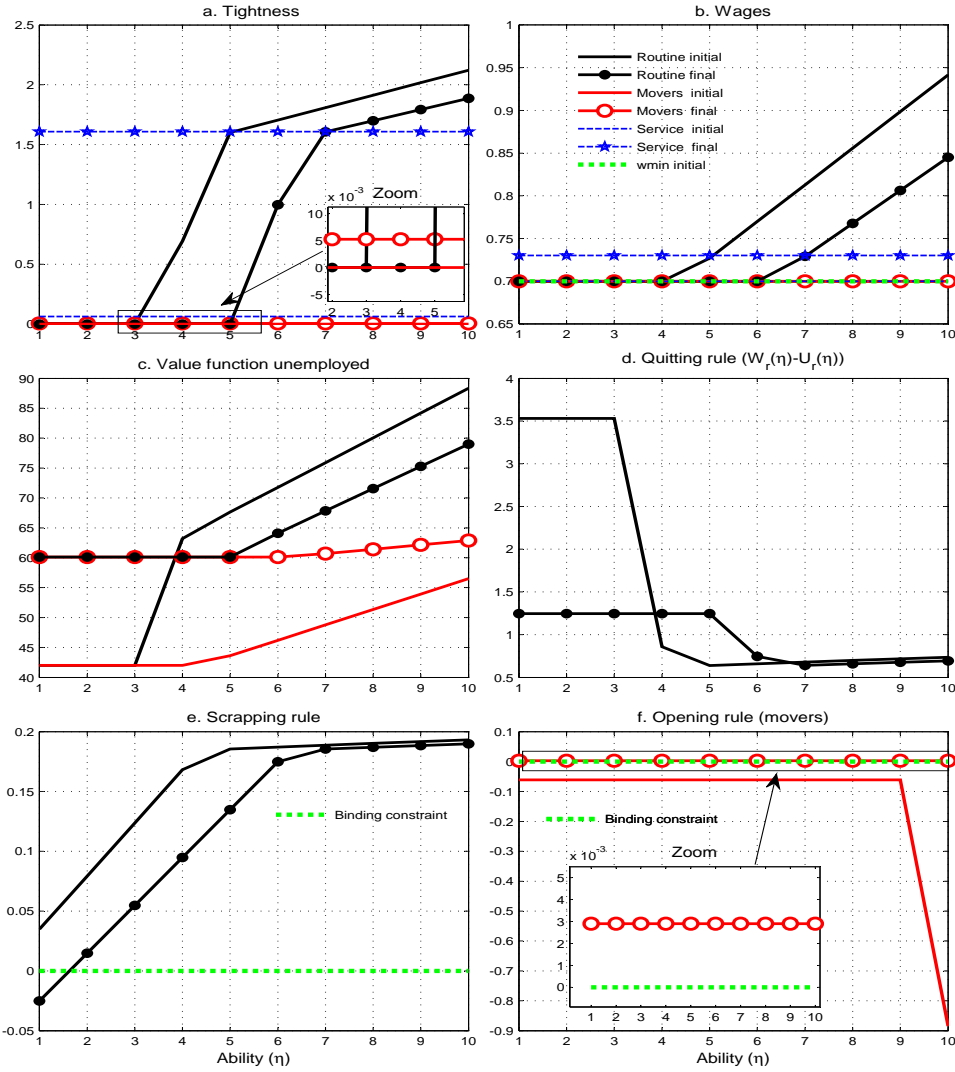


Figure 5: **STEADY STATE: DECISION RULES IN CONTINENTAL EUROPE.** "initial" : at the beginning of the technological changes. "final" at the end of the technological changes. Panels d. e. f. quitting, scrapping and opening rules as explained in Section 2.2.3.

period 0. Therefore, workers with  $\eta \leq \eta(3)$  are in an unemployment trap before the beginning of the technological change. With the structural change, the set of opportunities changes. Panel c. of Figure 5 shows that the best option is to move from routine jobs to new manual jobs for  $\eta \leq \eta(5)$ . However, given that  $\eta$ -type workers with  $\eta \leq \eta(3)$  were not previously in routine jobs, only workers of type  $\eta = \{\eta(4), \eta(5)\}$  switch occupations during the transition, i.e. 20% of the population. Panel f. of Figure 5 shows that these mobility choices allow workers to meet job openings for inexperienced displaced workers.

These jobs, now profitable thanks to the structural change, lead to hirings and thus labour market tightness becomes greater than zero (panel a. of Figure 5). Because of the existence of a MW, bridge jobs from routine markets to services are scarce. In this first stylized European labour market, a slight increase in the MW during the structural change can lead to an equilibrium without reallocations, i.e. an unemployment trap/rest unemployment. Equilibrium labour market tightness is equal to zero for movers before and after the structural change. Given this absence of opportunities to move to other jobs, all workers remain rest unemployed in their routine labour markets. The benefit of these LMIs is that wage inequalities could be contained. Finally, an additional cost of the MW is the potential existence of endogenous job destructions, but these are prevented here thanks to dismissal costs. Indeed, without dismissal costs, the "scrapping rules" exclude some workers from routine tasks. The combination of unproductive jobs and a high MW leads to an unprofitable employment relationship for the firm. With the decline in the productivity of routine jobs, this selection process is at work.

