# Estimating Incentive and Welfare Effects of Non-Stationary Unemployment Benefits

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The distribution of unemployment duration in a general equilibrium matching model with spell-dependent unemployment benefits displays a time-varying exit rate. Building on Semi-Markov processes, we obtain an expression for the aggregate unemployment rate under endogenous heterogeneous search effort. Structural estimation using a German micro-data set (SOEP) allows us to discuss the effects of a recent unemployment benefit reform (Hartz IV). The reform reduced unemployment by only 0.3%. Contrary to general beliefs, we find that workers as a whole gain even though the long-term unemployed lose. The reason is the rise in the wage caused by more vacancies per unemployed worker.

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## 1 Introduction

Continental European unemployment is notorious for its persistence. France, Italy and Germany have had rising unemployment rates from the 1960s up to 2000 and even onward. There seems to be a consensus now that a combination of shocks and institutional arrangements lies at the origin of these high unemployment rates (Ljungqvist and Sargent, 1998, 2007a, b; Mortensen and Pissarides, 1999; Blanchard and Wolfers, 2000). Neither institutions nor shocks alone explain the rise in unemployment: institutions have always been there but unemployment has not (at least not at this level) and shocks have hit many countries but not all countries have high unemployment rates. The step from this shock-institutions insight towards finding a solution to the European unemployment problem seems to be short: As shocks will not go, we need to address the institutions.

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A common suggestion to fight unemployment is to reduce long and generous unemployment benefits. This raises other questions, however: Should one reduce the length and level of unemployment benefits in order to reduce unemployment? One seems to be faced by a classic efficiency-equity trade-off. While reducing unemployment per se is beneficial, income of the unemployed and the insurance mechanism implicit in unemployment benefits should not be neglected.

We examine qualitatively and quantitatively the employment and welfare effects of a policy reform which reduces the length and level of unemployment benefits. We use Germany as an example of a continental European country for three reasons. First, the unemployment rate in Germany has been rising for many decades, just as e.g. in France or Italy. Second, the German unemployment benefit system has a two-tier structure which is typical for many OECD countries. Third, the so-called "Hartz IV reform" implemented in January 2005 comprises both the reduction of benefit levels and the cut of the duration of entitlement. Reforms of this type were undertaken in many other OECD countries as well (OECD, 2004).

The reform did not change the level of unemployment insurance (UI) payments. Unemployment assistance (UA) payments, formerly proportional to net earnings before the job loss, were replaced by a uniform benefit level, however. The effect of this new rule on the income of long-term unemployed workers was ambiguous. There were unemployed whose benefit payments were lower before 2005 than after the reform, mainly unemployed workers from the low wage sector. Those were the "winners" of the reform (47 percent of long-term unemployed). On the other hand, there were also long-term unemployed with relatively high wages before entering unemployment. These were affected negatively by the new law and their income has dropped (53 percent of long-term unemployed). Despite the fraction of "winners" and "losers" is roughly equal, the gain of the winners has turned out to be lower than the loss of the losers leading to a loss of the average worker of a bit more than 7% due to Hartz IV (Blos and Rudolph, 2005; OECD, 2007). The reform also adjusted, for workers who entered unemployment from February 2006 onward, the maximum duration of entitlement to UI payments. It was (almost) uniformly reduced to 12 months (formerly, 15 months was the average).

At first sight, the reforms seem to have worked.[2] The reported unemployment rate dropped between January 2005 and January 2007 from 12.3% to 10.2%. On the other hand, growth rates in Germany were (for German standards) fairly high. While the German economy shrank in 2003, it has recovered since then and probably also created new jobs. The real GDP grew by 0.8 percent in 2005 and by 2.9 percent in 2006. The question therefore arises whether the drop in unemployment can be credited to the reform. It is also a priori unclear how strongly various groups were affected by the reform. Did utility of the (short- and long-term) unemployed or employed workers rise or fall? Did firms gain from the reform? What about social welfare?

We provide answers by using a model which combines various strands of the literature and adds some new and essential features. We employ a general equilibrium matching framework and extend the standard text-book model for time-dependent unemployment

[2] We talk about reforms as the measures we highligth are part of a series of reforms (Hartz I to Hartz IV). Our central measures were those who probably had the strongest effect and were one of the most discussed in the public.

benefits, endogenous effort, risk-averse households, an exogenous "spell-effect" and Semi-Markov features. Each of these extensions is crucial. Unemployment benefits in our model need to depend on the length of the unemployment spell as this is a feature of basically all OECD unemployment benefit systems. Letting agents optimally choose their effort to find a job, we can analyze the incentive effects of (reforms of) the unemployment benefit system on the search intensity. Risk-averse households are required as we also want to evaluate insurance effects. The spell-effect allows us to obtain - depending on how fast it sets in - rising (up to some upper limit), falling or hump-shaped exit rates. Finally, tools from the Semi-Markov literature are required as this allows us to deduce the aggregate unemployment rate from individual search. We can thereby compute macro efficiency effects resulting from micro incentives.

We solve this model numerically by looking at Bellman equations as differential equations. This gives us solutions which are as accurate as numerical precision and which do not require us to approximate the model in any way. Optimal behaviour implies an exit rate into employment which is a function of the time spent in unemployment. We thereby obtain a flexible enough endogenous distribution of unemployment duration which we employ for structural estimation of model parameters. Estimation by maximum likelihood is then (relatively) straightforward.

The main theoretical contribution of our analysis is the explicit treatment of the Semi-Markov nature of optimal individual behaviour due to the presence of spell-dependent unemployment benefits: Optimal exit rates not only depend on whether the individual is unemployed (the current state of the worker) but also on how long an individual has been unemployed. While this Semi-Markov aspect has been known for a while, it has not been fully exploited so far in the search literature. Using results from the applied mathematics literature, we obtain analytic expressions for individual employment probabilities contingent on current employment status and duration of unemployment. They allow us to compute aggregate unemployment rates using a law of large numbers in our pure idiosyncratic risk economy. Given this link from optimal individual behaviour to aggregate outcomes, we can analyze the distribution and efficiency effects of changes in level and length of unemployment benefits.

The main empirical contribution is the careful modelling of exit rates into employment. Individual incentives due to falling unemployment benefits imply more search effort and therefore higher exit rates over time. Empirical evidence shows, however, that exit rates tend to fall - at least after some initial increase over the first 3-4 months of unemployment. We therefore combine individual incentive effects with an exogenous time-decreasing spell-effect and with unobserved heterogeneity. As is well known, the latter implies inter alia falling aggregate exit rates even though individual exit rates are rising. Structural estimation then establishes the importance of the time-effect and the unobserved heterogeneity effect. We find that the model can replicate empirical stylized facts of first rising and then falling exit rates.

The main policy contribution is our emphasis and structural estimation of the trade-off between insurance and incentive effects of labour market policies. The degree of risk-aversion - crucial for understanding the insurance effect - is jointly estimated with exit rates and the spell-effect (and other model parameters). A comparative static analysis using the estimated version of the theoretical model then allows us to derive precise predictions about the employment and distribution effects of changes in the length and level of unemployment benefits.

Providing a short preview of our results, we find that the reform did decrease the unemployment rate - which is the desirable effect - but only by 0.3% - which is disappointing. Very much to our surprise, we also find that the reform increased wages and decreased profits. Usually, one would expect that a reduction of alternative income reduces equilibrium wages. While this channel is present in our setup as well, the general equilibrium effect of a rise in the number of vacancies per unemployed worker overcompensates the first effect - wages rise when benefits fall. The mechanism is very simple: lower benefits induce the unemployed to search harder which in turn induces firms to open more vacancies per unemployed worker. As wages rise, profits fall.

This rise in wages is also the reason why the reform is social welfare increasing. The uninterested worker (behind the veil of ignorance) experiences a rise in expected utility. This is *not* due to a better insurance mechanism cause by the reform. In fact, the insurance mechanism is worsened when unemployment benefits are reduced. The rise in expected utility is entirely due to the general equilibrium increase in the wage. The only drawback of the reform is that the long-term unemployed workers lose. A Pareto-improving reform would have been more desirable.