How does the structural change modify the allocation of employment across markets? Panel a. of Figure 6 shows that the lowest-skilled workers  $\eta$  are not employed before the structural change and can only follow the rest unemployment option (the top red line in panel b. of Figure 6). For  $\eta \in \{\eta(2), \eta(3)\}$ , the structural change is not really good news: during the first 45 quarters, there are no job openings in the labour markets of their  $\eta$ -specific tasks and the jobs allowing them to begin a new career in the service sector are not yet open. At the pace of the exogenous separation  $s$ , the employment rate of these  $\eta$ -type workers declines, whereas their unemployment rates continuously increase. At the aggregate level (panel f. of Figure 6), this phenomenon leads to an increase in inequalities among unskilled workers. The chance of being unemployed increases for routine workers, whereas it declines for those searching for a job in the service sector. During 12 years, the inequality of access to jobs increases because the high MW prevents job creation at the bottom of the wage distribution, thereby shutting down the reallocation

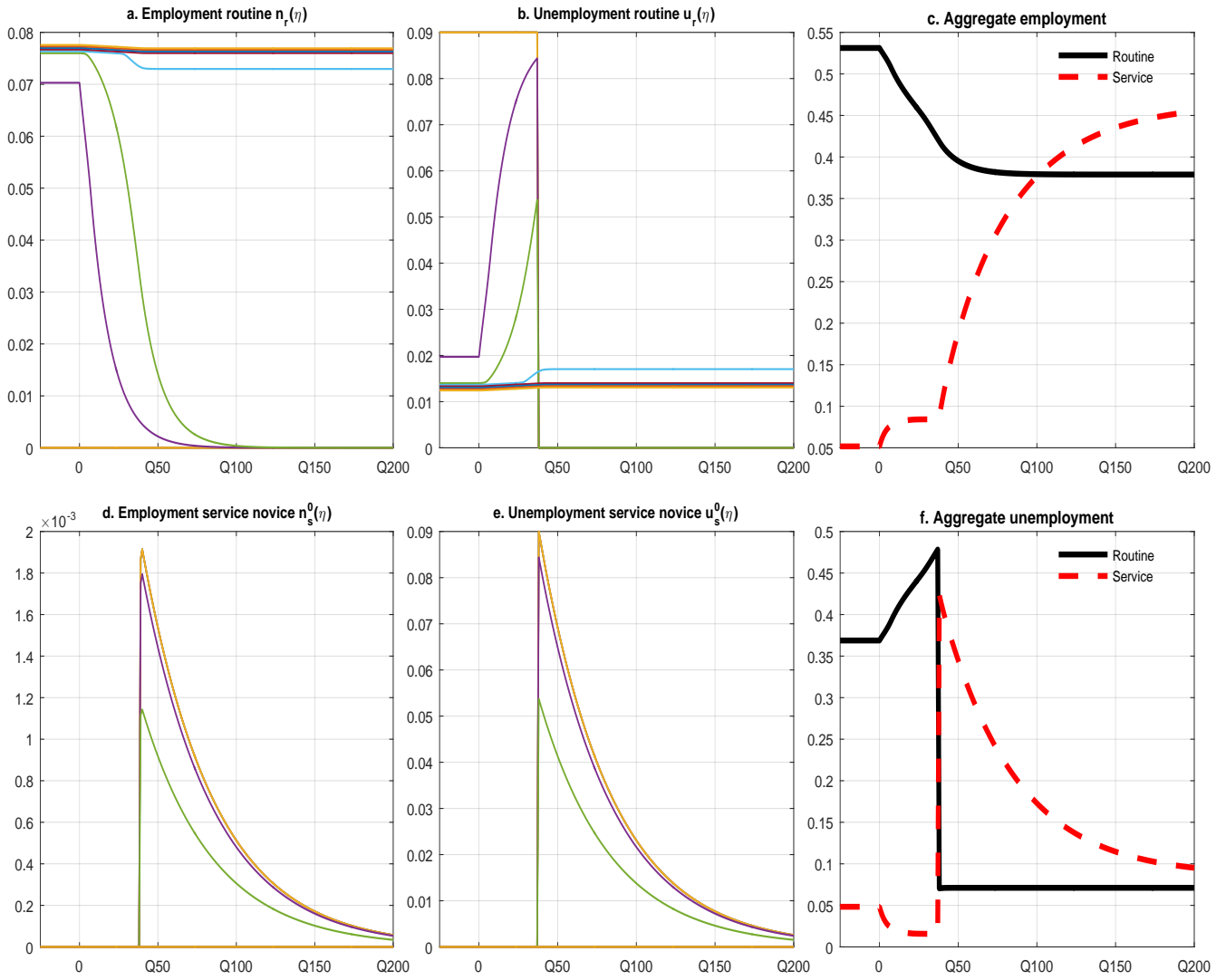


Figure 6: **EVOLUTION OF EMPLOYMENT STOCKS IN CONTINENTAL EUROPE.** In all graphs, time (in quarters) is on the horizontal axis, where 0 denotes the beginning of the structural change. Panels a. b. d. and e.: one line for each ability level. Panels c. and f.: aggregation over all ability levels.

process. After 12 years (more than 45 quarters), the increase in marginal returns in the service sector allows new jobs to compensate for the high MW. Therefore, some bridge jobs can be created, giving new opportunities to the unemployed workers trapped in rest unemployment (panels b. and d. of Figure 6). In panel b., we see that the stock of the unemployed workers  $u_r(\eta)$  falls sharply to zero and becomes the new initial stock of the unemployed moving into the service sector ( $u_s^0(\eta)$ ).  $\eta$ -type workers, for  $\eta \in \{\eta(1), \eta(2), \eta(3)\}$ , take advantage of this opportunity, and move into jobs in the service sector. However, given that the duration of the structural change lasts 50 quarters, the marginal return goes beyond the constraint of the MW, but only by a small gap. Further, the capitalized profits in the jobs directed to inexperienced workers are small, leading to few vacancies in this labour market. The number of unemployed workers thus rises dramatically, leading to a strongly persistent reallocation process. After 50 years, the path of aggregate employment is not fully stabilized (panels d. and e. of Figure 6). At the sectoral level, panels c. and f. show the two regimes characterizing the structural change. In the first step (the first 12 years), there are employment losses in routine jobs accompanied by small gains in the service sector and no reallocations (unemployment continuously increases). In the second step, and only at the end of the structural change (no more gains can be expected), a small set of bridge jobs opens, allowing for a gradual reduction in unemployment in the services sector.