Our paper is related to various strands in the literature. From a theoretical perspective, we build on the search and matching framework of Diamond (1982), Mortensen (1982) and Pissarides (1985), recently surveyed by Rogerson et al. (2005). Time-dependent unemployment benefits and endogenous effort have been originally analyzed by Mortensen (1977) in a one-sided job search model. Equilibrium search and matching models include Cahuc and Lehman (2000), Fredriksson and Holmlund (2001).[3] These models, however, are less powerful than our model in explaining the anticipation effect of the reduction in benefits, as exit rates within each benefit regime are constant. There also exists a substantial literature that studies optimal insurance allowing for an arbitrary time path of unemployment benefit payments (Shavell and Weiss, 1979; Hopenhayn and Nicolini, 1997; Shimer and Werning, 2007). Our focus is more of a positive nature trying to understand the welfare effects of existing systems which have a simpler benefit structure than the ones resulting from an optimization approach. We also allow for an unlimited number of transitions between employment and unemployment and undertake a general equilibrium analysis as in Moscarini (2005).[4]

From an empirical perspective, we estimate a parametric duration model (Lancaster, 1990) in which time dependence of the hazard function due to time-dependent benefits is fully described by the equilibrium solution of our theoretical model. Econometric models with time-dependent benefits were originally estimated by van den Berg (1990) and Ferrall (1997).[5] Van den Berg et al. (2004) and Abbring et al. (2005) extend the setting by

[3] Albrecht and Vroman (2005) and Coles and Masters (2007) also have time-dependent unemployment payments but they do not analyze the implications for individual effort. Albrecht and Vroman focus on the equilibrium wage dispersion and inefficient job rejection. Coles and Masters model aggregate uncertainty implying implicit transfers between firms and the stabilizing effect this has on the unemployment rate over the cycle.

[4] Acemoglu and Shimer (1999) do consider a general equilibrium model, but their setting is restricted to time-invariant benefits only.

[5] See also Eckstein and van den Berg (2007) for literature review on nonstationary empirical models.

introducing time dependence due to monitoring and sanctions. In contrast to our model, this literature deals with one-sided job search, which makes application of its estimates in a general equilibrium analysis rather difficult. In addition to that, focus on the incentive effect in is only partial (van den Berg et al., 2004; Abbring et al., 2005) and insurance effect remains largely unaddressed. There also exists a larger empirical equilibrium search literature that deals with unemployment benefit heterogeneity (Bontemps et al., 1999), heterogeneity in workers abilities (Postel-Vinay and Robin, 2002) and heterogeneity in workers value of nonparticipation (Flinn, 2006). Unlike in our model, however, neither of these contributions views heterogeneity as being a result of non-stationary unemployment benefits.

Finally, Semi-Markov methods are taken from the applied mathematical literature, see e.g. Kulkarni (1995) or Corradi et al. (2004).

The structure of our paper is as follows. In section 2 we present the theoretical model, institutional setting, behaviour of supply and demand sides and the combination of both in economic welfare. Section 3 describes the equilibrium properties of the model. Section 4 illustrates the structural estimation and the underlying data. The simulation results and the evaluation of the institutions reforms are presented in section 5. Section 6 concludes.

# 2 The model

We use a Diamond-Mortensen-Pissarides type matching model and extend it for time-dependent unemployment benefits, endogenous effort, risk-averse households and an exogenous spell-effect. To solve it, we use Semi-Markov tools. The separation rate for jobs is constant and there is no search on the job. We focus on steady states in our analysis. Households are ex-ante identical but endogenously heterogenous in their unemployment duration.

## 2.1 Production, benefits and employment

The economy has a work force of exogenous constant size $N$. Employment is endogenous and given by $L$ and the number of unemployed amounts to $N - L$. Firms produce under perfect competition on the goods market and each worker-firm match produces output $A$, which is constant. The production process of the worker and the firm can be interrupted by exogenous causes which occur according to a time-homogenous Poisson process with a constant arrival rate $\lambda$.

Unemployed workers receive UI benefits $b_{UI}$ and UA benefits $b_{UA}$. Benefits are modelled to reflect institutional arrangements in many European countries. One of the most important features is the dependence of UI benefits on the unemployment spell. Workers with a spell $s$ shorter than $\bar{s}$ (say one year) receive UI benefits $b_{UI}$, afterwards, they receive $b_{UA}$,

$$b(s) = \begin{cases} b_{UI} & 0 \leq s \leq \bar{s} \\ b_{UA} & \bar{s} < s \end{cases} . \tag{1}$$

We assume $b_{UI} > b_{UA} \geq 0$. Benefits can be paid either at a fixed level or proportional to previous income.

An unemployed worker finds a job according to a time - inhomogeneous Poisson process with arrival rate $\mu(.)$. This rate will also be called the job-finding rate, hazard rate or exit rate (into employment). We allow this rate to depend on effort $\phi(s(t))$ an individual exerts to find a job. Effort today in $t$ depends on the length $s(t)$ this individual has been spending in unemployment since his last job. The spell increases linearly in time and starts in $t_0$ where the individual has lost the job, i.e. $s(t) = t - t_0$. An individual whose duration of unemployment spell $s(t)$ exceeds the length of entitlement to UI benefits $\bar{s}$ (i.e. $s(t) \geq t_0 + \bar{s}$) will be called a long-term unemployed.

In addition to effort, the exit rate of an individual will also depend on aggregate labour market conditions and on something which, for simplicity, we call a spell-effect. Labour market conditions are captured by labour market tightness $\theta$ that differs across steady states, $\theta \equiv V/(N-L)$. We assume that effort and tightness are multiplicative: no effort implies permanent unemployment and no vacancies imply that any effort is in vain. The spell-effect captures all factors exogenous to the individual which affects her exit rate into employment. This can include stigma (Vishvanath, 1989), ranking (Blanchard and Diamond, 1994) and gains or losses in individual search productivity. We denote this effect by $\eta(s)$. Assuming that a stigma becomes worse the longer $s$, we would expect $\eta(s)$ to fall in $s$. Summarizing, the exit rate will be of the form $\mu(\phi(s(t))\theta, \eta(s))$.[6]

There is a long discussion in the literature whether aggregate falling exit rates are due to a time effect (as modeled here by $\eta(s)$) or due to unobserved heterogeneity (Kiefer and Neumann, 1981, Flinn and Heckman, 1982 and, non-parametrically, Heckman and Singer, 1984, van den Berg and van Ours, 1996). We take unobserved heterogeneity into account in our empirical part and discuss its effects there.

The outcome of our time-varying exit rate will be an endogenous distribution of unemployment duration. Its density is given by (e.g. Ross, 1996, ch. 2)

$$f(s) = \mu(\phi(s)\theta, \eta(s))\, e^{-\int_0^s \mu(\phi(u)\theta, \eta(u))du}. \tag{2}$$

This density will be crucial later for various purposes including the estimation of model parameters. It is endogenous to the model, as exit rate $\mu(\phi(s(t))\theta, \eta(s))$ follows from the optimizing behaviour of workers and firms.

Unemployment benefit payments to short- and long-term unemployed are financed by a tax rate $\kappa$ on gross wages and by transfers $\Pi$ from firms. The labour tax $\kappa$ implies that the net wage is $w = (1-\kappa)\, w^{gross}$.[7] The number of short-term unemployed workers is $\int_0^{\bar{s}} f(s)\, ds\, (N-L)$ and $\int_{\bar{s}}^{\infty} f(s)\, ds\, (N-L)$ is the number of the long-term unemployed. The budget constraint of the government therefore reads

$$\left(b_{UI} \int_0^{\bar{s}} f(s)\, ds + b_{UA} \int_{\bar{s}}^{\infty} f(s)\, ds\right)(N-L) = \kappa \frac{w}{1-\kappa} L + \Pi. \tag{3}$$

[6] Given our focus on individual search behaviour, we start at the individual level and then derive a matching function (see the discussion following (19)) rather than the other way round. Both ways are of course equivalent.

[7] The transfers from firms is a modelling device which makes sure that all financial flows are taken into account as well. This makes our setup a true general equilibrium setup. More precisely speaking, the transfers $\Pi$ amount to the difference between aggregate profits and aggregate vacency costs, $\Pi \equiv (A - w/(1-\kappa))\, L - \gamma M$ where $M$ is the number of vacancies. Quantitatively speaking, $\Pi$ is neglegibly small. It is only around 0.2% of total income of the government.

The government adjusts the wage tax $\kappa$ such that this constraint holds at each point in time.