**Increasing MW along the transition path.** According to Eurostat data, the MW in Continental Europe has increased over the recent decades. This case is thus more realistic from our point of view. The MW goes up by 2.8% in a linear fashion during the technological transition.

Figure 7 suggests that the gradual employment reallocation described in the last paragraph stops when the MW increases along with technological changes. The economy remains segmented and the chances of being employed decrease in the routine labour market, with the lowest-skilled workers at greatest risk. The corollary is an increase in the number of unemployed workers, who are then in permanent rest unemployment.

### 3.3.2 Nordic Europe

Concerning the initial steady state, Figure 8 shows that Nordic Europe looks like Continental Europe (Figure 5). Only  $\eta$ -type of workers with  $\eta > \eta(3)$  can work in routine jobs,

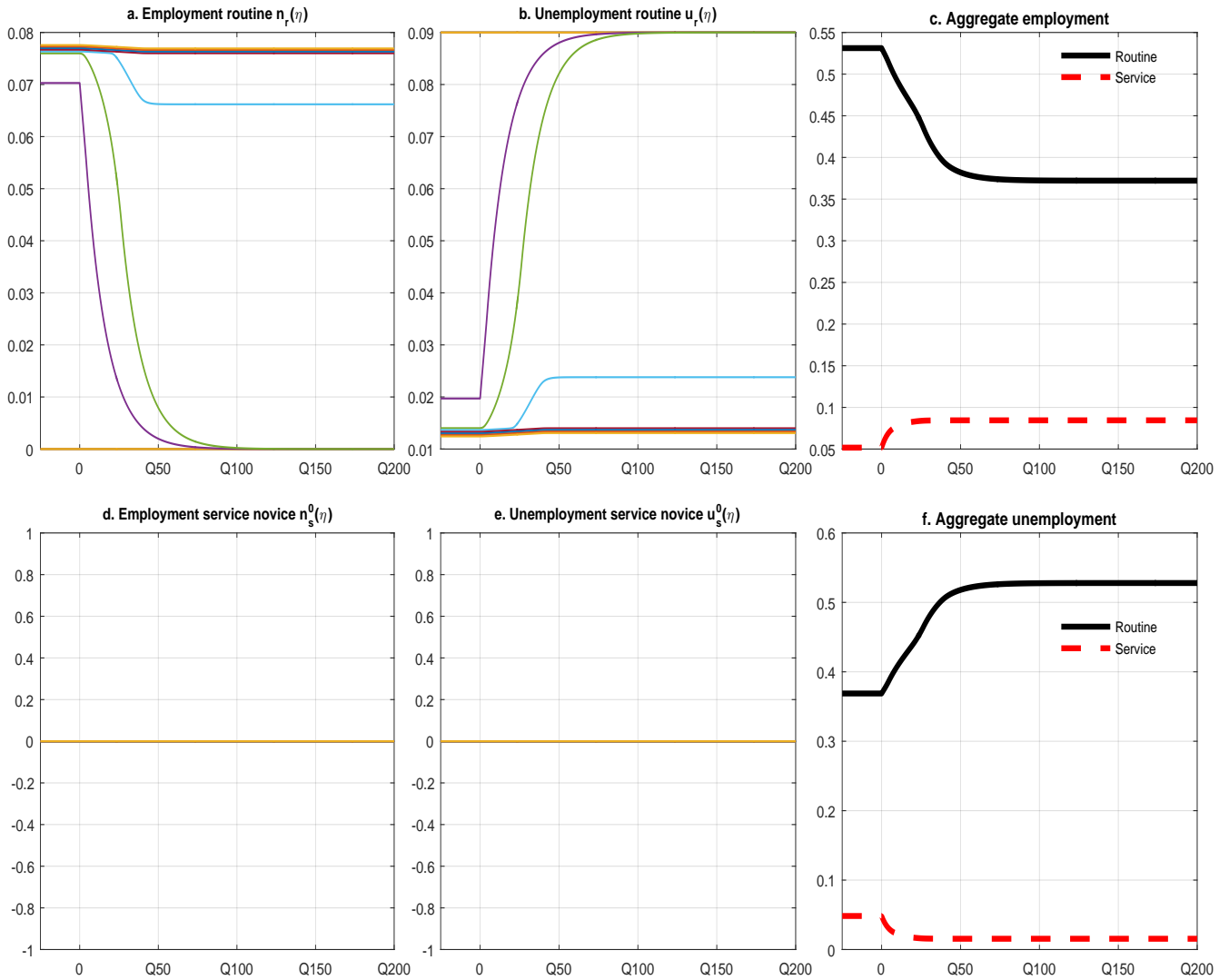


Figure 7: **EVOLUTION OF EMPLOYMENT STOCKS IN CONTINENTAL EUROPE. INCREASING MW.** In all graphs, time (in quarters) is on the horizontal axis, where 0 denotes the beginning of the structural change. Panels a. b. d. and e.: one line for each ability level. Panels c. and f.: aggregation over all ability levels.

with the remainder employed in the service sector. In panel c., at the initial steady state, unemployment value is greater in routine jobs for  $\eta > \eta(3)$ . The important difference with Continental Europe is that there is no trap at the initial steady state for Nordic Europe. Panel f. of Figure 8 shows that "the bridge" jobs of inexperienced manual workers are profitable for the service-producing firm at the initial steady state. Therefore, an individual guided towards working in a routine job after leaving education can move into the labour market of the service sector as a novice worker.