## 2.2 Optimal behaviour

Households are infinitely lived and do not save. They have a strictly positive time preference rate $\rho$. The present value of having a job is given by $V(w)$ and depends on the current endogenous wage $w$ only. Employed workers enjoy instantaneous utility $u(w)$. The value $V(w)$ is constant in a steady state as the wage is constant, but differs across steady states. Whenever a worker loses his job, he enters the unemployment benefit system by obtaining insurance payments $b_{UI}$ for the full length of $\bar{s}$. Workers are immediately granted full benefit entitlements, i.e. unemployment payments are not experience rated. See the bargaining setup for further discussion. Hence, the value of being unemployed when just having lost the job is given by $V(b_{UI}, 0)$ where 0 stands for a spell of length zero. This leads to a Bellman equation for the employed worker of

$$\rho V(w) = u(w) + \lambda \left[ V(b_{UI}, 0) - V(w) \right]. \tag{4}$$

The Bellman equation for the unemployed worker reads

$$\rho V(b(s), s) = \max_{\phi(s)} \left\{ u(b(s), \phi(s)) + \frac{dV(b(s), s)}{ds} + \mu(\phi(s)\theta, \eta(s)) \left[ V(w) - V(b(s), s) \right] \right\}. \tag{5}$$

The instantaneous utility flow of being unemployed, $\rho V(b(s), s)$, is given by three components. The first component shows the instantaneous utility resulting from consumption of $b(s)$ and effort $\phi(s)$. The second component is a deterministic change of $V(b(s), s)$ as the value of being unemployed changes over time. The third component is a stochastic change that occurs at job-finding rate $\mu(\phi(s)\theta, \eta(s))$. When a job is found, an unemployed gains the difference between the value of being employed $V(w)$ and $V(b(s), s)$.

An optimal choice of effort $\phi(s)$ for (5) requires

$$u_{\phi(s)}(b(s), \phi(s)) + \mu_{\phi(s)}(\phi(s)\theta, \eta(s)) \left[ V(w) - V(b(s), s) \right] = 0, \tag{6}$$

where subscripts denote (partial) derivatives. It states that the expected utility loss resulting from increasing search effort must be equal to expected utility gain due to higher effort.

We require that the value of unemployment an instant before becoming a long-term unemployed is identical to the value of being long-term unemployed at $\bar{s}$, i.e.

$$V(b_{UI}, \bar{s}) = V(b_{UA}, \bar{s}). \tag{7}$$

The value of a job $J$ to a firm is given by instantaneous profits $A - w/(1-\kappa)$, which is the difference between revenue $A$ and the gross wage $w/(1-\kappa)$, reduced by the risk of being driven out of business

$$\rho J = A - w/(1-\kappa) - \lambda J, \tag{8}$$

where $\rho > 0$ stands for the interest rate (being identical to the discount rate of households) and where we anticipate that the value of a vacancy is zero.

Given that individual arrival rates are a functions of the individual unemployment spell, the expected rate of exit out of unemployment is just the mean over individual arrival rates, given the endogenous distribution of the unemployment spell $f(s)$ from (2),

$$\bar{\mu} = \int_0^\infty \mu(\phi(s)\theta, \eta(s)) f(s) ds. \tag{9}$$

As a consequence, the vacancy filling rate is $\theta^{-1}\bar{\mu}$. The value of a vacant job is $\rho J_0 = -\gamma + \theta^{-1}\bar{\mu}[J - J_0]$. With free entry, the value of holding a vacancy is $J_0 = 0$, leading to

$$J = \gamma\theta/\bar{\mu}. \tag{10}$$

We let wages be determined by Nash bargaining. We assume that the outcome of the bargaining process is such that workers receive a share $\beta$ of the total surplus of a successful match $V(w) - V(b_{UI}, 0) = \beta\left[J\left(\frac{w}{1-\kappa}\right) - J_0 + V(w) - V(b_{UI}, 0)\right]$. The total surplus is the gain of the firm plus the gain of the worker from the match where the latter depends crucially on the outside option of the worker. The fact that we use $V(b_{UI}, 0)$ as the outside option of the worker means that all workers (even if only working for an instant or, in the limit, if only bargaining) are entitled to full unemployment benefits, i.e. $b_{UI}$ over the full length $\bar{s}$ and $b_{UA}$ for $s > \bar{s}$.[8] An alternative would consist in specifying $V(b(s), s)$ as the outside option: if the bargain fails, the unemployed worker remains unemployed and continues to receive benefits she received before the unsuccessful bargaining. This would be theoretically interesting as an endogenous wage distribution would arise (see Albrecht and Vroman, 2005) where the distinguishing determinant across workers is the previous unemployment spell. Using an identical outside option for all individuals, however, has the advantage that all workers are homogenous. Once an unemployed finds a job, all history is deleted, all workers are the same and, independently of their employment history, earn the same wage.[9]

Following the steps as in Pissarides (1985), we end up with a generalized wage equation that reads (see app. B.1.1)

$$(1-\beta) u(w) + \beta\frac{w}{1-\kappa} = (1-\beta) u(b_{UI}, \phi(0)) + \beta[A + \theta\gamma]. \tag{11}$$

The left hand side corresponds to what in models with risk-neutrality and without taxation is simply the wage rate. If we had $\kappa = 0$ and $u(w) = w$, we would obtain just $w$ on the left. Consequently, the worker is compensated for the outside option in the case of unemployment $u(b_{UI}, \phi(0))$. The tax rate, that appears as the term $w/(1-\kappa)$, results from the instantaneous profit of a firm (8) which needs to pay a gross wage of $w/(1-\kappa)$. The right hand side is a simple generalization of the standard wage equation of Pissarides (1985). Instead of benefits for the unemployed (which we would find on the right for risk-neutral households and no time-dependence of effort), we have instantaneous utility from

[8] In the quantitative part, the "full length" $\bar{s}$ will be provided by the data. In this sense, entitlement is taken into account.

[9] Our assumption that all workers, even if they have worked only for a second, are entitled to $b_1$ for the full period of length $\bar{s}$ is identical to saying that benefit payments are not experience rated. While the absence of experience rating is generally distorting the firms decision to lay off workers (see e.g. Mongrain and Roberts, 2005), this does not play a role in our setup as the separation rate is exogenous. It would be interesting to study the impact of endogenous separation decisions but we leave this for future research.

being unemployed. The impact of the production side is unchanged when compared to the standard wage equation.

Instead of specifying the outside option differently, one could also allow for strategic bargaining. Many recent papers have used strategic bargaining given that either payoffs change over time and Nash bargaining would correspond to myopic behaviour (Coles and Wright, 1998; Coles and Muthoo, 2003), that a careful analysis of on-the-job search makes strategic bargaining more appropriate (Cahuc, Postel-Vinay and Robin, 2006) or that unemployment does not have such a strong effect on bargaining as generally thought (Hall and Milgrom, 2008).[10] Brügemann and Moscarini (2007) find (for a different question) that the quantitative differences between different wage-setting rules are small. Given that we want to focus here on the direct incentive effects of non-stationary unemployment benefits on search effort, we feel justified to "switch off" the strategic channel and leave this for future work.

## 2.3 The insurance effect

In addition to the incentive effect of reforms, we would also like to understand the insurance effect. In a world without moral hazard, optimal unemployment insurance would require unemployment benefits equal to the net wage. With moral hazard, i.e. with effort being a function of unemployment benefits, insurance consideration must take into account that effort decreases in unemployment benefits.

We can easily understand whether the insurance effect was taken into account in an appropriate way by computing expected utility of an individual which is "behind the veil of ignorance". This is similar in spirit to social welfare functions employed by Hosios (1990) or Flinn (2006). One can alternatively look at this expected utility as average utility over all (employed and unemployed) workers. Expected utility $EU$ is given by

$$EU \equiv \frac{L}{N}V(w) + \frac{N-L}{N}\left(\int_0^{\bar{s}} V(b_1,s) f(s)\, ds + \int_{\bar{s}}^{\infty} V(b_2,s) f(s)\, ds\right). \qquad (12)$$

It is computed by the share $L/N$ of employed workers times their welfare $V(w)$ plus the share $(N-L)/N$ of unemployed workers times the average welfare of an unemployed. This average is obtained by integrating over all spells $s$, where $f(s)$ is the endogenous density (2), with exit rates $\mu(\phi(s)\theta, \eta(s))$ that follow from the steady state solution of the model, and the $V(b_i, s)$ are the values of being unemployed with a spell $s$ and benefit payments $b_i$ from (1).

# 3 Equilibrium properties

## 3.1 Individual (un)employment probabilities

In models with constant job-finding and separation rates, the unemployment rate can easily be derived by assuming that a law of large numbers holds. Aggregate employment dynamics can then be described by $\dot{L} = \mu[N-L] - \lambda L$ which allows to compute unemployment rates.

[10] Coles and Masters (2004) analyse wage setting by strategic bargaining in a matching setup with non-stationary unemployment benefits. They do not consider endogenous search intensity, however.

With spell-dependent effort, individual arrival rates $\mu(.)$ are heterogeneous and employment dynamics need to be derived using techniques from the literature on Semi-Markov or renewal processes, e.g. Kulkarni (1995) or Corradi et al. (2004).

The generalization of Semi-Markov processes compared to continuous time Markov chains consists in allowing the transition rate from one state to another to depend on the time an individual has spent in the current state. We apply this here and let the transition rate from unemployment to employment depend on the time $s$ the individual has been unemployed. Hence, switching from a constant job-finding rate $\mu$ to a spell-dependent rate $\mu(s)$ implies switching from Markov to Semi-Markov processes. Processes are called "semi" as the history-dependence of the job finding rate $\mu(s)$ is not Markov. Processes are still called "Markov" as once an individual has found a job, history no longer counts. This is also why these processes are called renewal processes: whenever a transition to a new state occurs, the system starts from the scratch, it is "renewed" and history vanishes.

We start by looking at individual employment probabilities. Let $p_{ij}(\tau, s(t))$ describe the probability with which an individual, who is in state $i$ (either $e$ for employed or $u$ for unemployed) today in $t$, will be in state $j \in \{e, u\}$ at some future point in time $\tau$, given that his current spell is now $s(t)$. These expressions read, starting with $s(t) = 0$ and taking into account that the separation rate $\lambda$ remains constant (see app. A.5),

$$p_{uu}(\tau, 0) = e^{-\int_t^\tau \mu(s(y))dy} + \int_t^\tau e^{-\int_t^v \mu(s(y))dy} \mu(s(v))\, p_{eu}(\tau - v)\, dv, \tag{13a}$$

$$p_{eu}(\tau) = \int_t^\tau e^{-\lambda[v-t]} \lambda p_{uu}(\tau - v, 0)\, dv. \tag{13b}$$

Expressions for complementary transitions are given by $p_{ue}(\tau) = 1 - p_{uu}(\tau)$ and $p_{ee}(\tau) = 1 - p_{eu}(\tau)$, respectively.

These equations have a straightforward intuitive meaning. Consider first the case of $\tau$ being not very far in the future. Then all integrals (for $\tau = t$) are zero and the probability of being unemployed at $\tau$ is, if unemployed at $t$, one from (13a) and, if employed at $t$, zero from (13b). For a $\tau > t$, the part $e^{-\int_t^\tau \mu(s(y))dy}$ in (13a) gives the probability of remaining in unemployment for the entire period from $t$ to $\tau$. An individual unemployed today can also be unemployed in the future if he remains unemployed from $t$ to $v$ (the probability of which is $e^{-\int_t^v \mu(s(y))dy}$), finds the job in $v$ (which requires multiplication with the exit rate $\mu(s(v))$) and then moves from employment to unemployment again over the remaining interval $\tau - v$ (for which the probability is $p_{eu}(\tau - v)$). As this path is possible for any $v$ between $t$ and $\tau$, the densities for these paths are integrated. The sum of the probability of remaining unemployed all of the time and of finding a job at some $v$ but being unemployed again at $\tau$ gives then the overall probability $p_{uu}(\tau, 0)$ of having no job in $\tau$ when having no job in $t$. Note that there can be an arbitrary number of transitions in and out of employment between $v$ and $\tau$. The interpretation of (13b) is similar. The probability of remaining employed from $t$ to $v$ is simpler, $e^{-\lambda[v-t]}$, as the separation rate $\lambda$ is constant.

As we can see, these equations are interdependent: The equation for $p_{uu}(\tau)$ depends on $p_{eu}(\tau - v)$ and the equation for $p_{eu}(\tau)$, in turn, depends on $p_{uu}(\tau - v)$. Formally speaking, these equations are integral equations, sometimes called Volterra equations of the first type (13b) and of the second type (13a). Integral equations can sometimes be transformed into differential equations, which will simplify their solution in practice. In our case, however, no transformation into differential equations is known.

After having computed the probability of being unemployed in $\tau$ when being unemployed in $t$ for individuals that just became unemployed in $t$, i.e. who have a spell of length $s(t) = 0$, we will need an expression for $p_{uu}(\tau, s(t))$. This means, we will need the transition probabilities for individuals with an arbitrary spell $s(t)$ of unemployment. Luckily, given the results from (13a and b), this probability is straightforwardly given by

$$p_{uu}(\tau, s(t)) = e^{-\int_t^\tau \mu(s(y))dy} + \int_t^\tau e^{-\int_t^v \mu(s(y))dy} \mu(s(v)) p_{eu}(\tau - v) dv. \tag{14}$$

An unemployed with spell $s(t)$ in $t$ has different exit rates $\mu(s(y))$ which, however, are known from our analysis of optimal behaviour at the individual level. Hence, only the integrals in (14) are different, the probabilities $p_{eu}(\tau - v)$ can be taken from the solution of (13a and b).

## 3.2 Aggregate unemployment

Given our finding in (13) and (14) on $p_{eu}(\tau)$ and $p_{uu}(\tau, s(t))$, we can now compute the expected number of unemployed for any distribution of spell $F(s)$,

$$E_t[N - L_\tau] = [N - L_t] \int_0^\infty p_{uu}(\tau, s(t)) dF(s(t)) + p_{eu}(\tau) L_t. \tag{15}$$

Starting at the end of this equation, given there are $L_t$ employed workers in $t$, the expected number of unemployed workers at some future point $\tau$ out of the group of those currently employed in $t$ is given by $p_{eu}(\tau) L_t$. Again, one should keep in mind that the probability $p_{eu}(\tau)$ allows for an arbitrary number of switches between employment and unemployment between $t$ and $\tau$, i.e. it takes the permanent turnover into account.

For the unemployed, we compute the mean over all probabilities of being unemployed in the future, if unemployed today, by integrating over $p_{uu}(\tau, s(t))$ given the current distribution $F(s(t))$. Multiplying this by the number of unemployed today, $N - L_t$, gives us the expected number of unemployed at $\tau$ out of the pool of unemployed in $t$. The sum these two expected quantities gives the expected number of unemployed at some future point $\tau$.

The expected unemployment rate at $\tau$ is simply the expression (15) divided by $N$. When we focus on a steady state, we let $\tau$ approach infinity. In order to obtain a simple expression for the aggregate unemployment rate and to show the link to the textbook expression, we assume a pure idiosyncratic risk model where micro-uncertainty cancels out at the aggregate level. Hence, we assume a law of large numbers holds and the population share of unemployed workers equals the average individual probability of being unemployed. This "removes" the expectations operators, so that (15) for a steady state becomes $N - L = [N - L] \int_0^\infty p_{uu}(s(t)) dF(s(t)) + p_{eu} L$. We have replaced $L_\tau = L_t$ by the steady state employment level $L$ and the individual probabilities by the steady state expressions $p_{uu}(s(t))$ and $p_{eu}$. The probability $p_{eu}$ is no longer a function of $\tau$ as this probability will not change in steady state, while there will always be a distribution of $p_{uu}(s)$, even in steady state.

Solving for the unemployment rates gives

$$\frac{N - L}{N} = \frac{p_{eu}}{p_{eu} + \left[1 - \int_0^\infty p_{uu}(s(t)) dF(s(t))\right]} = \frac{p_{eu}}{p_{eu} + \int_0^\infty p_{ue}(s(t)) dF(s(t))}, \tag{16}$$

where the second expression is more parsimonious. If we assumed a constant job arrival rate here, we would get $p_{eu} = p_{uu} = \lambda/(\lambda+\mu)$ and $p_{ue} = \mu/(\lambda+\mu)$. Inserting this into our steady state results would yield the standard expression for the unemployment rate, $(N-L)/N = \lambda/(\lambda+\mu)$. In our generalized setup, the long-run unemployment rate is given by the ratio of individual probability $p_{eu}$ to be unemployed when employed today divided by this same probability plus $1-\int_0^\infty p_{uu}(s(t))\,dF(s(t))$.