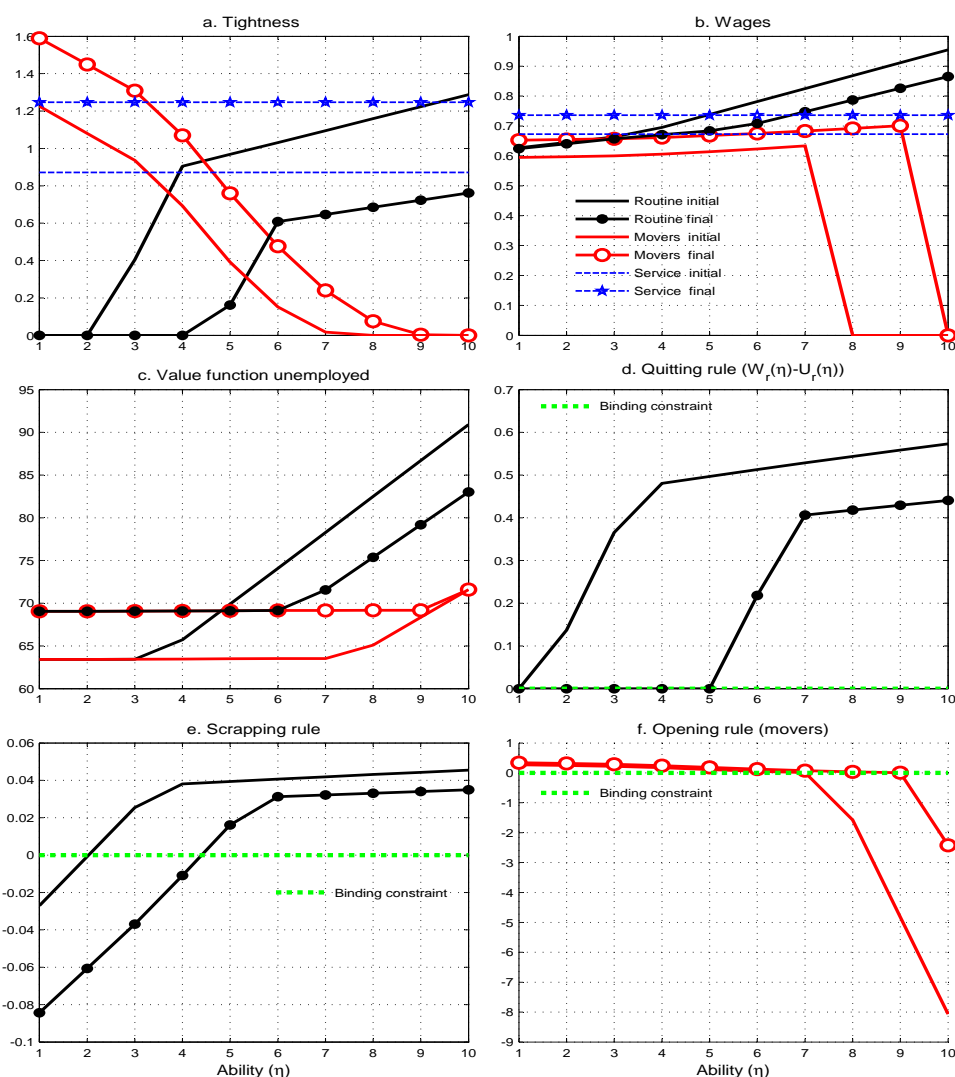


Figure 8: **STEADY STATE: DECISION RULES IN NORDIC EUROPE.** "initial" : at the beginning of the technological changes. "final" at the end of the technological changes. Panels d. e. f. quitting, scrapping and opening rules as explained in Section 2.2.3.

In addition, the labour reallocation (final steady state) affects more people in Nordic



Europe: 33% compared with 20% (panel c. of Figure 8). Moreover, the gap between marginal returns in "bridge" jobs and their costs is larger (panel f. of Figure 8), leading to higher labour market tightness than in Continental Europe. Hence, the attractiveness of the service sector is larger in Nordic than in Continental Europe. Note that, for  $\eta = \eta(4)$ , workers initially employed in routine jobs can be fired during the structural change. Indeed, panel e. of Figure 8 indicates that it is optimal to scrap such jobs.