## 3.3 Functional forms and steady state

For estimation purposes and for the numerical solution, we need functional forms for the instantaneous utility function and for the arrival rate. We assume that the instantaneous utility function of an unemployed worker used e.g. in (5) is

$$u(b(s),\phi(s)) = \frac{b(s)^{1-\sigma}-1}{1-\sigma} - \phi(s). \tag{17}$$

Effort is measured in utility terms.[11] The utility function of an employed worker has the same structure only that consumption is given by $w$ and there is no explicit effort. One could therefore look at $\phi$ as a measure of the difference between disutility from searching and disutility from work.

For reasons that will be discussed in the next section, let us express the spell-effect as

$$\eta(s) = \eta_0 g(s). \tag{18}$$

The arrival rate of jobs $\mu(\phi(s)\theta,\eta(s))$ is assumed to obey

$$\mu(\phi(s)\theta,\eta(s)) = \eta(s)[\phi(s)\theta]^\alpha, \tag{19}$$

This specification can easily be made plausible when linking it to a matching function. The matching function represents the aggregate arrival rate. Hence, it needs to equal the sum over individual arrival rates. Defining $\Omega \equiv \int \eta(s)\phi(s)^\alpha f(s)\,ds$, we find[12] $m(N-L,V) = (N-L)\int \mu(s) f(s)\,ds = \Omega[N-L]^{1-\alpha}V^\alpha$. This shows that we succeed in identifying the elasticity $\alpha$ of vacancies as we assume that both effort and tightness have the same power $\alpha$ in (19). The more appropriate interpretation for $\alpha$ is therefore the elasticity of effort.

In a steady state, all aggregate variables are constant and there will be a stationary distribution for unemployment spells. The solution of the steady state can most easily be found in two steps. Taking the wage $w$ and labour market tightness $\theta$ as exogenous, one can use expressions related to the unemployed for effort, the value of being unemployed and the value of a job, $\phi(b(s),s)$, $V(b(s),s)$ and $V(w)$. Once these quantities are known, one can use the remaining equations of the model to solve for the wage rate and tightness, $w$

[11] The term "-1" is essential here. While omitting "-1" would still yield risk aversion, including it makes the utility function continuous in $\sigma$, insuring that the likelihood function satisfies necessary regularity conditions.

[12] Note that one could argue that the individual arrival rate is a function of the ratio $V/(\Omega U)$ and not of the ratio $\theta = U/V$ as used here. The former specification would assume a negative externality: If everybody searches harder, my individual arrival rate decreases. Computing the aggregate matching function would then yield $m(U,V) = (\Omega U)^{1-\alpha}V^\alpha$. We do not believe that this will make a major quantitative importance and we therefore stick to our specification. For details, see app. B.1.4.

and $\theta$. In doing so, all other endogenous variables (exit rate $\mu(s)$ and the implied density $f(s)$, instantaneous utilities $u(.)$, the tax rate $\kappa$, individual employment probabilities $p_{ij}$ and the implied number of short- and long-term unemployed and the unemployment rate $(N-L)/N$, the number of vacancies, the value function $J$ for the firm and social welfare $EU$) are determined as well.[13]

# 4 Structural estimation

## 4.1 Exit rates out of unemployment

Before we estimate the model using the data from the German Socio-Economic Panel (SOEP), we need to specify the functional forms for our spell-effect (18).[14] In order to do so, we consider the distributional aspects of our data on the observed unemployment duration. The left panel of fig. 1 shows the nonparametric estimate of the hazard function from the entire sample of unemployment durations. The right panel of this figure shows as the solid line the hazard function for the subsample of individuals with entitlement length equal to 12 months. The dashed line shows the hazard rate of those nonentitled to unemployment insurance $b_{UI}$.[15] Both panels plot exit rates for the first 2.5 years of unemployment.

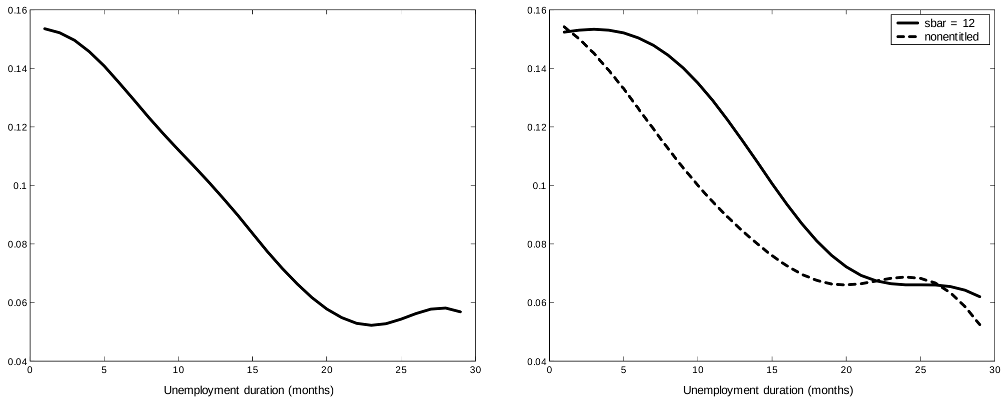


**Figure 1** *Non-parametric hazard functions (entire sample and* $\bar{s}=12$*)*

From these figures we can see a clear downward time dependence of the exit risk. On the one hand this may be the evidence of the true downward state dependence of an individual hazard rate (see e.g. van den Berg and van Ours, 1996, or Eckstein and Wolpin, 1995, for the evidence of this). On the other hand, this may be due to some unobserved heterogeneity in the data (Heckman and Singer, 1984; van den Berg and van Ours, 1996). Indeed, as far as German benefit system is concerned there is at least one likely source of such unobserved heterogeneity. Namely, all individuals receiving UI benefits may or may not be eligible to UA

[13]Appendix A.2 provides an explicit presentation of all equations (which above in the model description are given implicitly) and describes the solution procedure.

[14]For more background on the SOEP, our sampling method and for descriptive statistics, see app. A.1.

[15]See Tanner and Wong (1983) for the definition of the estimator and consistency proof. We use Gaussian kernel. Optimal bandwith is estimated by cross-validation discussed in Tanner and Wong (1984).

benefits, once the entitlement period expires. Eligibility to UA benefits is determined at the "means test", where an individual has to provide lengthy information about income sources of the household, number and age of dependents etc. If the means are sufficient, the person becomes ineligible to UA benefits, but might still claim social assistance, which eventually may or may not be provided. Unobservability, in our context, is in the fact that once exit out of unemployment occurs before the expiration of entitlement, an econometrician cannot know about the outcome of the means test. The individuals themselves, however, are very likely to know what the result of the test will be. So, in case they do not expect to pass the test, they would search harder and therefore exit faster. This behaviour, if uncontrolled for, results in a decreasing nonparametric estimate of the hazard rate. Clearly the true individual exit rate in this particular case may as well be constant, or increasing up to the expiration of entitlement and constant thereafter, as in Mortensen (1977), van den Berg (1991) and also in our theoretical model. Finally, both true individual state dependence and unobserved heterogeneity may manifest themselves simultaneously (see e.g. van den Berg and van Ours, 1996, 1999, for evidence of this in U.S. and French data respectively).[16]

Thus the individual exit rate derived from the theoretical model must be sufficiently flexible to capture both of these aspects. It needs to have a parametric form flexible enough to replicate the observed downward pattern even if no unobserved heterogeneity is present. Simultaneously it needs to make provision for unobserved heterogeneity at least with respect to the outcome of the means test and match the observed downward pattern even if the true individual exit risks are increasing or constant. Our aim is to provide a fully structural econometric model that estimates the deep parameters of the theoretical model of Section 2 adequately addressing both above possibilities.