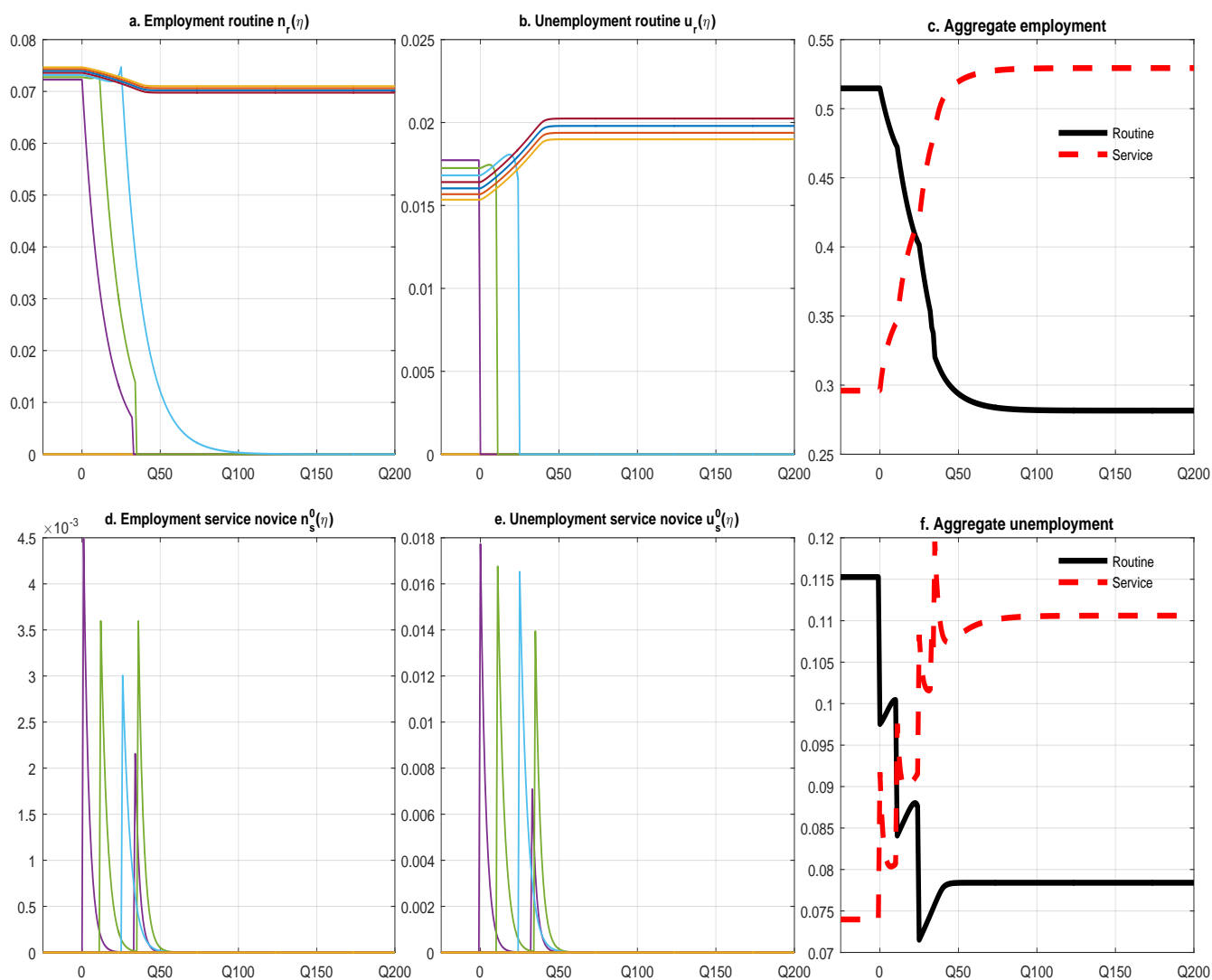


Figure 9: **EVOLUTION OF EMPLOYMENT STOCKS IN NORDIC EUROPE.** In all graphs, time (in quarters) is on the horizontal axis, where 0 denotes the beginning of the structural change. Panels a. b. d. and e.: one line for each ability level. Panels c. and f.: aggregation over all ability levels.

What about the dynamics in Nordic Europe? Even if the speed of the reallocation process is larger than that in Continental Europe (33% vs 20%), after 50 quarters, the process is finished (panels e. and d. of Figure 9). Another important difference lies in the absence of "rest unemployment" (panel b. of Figure 9). Despite generous unemployment insurance, bridge jobs are still being created at the beginning of structural changes. Further, as in the US economy, labour reallocations occur across sectors at the beginning of the structural change (panels c. and f. of Figure 9). Panel a. of Figure 9 shows that the scrapping of routine jobs is effective 45 quarters after the beginning of the structural change, when workers of type  $\eta = \eta(4)$  are fired. These workers choose to search for manual jobs (as captured by the fourth peak of  $u_r^0(\eta)$  in panel e), which leads to new hires (panel d. of Figure 9). Interestingly, Figure 8 suggests that, at the initial and final steady states, routine jobs for  $\eta = \eta(5)$  are profitable (panel e.). This is also the case for "the bridge jobs" of inexperienced manual workers (panel f.). However, along the transition, routine workers with  $\eta = \eta(5)$  decide to quit their jobs (panel d.). The quitting rule binds along the transition, giving rise to the fourth peak in panel e. of Figure 9. In a nutshell, the comparison of panel c. of Figures 4 and 9 illustrates how the level of UB influences the composition of employment at the end of the structural changes. The dominant effect is a reduction in the size of the sector that trains inexperienced manual workers, thereby reducing the share of manual workers in unskilled workers.

### 3.4 Comparing employment performances

What do we learn at the macroeconomic level from these microeconomic labour market decisions? To clarify the comparison of the results, we summarize the dynamics of aggregate employment in two figures. Figure 10 reports the US and Nordic Europe cases, while Figure 11 displays the cases for Continental Europe. To control for the basic effects of heterogeneous LMIs on the employment rate, we report the transition paths after normalizing to 100 the initial level of employment (before the structural change).