## 4.2 Econometric model

- Specification

Our data are sampled as a flow of entrants into unemployment and employment. Therefore, exit rates contain all information necessary for the construction of the likelihood function. The exit rate from our theoretical model is given by (19). The effort level $\phi(s)$ needs to be replaced by the optimal value implied by the first-order condition (6), i.e. $\phi(s)$ is a function of the duration $s$ given the particular benefit environment (insurance and assistance benefits together with the entitlement length), the spell-effect $\eta(s)$, the wage $w$ and labour market density $\theta$. To stress this dependence but to keep notation short, we group these explanatory variables into a vector $\mathbf{z} \equiv \{b_{UI}, b_{UA}, \bar{s}, w, \theta\}$ and write $\phi = \phi(s, \mathbf{z})$ in the econometric part of this paper. With respect to this group of variables it is finally important to notice that even though $w$ and $\theta$ are endogenous to the theoretical model they are exogenous to the duration of unemployment which is our dependent variable. Therefore one can either substitute them out using their theoretical solutions, which depend on the productivity $A$ and vacancy costs $\gamma$ among others, or one can use the data on $w$ and $\theta$ directly. Using the data on $w$ and $\theta$ directly simplifies an already complex numerical task of fitting the non-stationary model considerably, making it faster by a factor of about 4. Moreover, it lifts

[16]Here we also need to note that in what follows we would rather view as a failure at the means test only a situation in which a complete ineligibility to either UA benefits or social assiatnce obtains.

the necessity of having employer-side data which are unavailable in SOEP as well as in any typical panel household survey.

Clearly, there also exist other variables that may potentially affect both the effort and the shape of the spell-effect. We group these additional explanatory variables in a vector $\mathbf{x}$ that contains the rest of personal characteristics. We assume that these variables enter the exit rate to employment and the separation rate with corresponding parameters $\boldsymbol{\varsigma}$ and $\boldsymbol{\zeta}$.[17] Hence, the separation rate now reads $\lambda(\mathbf{x})$ and the spell-effect (18) now reads $\eta(\mathbf{x},s) = \eta_0(\mathbf{x})\, g(s)$.

Summarizing, conditional on the vector of observed characteristics, the exit rate from (19) can be written as

$$\mu_j(s, \mathbf{x}, \mathbf{z}) = \eta(\mathbf{x},s)\left[\phi(s, \mathbf{z})\,\theta\right]^{\alpha}, \qquad j = 1{,}2. \tag{20}$$

For ease of distinction between short-term and long-term benefit regimes, $j$ indicates the regime before ($j = 1$) and after ($j = 2$) expiration of unemployment insurance payments.[18]

We have four different types of labour market trajectories in our data set. The first group consists of individuals who enter unemployment with the right to claim UI benefits and exit unemployment before the expiration of entitlement period ($s \leq \bar{s}$). As argued above, for these individuals we do not observe the outcome of the means test for eligibility to $b_{UA}$. We do assume, however, that individuals know about the outcome even before applying for $b_{UA}$. Therefore, let $\phi(s, \mathbf{z}|0)$ indicate the search effort given that $b_{UA} = 0$, which corresponds to the hypothetical failure at the test. Similarly, let $\phi(s, \mathbf{z}|b_{UA})$ stand for the hypothetical case in which the test will be passed (and so, $b_{UA} > 0$). Finally, let $\pi$ denote the fraction of the individuals that pass the test and $\boldsymbol{\xi}$ denote the vector of all the parameters of interest. Then, for a single spell data, the individual log-contribution of this group is

$$\begin{aligned}\ln \ell(\boldsymbol{\xi}) &= \ln\Big(\pi\left[\mu_1(s, \mathbf{x}, \mathbf{z}|b_{UA})\right]^{d_u} e^{-\int_0^s \mu_1(u,\mathbf{x},\mathbf{z}|b_{UA})du} \\ &\qquad + (1-\pi)\left[\mu_1(s, \mathbf{x}, \mathbf{z}|0)\right]^{d_u} e^{-\int_0^s \mu_1(u,\mathbf{x},\mathbf{z}|0)du}\Big),\end{aligned} \tag{21a}$$

where $d_u$ is a dummy variable such that $d_u = 1$ if unemployment spell is uncensored.

The second group comprises individuals who enter unemployment with the right to claim UI benefits, fail to find a job before entitlement expires, transit to either UA or zero benefit level and thereby reveal the outcome of the means test, and exit unemployment (or not) only after the expiration of entitlement ($s > \bar{s}$). The contribution of such individuals to the log-likelihood is given by

$$\begin{aligned}\ln \ell(\boldsymbol{\xi}) &= -\int_0^{\bar{s}} \mu_1(u, \mathbf{x}, \mathbf{z})\, du + d_t \ln \pi + (1-d_t)\ln(1-\pi) \\ &\quad + d_u \ln \mu_2(s, \mathbf{x}, \mathbf{z}) - \int_{\bar{s}}^{s} \mu_2(u, \mathbf{x}, \mathbf{z})\, du,\end{aligned} \tag{21b}$$

[17] In principle, it would always be desireable to integrate some aspects of this ex ante heterogeneity into the theoretical model right from the beginning. Our objective, however, is to focus on the implications of a two-tier benefit system under optimal effort with anticipated end date of the entitlement. We therefore leave theoretical treatment of complementary ex ante heterogeneity for future research. It is standard in the literature to model the basic feature of optimal behaviour one is interested in and capture the rest of heterogeneity in the econometric part (see e.g. van den Berg and Ridder, 1998, or Flinn, 2006).

[18] Appendix A.3 shows the differential equation that solves for $\mu_j(s)$ once optimal search effort is substituted out.

where $d_t$ is a dummy variable such that $d_t = 1$ if we observe that an individual passes the means test.

The third group embarks all individuals who do not have the right to claim UI benefits and enter unemployment receiving lower UA benefits from the very beginning ($d_t = 1$) or not receiving benefits at all ($d_t = 0$). Their contribution to the log-likelihood is therefore

$$\ln \ell(\boldsymbol{\xi}) = d_t \ln \pi + (1 - d_t) \ln (1 - \pi) + d_u \ln \mu_2 (s, \mathbf{x}, \mathbf{z}) - \int_0^s \mu_2 (u, \mathbf{x}, \mathbf{z})\, du. \tag{21c}$$

For our final group which consists of entrants to employment the log-contribution is simply

$$\ln \ell(\boldsymbol{\xi}) = d_j \ln \lambda(\mathbf{x}) - \lambda(\mathbf{x})\, l, \tag{21d}$$

where $d_j$ is a dummy variable such that $d_j = 1$ if employment spell is uncensored and $l$ is the duration of employment.[19]

The parameterization for $\eta_0(\mathbf{x})$ is the usual $\eta_0(\mathbf{x}) = e^{\mathbf{x}'\boldsymbol{\varsigma}}$, where intercept term is included in $\mathbf{x}$. Similarly, the conditional rate of exit out of unemployment is parameterized as $\lambda(\mathbf{x}) = e^{\mathbf{x}'\boldsymbol{\zeta}}$. Our parametric assumptions about the shape of $g(s)$ is

$$g(s) = S(s, \delta) + 1, \tag{22}$$

where $S(s, \delta)$ denotes a survivor function of the chi-square distribution with $\delta$ degrees of freedom (see app. B.3.5). Intercept in $\mathbf{x}$ plays a role of a scaling parameter that adjusts $g(s)$ appropriately. Our choice the particular form in (22) is motivated by the nonparametric estimates in fig. 1, where even in absence of unobserved heterogeneity the individual exit risk is well-matched by the reverse S-shaped curve. Sensitivity analysis with other parametric alternatives, e.g. the survivor function of the Weibull distribution, which has one parameter more, have shown no significant improvement in the model fit.

With these parametric form the entire vector $\boldsymbol{\xi}$ of parameters to estimate finally becomes $\boldsymbol{\xi} = \{\alpha, \sigma, \delta, \pi, \boldsymbol{\varsigma}, \boldsymbol{\zeta}\}$.

It is possible to further argue that along with unobserved outcome of the means test there may potentially exist other unmeasured heterogeneity that enters $\mathbf{x}$ and therefore the model needs to be extended to account for it. As $\mathbf{x}$ determines both the transition rate to employment and the transition rate to unemployment, different aspects of this unmeasured heterogeneity may differently influence the transitions to and from these states. Thus, in general, the distribution of unmeasured heterogeneity that affects one of the exit rates should be correlated with the distribution of unmeasured heterogeneity that affects the other (see e.g. van den Berg et al., 1994). While not unthinkable, in our context it is quite difficult to fit such an extended model even with the simplest two-point discrete distributions. More importantly, however, it is quite difficult to perform comparative statics exercises taking this additional unobserved heterogeneity into account. For these reasons we for the moment refrain from building the additional unobserved heterogeneity into the econometric model.

[19] In case of failure at the means test and ineligibility to $b_{UA}$ it is possible to argue that the person still gets some sort of subsistence, e.g. due to within family transfers. One can express this subsistence level by, say, a fraction of $b_{UI}$ and try to estimate this fraction along with the rest of the parameters. Indeed, we also follow this way. When trying to estimate this fraction, however, we find that it always converges to zero.

- Estimation procedure

Estimation of model parameters uses a part of the numerical solution method for the steady state. As described in app. A.2, for a given wage $w$ and vacancy to unemployment ratio $\theta$, the individual exit rate can be computed at any moment of the unemployment spell. Using individual survey data implies that the wage $w$ for each individual is known and the corresponding $\theta$ can be taken from macro data. Thus for any given parameter vector $\boldsymbol{\xi}$ and a prespecified value for the time preference rate $\rho$ (0.003, corresponding to an annual interest rate of 3.7%) individual exit rates immediately follow. Details on the implementation can be found in app. B.3.7-A.3.

Note that $\boldsymbol{\xi}$ is estimated without explicitly specifying the wage setting mechanism. If we used linked employer-employee data, the model could be estimated by using the observable productivity data. This would also allow us to estimate the bargaining power parameter $\beta$ as well as provide more information on the discrepancy between the observed wage and an endogenous wage solution implied by the model. For the rest of the parameters unrelated to wage setting mechanism, however, both approaches must be equivalent (assuming that wage setting in the second one is correctly specified).

- Identification

Identification of the model parameters comes from different sources. From (21d) we can see that separation rate parameters $\boldsymbol{\zeta}$ are always identified from the data on the job duration $l$ and observed individual characteristics.

To demonstrate identifiability of $\eta_0$, $\alpha$ and $\sigma$ we need to consider the endpoint condition that pins down the path of the optimal exit rate at infinity. This condition is shown in equation (A.9) in app. A.3 and corresponds to the exit rate in a completely stationary environment, where the two-step system and the exogenous spell-effect have no impact anymore. From equation (A.9) we see that $\sigma$ is identified through the variation in benefit level. For a fixed rate of time preference, and given the identified $\lambda$, the middle term in this equation further suggests that wage variation will identify $\alpha$ and $\eta_0$ up to scaling, even if $\theta$ is a constant. From this follows that in the the solution for the exit rate $\mu_2$ the unemployment duration, wage and benefit data will identify $\eta_0$, $\alpha$ and $\sigma$. Clearly, once $\eta_0$ is identified from the above listed data, the parameters $\boldsymbol{\varsigma}$ are always identified from the observed individual characteristics.

Identification of the exogenous spell-effect comes from the optimal solution for the time path of exit rate $\mu_j(s)$ itself. Consider this path, which is shown in equation (A.8), app. A.3. From the second term in this equation we see that the spell-effect will always be identified as long as $\dot{\eta}(s)/\eta(s)$ remains a time-dependent function, which is true for our specification. Identification of the particular parameters that describe the spell-effect will depend on its parametric form. With our specification in (22), $\delta$ is always identified being just a single parameter.

Finally, the fraction $\pi$ of those who pass the means test is always identified at least via observability of the outcome of this test in the subsample of individuals that fail to exit unemployment before the entitlement period is over, transiting to a lower-benefit regime, and in the subsample of individuals with no entitlement to UI benefits. This is seen from (21b) and (21c).

## 4.3 Estimation results

The table below reports estimation results for the specifications that exclude (left panel) and include (right panel) observed individual characteristics. Numerical complexity of the model makes us restricting attention on only a small number of key characteristics, which are *Sex* (=1 if male), *Region* (=1 if an individual comes from East Germany) and *Skill* (=1 if an individual has a higher vocational or higher education according to ISCED-1997).

| | | Coeff. | SE | z-Stat. | p-Value | Coeff. | SE | z-Stat. | p-Value |
|---|---|---|---|---|---|---|---|---|---|
| $\zeta$ | intercept | −4.5307 | 0.0568 | −79.8132 | 0.0000 | −5.0602 | 0.1104 | −45.8410 | 0.0000 |
| | sex | | | | | 0.5103 | 0.1165 | 4.3800 | 0.0000 |
| | region | | | | | 0.8414 | 0.1146 | 7.3407 | 0.0000 |
| | skill | | | | | −0.4036 | 0.1460 | −2.7644 | 0.0057 |
| $\varsigma$ | intercept | −3.6627 | 0.5376 | −6.8132 | 0.0000 | −3.4799 | 0.4919 | −7.0751 | 0.0000 |
| | sex | | | | | 0.0919 | 0.1235 | 0.7443 | 0.4567 |
| | region | | | | | 0.0432 | 0.1223 | 0.3528 | 0.7242 |
| | skill | | | | | 0.1956 | 0.1670 | 1.1708 | 0.2417 |
| $\alpha$ | | 0.5047 | 0.0734 | 6.8759 | 0.0000 | 0.4612 | 0.0784 | 5.8845 | 0.0000 |
| $\sigma$ | | 0.6599 | 0.1214 | 5.4355 | 0.0000 | 0.7069 | 0.1190 | 5.9376 | 0.0000 |
| $\delta$ | | 11.8707 | 1.6548 | 7.1734 | 0.0000 | 11.9290 | 1.9331 | 6.1709 | 0.0000 |
| $\pi$ | | 0.2447 | 0.0308 | 7.9536 | 0.0000 | 0.2443 | 0.0296 | 8.2466 | 0.0000 |
| $\log \mathcal{L}$ | | | | −2846.70 | | | | −2804.66 | |

**Table 1** *Estimation results*

As for the estimation results alone, our main finding is the significance of $\alpha$. This means that changes in the optimal effort levels in response to any unemployment benefit reform, be it the reform of $b_{UI,UA}$ or of $\bar{s}$, will have a significant impact on the exit rate out of unemployment. This finding in particular contributes to the empirical reduced form literature that analyses the dependence between unemployment benefits and the probability of leaving unemployment. Evidence on this dependence are somewhat conflicting with earlier Hujer and Schneider (1989) and Arulampalam and Stewart (1995) finding mostly no significant influence of benefits and later Carling et al. (2001) and Røed and Zhang (2003) stating the opposite.[20] Rather than conducting a reduced form analysis, we address the same question form an entirely structural perspective, providing thereby an alternative view. While we do not rule out that for certain types of heterogeneous agents the change in benefits may play no role, our result on the significance of $\alpha$ shows that in sufficiently aggregate terms there exists a positive significant relationship between the reemployment probability and any change in the level of unemployment benefit payments. Consequently, any change in the design of unemployment benefit mechanism will induce a significant response on the macro level.

[20] Application is to different countries. Moreover, later studies, notably Røed and Zhang (2003), provide more sophisticated treatment of unobserved heterogeneity in comparison to earlier ones.

Our next important finding is on the role of unobserved heterogeneity with respect to the outcome of means test. From tab. 1 we can see that $\pi$ is always significant at 5% level. Together with significance of $\alpha$ this implies that the prospect of not passing the means test significantly increases search effort and exit probability. While importance of unmeasured heterogeneity is frequently highlighted in the literature on structural estimation of search models, much fewer attempts have been made to explicitly address the exogenous spell dependence. Since our model is nonstationary from the very beginning, accounting for this spell-dependence is particularly easy. From tab. 1 we can see that the estimate of $\delta$ is significantly different from zero. However, absence of exogenous spell dependence is not nested in our specification, because (22) does not include time-invariance as a special case. Therefore the appropriate test for exogenous spell-dependence is the Vuong (1989) test for overlapping models, where spell-effect in the competing model is absent, i.e. $\eta_0(\mathbf{x},s) = \eta_0(\mathbf{x})$. Under null hypothesis of equivalence of two specifications the test statistic is distributed as a mixture of squared standard normal variates, which can be easily simulated. We find that in both unconditional and conditional models the hypothesis of absence of exogenous spell-dependence is clearly rejected.[21] This means that, once key unobserved component is accounted for, there still remains a significant degree of downward state dependence among long-term unemployed. Coexistence of unobserved heterogeneity and duration dependence aligns with the similar finding of van den Berg and van Ours (1996, 1999), who use an entirely different modelling approach.

Finally, our estimate of the utility parameter $\sigma$ is also very comforting. First, the degree of risk aversion is high enough to reject the hypothesis of risk neutrality. Second, significance of $\sigma$ provides the empirical evidence on the existence of a significant insurance effect of a benefit reform.