Figure 10 suggests that the performances of the United States and Nordic Europe are close. A surprising result is that during the reallocation process, search unemployment induces a fall (rise) in aggregate unemployment (employment). The short-term transitory employment gains come from the wage flexibility that eases the reallocation. Indeed, workers who left routine jobs enjoy the prospect of becoming an experienced manual worker. During the wage bargaining process, they accept lower wages to access the learn-

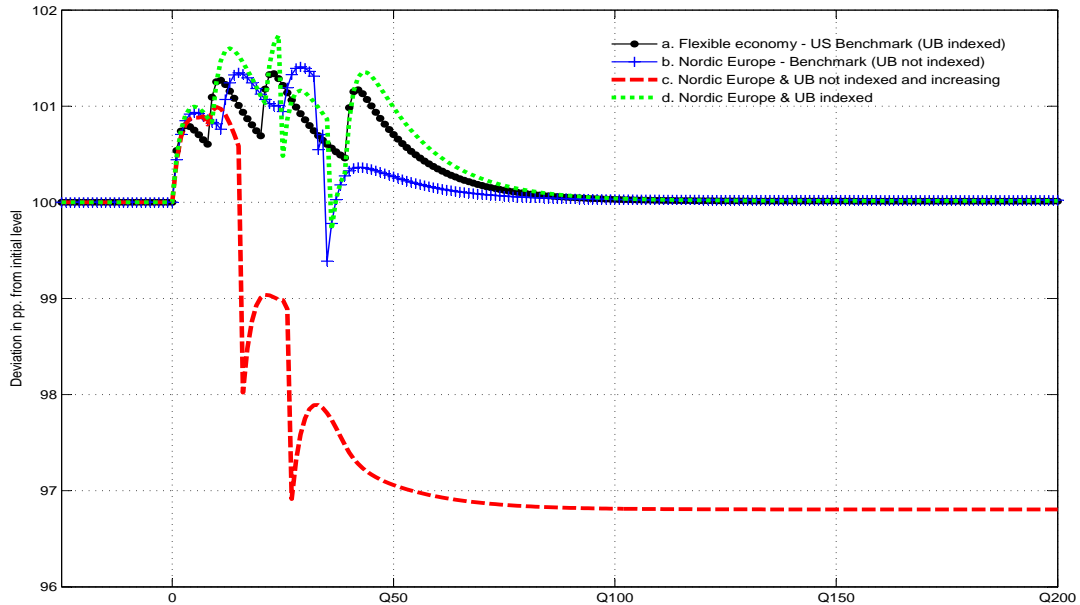


Figure 10: **AGGREGATE EMPLOYMENT RATE IN THE UNITED STATES AND NORDIC EUROPE.** a. US economy, UB given by Equations (22)-(23). b. Nordic case, constant replacement ratios  $\rho$  in Equations (24)-(25). c. replacement ratios  $\rho(t)$  linearly increase by 10% along the technological transition in Equations (24)-(25).

ing process and become experienced manual workers thereafter. This behaviour simply reflects the firm's interest in capturing a part of the worker's future rent, leading to a transitional decrease in labour costs and an increase in employment. This phenomenon can explain the rise in aggregate employment observed in the United States from 1985 to 2005. Note that the firm's greater ability to share the employment surplus does not contradict the wage increase at the bottom of the wage distribution, as observed during the job polarization process. While manual workers' wages increase, they do so to a lesser extent than the marginal returns for service firms. For countries in Nordic Europe, Figure 10 shows that this optimistic scenario is fragile and can disappear if social programmes become more generous (UB not indexed and increasing). In this case, the profitability of bridge jobs can fall to zero, thereby halting labour reallocations. Hence, employment losses in the routine labour market cannot be compensated for by employment gains in the service sector if these labour markets remain segmented. If, until the mid-1990s, these policies would have been applied in these countries, they would have reduced the size of social programmes from the end of the 1990s. This finding can also explain why they

enjoyed better labour market outcomes in the mid-2000s.

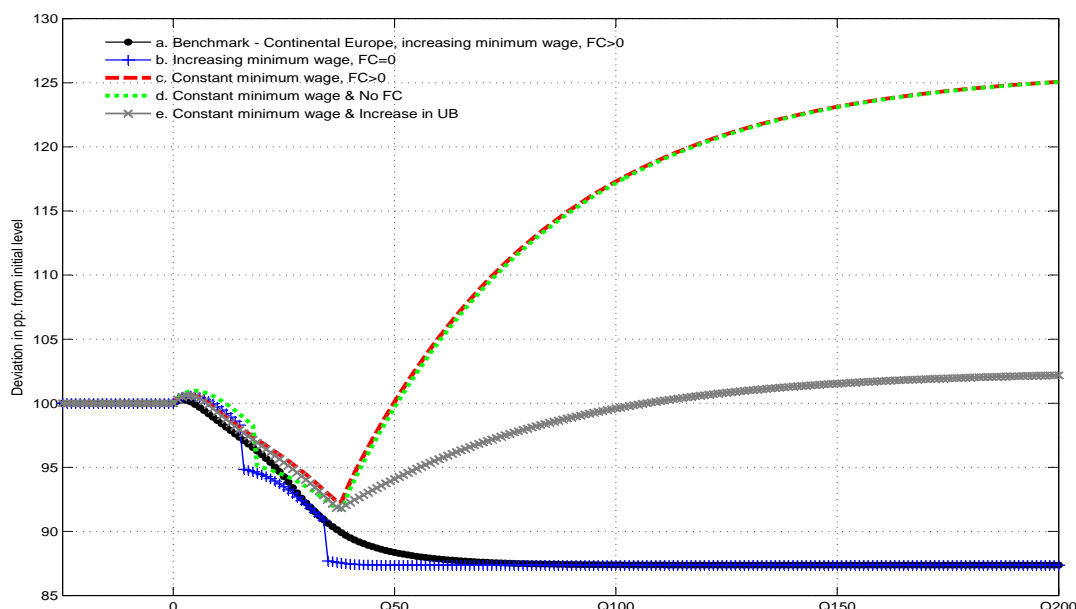


Figure 11: **AGGREGATE EMPLOYMENT RATE IN CONTINENTAL EUROPE.**

As shown in Figure 11, countries in Continental Europe with a rising MW can actually lose employment after technological changes. The economy falls into the trap of a segmented labour market, thereby generating employment losses. Such countries can benefit from structural changes by implementing a constant MW. Nevertheless, adjustments will be persistent: it takes 200 quarters (50 years) for the economy to converge to its final steady state. Under the existence of an MW, there is an employment decline due to the discrepancy between the disappearance of routine jobs and creation of new manual jobs. After this first regime, the rise in the employment rate is gradual, slowed by an MW that discourages job creation in manual tasks. This finding contrasts with economies where wage flexibility is not restricted by an MW as in the United States and Nordic Europe: after 50 quarters, all adjustments are completed. The Pissarides model allows us to measure the duration of this transitional effect in this type of economy. Finally, concerning the stylized facts on job polarization, the gradual decline in routine occupations implies that the share of service in total employment (we restrict our analysis to the employment of unskilled workers) increases more slowly than in the United States.

## 4 Conclusion

In this paper, we extended the basic Pissarides (1990) model to account for unbalanced dynamics across two sectors. By explicitly modelling job creation and wage bargaining in interaction with LMIs, this model is able to explain sluggish employment adjustments. Our model extension introduces an occupational choice for unemployed workers who search in the market where this is the most profitable. After an occupational change, we take into account the learning costs of the new occupation. As suggested by Acemoglu & Autor (2011), we use this framework to examine the job polarization process. More precisely, we aim to explain a puzzling conundrum: why does job polarization create jobs in the United States, whereas it destroys them in Europe? Our diagnostic is relatively simple: with a high MW/high UB, the creation of bridge jobs stalls and so does the reallocation process from the routine labour market to manual jobs. Hence, by cutting this bridge between these two labour markets, the MW/UB deprives the economy of a large part of its workforce, which are condemned to permanent rest unemployment. In this context, dismissal costs slow the decline in employment, whereas UB sustain this equilibrium with a trap. Although this paper illustrated some basic economic mechanisms, a more ambitious project might aim to introduce general equilibrium adjustments to capture the link between the dynamics of relative marginal returns across tasks as well as the interactions between skilled (abstract tasks) and unskilled labour. Finally, some empirical counterparts of the model must be identified, for different countries, to test the robustness of the arguments presented in this paper. Albertini et al. (2015) is a first step on this path.

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## A Derivation of wages

### A.1 Routine jobs

The first order conditions are given by

$$\xi J_r(\eta, t) = (1 - \xi)(W_r(\eta, t) - U_m(\eta, t)) \quad (32)$$

which, after replacing the value functions, gives:

- $U_m(\eta, t) = U_r(\eta, t)$

$$\begin{aligned} \xi y_r(t)\eta - w_r(\eta, t) + \beta(1 - s)J_r(\eta, t + 1) &= (1 - \xi) \left\{ w_r(\eta, t) - b_r(\eta, t) \right. \\ &\left. + \beta \left[ (1 - s)W_r(\eta, t + 1) + sU_r(\eta, t + 1) - f_r(\eta, t)W_r(\eta, t + 1) - (1 - f_r(\eta, t))U_r(\eta, t + 1) \right] \right\} \end{aligned}$$

- $U_m(\eta, t) = U_s^0(\eta, t)$

$$\begin{aligned} \xi y_r(t)\eta - w_r(\eta, t) + \beta(1 - s)J_r(\eta, t + 1) &= (1 - \xi) \left\{ w_r(\eta, t) - b_r(\eta, t) \right. \\ &\left. + \beta \left[ (1 - s)W_r(\eta, t + 1) + sU_s^0(\eta, t + 1) - f_s^0(\eta, t)W_s^0(\eta, t + 1) - (1 - f_s^0(\eta, t))U_s^0(\eta, t + 1) \right] \right\} \end{aligned}$$

After some rearrangement, we have

- $U_m(\eta, t) = U_r(\eta, t)$

$$\begin{aligned} w_r(\eta, t) &= \xi y_r(t)\eta + (1 - \xi)b_r(\eta, t) \\ &+ \beta \left[ (1 - s) \left( \xi J_r(\eta, t + 1) - (1 - \xi)(W_r(\eta, t + 1) - U_r(\eta, t + 1)) \right) \right. \\ &\left. + (1 - \xi)f_r(\eta, t)(W_r(\eta, t + 1) - U_r(\eta, t + 1)) \right] \end{aligned}$$

- $U_m(\eta, t) = U_s^0(\eta, t)$

$$\begin{aligned} w_r(\eta, t) &= \xi y_r(t)\eta + (1 - \xi)b_r(\eta, t) \\ &+ \beta \left[ (1 - s) \left( \xi J_r(\eta, t + 1) - (1 - \xi)(W_r(\eta, t + 1) - U_s^0(\eta, t + 1)) \right) \right. \\ &\left. + (1 - \xi)f_s^0(\eta, t)(W_s^0(\eta, t + 1) - U_s^0(\eta, t + 1)) \right] \end{aligned}$$

By using the job creation condition and  $\kappa/q_r(\eta, t) = \beta J_r(\eta, t + 1)$  as well as the first order condition resulting from the Nash sharing rule:

- $U_m(\eta, t) = U_r(\eta, t)$

$$(1 - \xi)(W_r(\eta, t + 1) - U_r(\eta, t + 1)) = \xi J_r(\eta, t + 1) = \xi \frac{\kappa}{q_r(\eta, t)}$$

- $U_m(\eta, t) = U_s^0(\eta, t)$

$$(1 - \xi)(W_s^0(\eta, t + 1) - U_s^0(\eta, t + 1)) = \xi J_s^0(\eta, t + 1) = \xi \frac{\kappa}{q_s^0(\eta, t)}$$

we obtain the following wage equation

- $U_m(\eta, t) = U_r(\eta, t)$

$$w_r(\eta, t) = \xi(y_r(t)\eta + \kappa\theta_r(\eta, t)) + (1 - \xi)b_r(\eta, t)$$

- $U_m(\eta, t) = U_s^0(\eta, t)$

$$w_r(\eta, t) = \xi(y_r(t)\eta + \kappa\theta_s^0(\eta, t)) + (1 - \xi)b_r(\eta, t)$$

## A.2 Service new (movers)

The first order conditions are given by

$$\xi J_s^0(\eta, t) = (1 - \xi)(W_s^0(\eta, t) - U_s^0(\eta, t)) \quad (33)$$



which, after replacing the value functions, gives:

$$\begin{aligned} \xi y_s(t) - w_s^0(\eta, t) + \beta(1-s)J_s(t+1) &= (1-\xi) \left\{ w_s^0(\eta, t) - b_r(\eta, t) \right. \\ &\left. + \beta \left[ (1-s)W_s(t+1) + sU_s(t+1) - f_s^0(\eta, t)W_s^0(\eta, t+1) - (1-f_s^0(\eta, t))U_s^0(\eta, t+1) \right] \right\} \end{aligned}$$

After some rearrangement, we have

$$\begin{aligned} w_s^0(\eta, t) &= \xi y_s(t) + (1-\xi)b_r(\eta, t) \\ &+ \beta \left[ (1-s) \left( \xi J_s(t+1) - (1-\xi)(W_s(t+1) - U_s(t+1)) \right) \right. \\ &\left. + (1-\xi) \left( f_s^0(\eta, t)(W_s^0(\eta, t+1) - U_s^0(\eta, t+1)) + U_s^0(\eta, t+1) - U_s(t+1) \right) \right] \end{aligned}$$

By using the job creation condition and  $\kappa/q_s^0(\eta, t) = \beta J_s^0(\eta, t+1)$  as well as the first order condition resulting from the Nash sharing rule:

$$(1-\xi)(W_s^0(\eta, t+1) - U_s^0(\eta, t+1)) = \xi J_s^0(\eta, t+1) = \xi \frac{\kappa}{q_s^0(\eta, t)}$$

we obtain the following wage equation

$$w_s^0(\eta, t) = \xi(y_s(t) + \kappa\theta_s^0(\eta, t) + (1-\xi) \left( b_r(\eta, t) + \beta(U_s^0(\eta, t+1) - U_s(t+1)) \right))$$

### A.3 Service

The first order conditions are given by

$$\xi J_s(t) = (1-\xi)(W_s(t) - U_s(t)) \quad (34)$$

which, after replacing the value functions, gives:

$$\begin{aligned} \xi y_s(t) - w_s(t) + \beta(1-s)J_s(t+1) &= (1-\xi) \left\{ w_s(t) - b_s(t) \right. \\ &\left. + \beta \left[ (1-s)W_s(t+1) + sU_s(t+1) - f_s(t)W_s(t+1) - (1-f_s(t))U_s(t+1) \right] \right\} \end{aligned}$$

After some rearrangement, we have

$$\begin{aligned} w_s(t) &= \xi y_s(t) + (1-\xi)b_s(t) \\ &+ \beta \left[ (1-s) \left( \xi J_s(t+1) - (1-\xi)(W_s(t+1) - U_s(t+1)) \right) \right. \\ &\left. + (1-\xi)f_s(t)(W_s(t+1) - U_s(t+1)) \right] \end{aligned}$$

By using the job creation condition and  $\kappa/q_s(t) = \beta J_s(t+1)$  as well as the first order condition resulting from the Nash sharing rule:

$$(1 - \xi)(W_s(t+1) - U_s(t+1)) = \xi J_s(t+1) = \xi \frac{\kappa}{q_s(t)}$$

we obtain the following wage equation

$$w_s(t) = \xi(y_s(t) + \kappa\theta_s(t)) + (1 - \xi)b_s(t)$$

## B Algorithm

Let us denote by  $\theta$  the vector of labour market tightness and by  $N$  the vector of employment stocks. Thus, the whole system can be written in a block-recursive way:

$$\theta_t = F_\theta(\theta_{t+1}, y_{t+1}) \tag{35}$$

$$N_{t+1} = F_N(N_t, \theta_t) \tag{36}$$

By using the block-recursive system, one can solve this problem as follows:

1. We consider a sequence of exogenous variables  $\{y_t\}_{t=1}^T$ .
2. For a terminal condition  $\theta_T$  we obtain by backward iteration the values for  $\theta_{T-1}, \theta_{T-2}, \dots, \theta_0$  using Equation (35).
3. On each date  $T-1, T-2, \dots, 0$  we check for the binding MW, the occupational choice, and the quitting and scrapping of all sectors.
4. With this vector  $\{\theta_t\}_{t=0}^T$ , we deduce, by using  $F_N$  in Equation (36), the vector  $\{N_t\}_{t=0}^T$ , given an initial condition  $N_0$ .

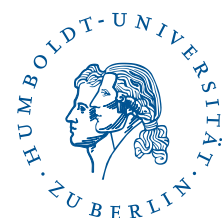
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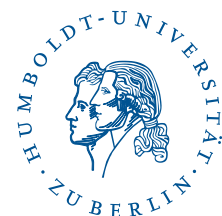
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