Regarding individual characteristics our results show a significant effect of these on job separation instances. All these effects are of the correct sign. At the same time, only the benefit scheme seems to be responsible for the exit from unemployment. From tab. 1 it is also easy to see that introduction of observed heterogeneity does not significantly influence the size of the parameters that determine the shape of the structural hazard function (namely $\alpha$, $\sigma$, and $\delta$). Thus, if one is not interested in policy modelling on sub-population level, fitting the unconditional model (without $\mathbf{x}$), and thereby substantially reducing the estimation time, could already be sufficient.

Finally, regarding the model fit, we plot the predicted survivor function for each specific sub-population against the Kaplan-Meier nonparametric estimates of the survival probability in unemployment, including their 95% confidence intervals. These plots can be seen in app. A.4, fig. 6 and 7. We can see that with two exceptions out of eight the model tends to fall short of the confidence interval between the 3rd and the 6th months of unemployment duration. Responsible for this is most likely the neglected within-group heterogeneity for the high-educated West Germans and low-educated East Germans, as the corresponding blocks in fig. 6 and 7 suggest. While the fit can be further refined by treating this within-group heterogeneity accordingly (and possibly introducing more unobserved heterogeneity,

[21] The values of Vuong LR test statistic, adjusted for the difference in the number of paremeters in the competing specifications using Schwarz correction factor (see Vuong, 1989, p.318), are 55.6839 and 50.4575 for the unconditional and conditional models respectively. The upper-tail 5% critical value of the simulated asymptotic distribution of the test statistic is 11.1297.

as discussed on p.16), our model still fairly accurately matches the survivor probability in the medium- to long-term unemployment, which was the primary target of the reform analyzed in this paper.

After having estimated all the parameters in $\boldsymbol{\xi}$ we are left with determining labour productivity $A$ and vacancy cost $\gamma$. The wage $w$ and tightness $\theta$ were taken as exogenous in this first part of the estimation which was built on the household side of the model only. As the wage and tightness are endogenous in general equilibrium, we now take the estimated parameters $\boldsymbol{\xi}$ and compute parameters $A$ and $\gamma$ using the full general equilibrium structure of our economy in the steady state. We compute $A$ and $\gamma$ such that the average wage in our sample result as general equilibrium endogenous variables in our model. See tab. 2 for results.

# 5 Evaluating the labour market reforms

In this chapter we use the structurally estimated parameters in order to describe the steady state equilibrium of 2004 and to evaluate the reforms effective as of January 2005.

## 5.1 The pre-reform steady state

Data is heterogeneous in many respects and we have vectors of $b_{UI,i}$, $b_{UA,i}$, $\bar{s}_i$ and the wage $w_i$. Building on the mean wage (used above e.g. to predict $A$ and $\gamma$), UI payment for our representative agent is given by the replacement rate $\rho_{UI}$ times the mean wage, corrected for the share $\omega$ of individuals who are entitled to UI payments, $b_{UI} = \omega\rho_{UI}w$. As only an estimated share of $\pi = 24.4\%$ pass the means test (see tab. 1), UA payments for our representative agent are the product of the replacement rate $\rho_{UA}$, the previous wage and the share $\pi$, $b_{UA} = \pi\rho_{UA}w$. The replacement rates we use are the averages over statuary replacement rates weighted by population size.[22] Average sample entitlement to UI payments is $\bar{s} = 12.18$ months, again for those entitled to UI payments. With these means for $b_{UA}$ and $\bar{s}$, our representative agent receives the same amount of benefits at each point in time $s$ as the mean in the data over a cohort of unemployed who all have an unemployment spell of $s$ (see app. B.4.1).

All parameters used in this paper apart from the ones presented in the tab. 1 plus some selected endogenous variables are provided in tab. 2. As in the estimation part, the time preference rate is chosen to fit an annual interest rate of 3.7%. The bargaining power $\beta$ is set equal to .5. As the conditional model dominates the unconditional model, we use these estimates from tab. 1 to predict the average separation rate $\lambda$ and the parameter $\eta_0$ in (19) and (20) for the spell-effect. By average we understand the representative individual in our data set, i.e. 53% male and 42% living in East-Germany. The corresponding separation rate $\lambda$, $\eta_0$ and the implied mean exit rate $\bar{\mu}$ can be seen in tab. 2.[23]

[22] When x% in our sample receive a $\rho_{UI}$ of 67% and the rest receives 60%, the replacement rate we use is $x\%67\% + (1 - x\%)\,60\%$.

[23] Results for the unconditional model or for male and female workers differ by around 0.1%.

| exogenous parameters | | | | predicted parameters | | | | |
|---|---|---|---|---|---|---|---|---|
| $\rho$ | $\beta$ | | | $\lambda$ | $\eta_0$ | $A$ | $\gamma$ | |
| .003 | .5 | | | .011 | .034 | 1206.9 | 49.02 | |
| **policy parameters** | | | | **equilibrium values** | | | | |
| $\rho_{UI}$ | $\rho_{UA}$ | $\bar{s}$ | $\omega$ | $w$ | $\theta$ | $(N-L)/N$ | $\kappa$ | $\bar{\mu}$ |
| .6 | .53 | 12.2 | .56 | 1166.3€ | .3 | 10.33% | 3.2% | 0.10 |

**Table 2** *Parameters and selected equilibrium values*

Our equilibrium values fit perfectly by construction for the wage and labour market tightness. Our tax rate $\kappa$ is sufficiently close to the actual social security contribution rate (this is the only purpose of taxes in our model). Given the average matching rate of 0.10 and the unemployment rate of 10.3%, our pre-reform steady state reflects the situation in Germany before January 2005 relatively well.

For comparative statics below, we will take the exogenous parameters, the estimated and the predicted parameters and the replacement rate for short-term unemployed $\rho_{UI}$ as given. We will then change long-term benefits $b_{UA}$ and the entitlement period $\bar{s}$ to understand the effects on equilibrium values.

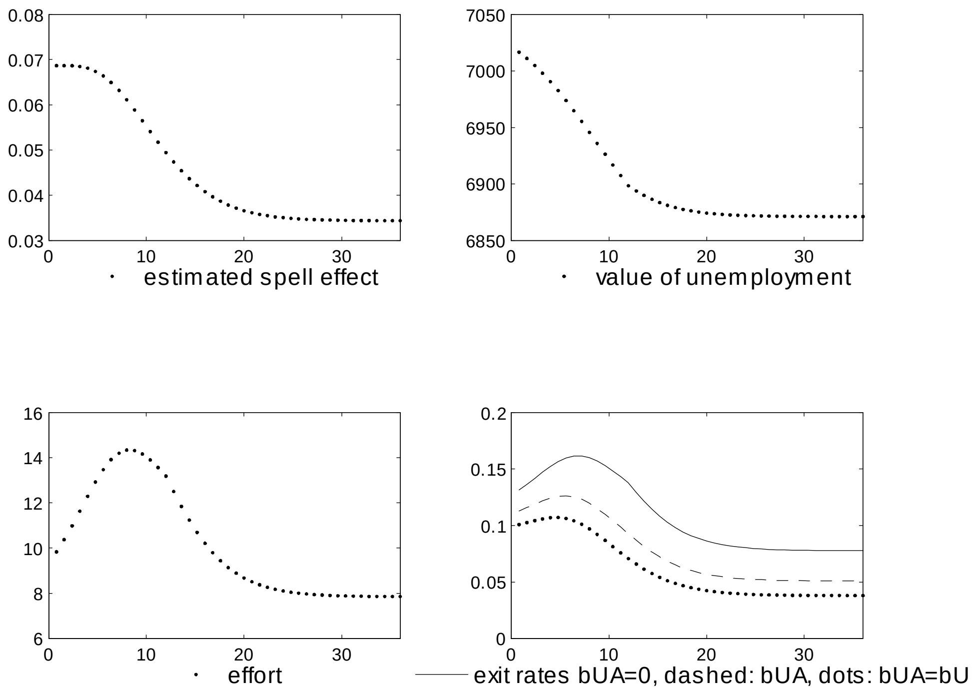


**Figure 2** *Productivity, effort, the exit rate and the value of being unemployed as a function of the spell $s$ (in months)*

Although the economy is in the steady state, there are still dynamics on the micro level as illustrated in fig. 2. At any point in time individuals find and lose jobs. The upper left panel shows that and how the estimated exogenous spell-effect from (18) with (22) falls over time. The value of being unemployed thereby unambiguously falls over time. This is shown by the upper right panel and needs to hold generally as (A.2) in the appendix shows. The intuition is simple: If there was no spell-effect ($\eta(s)$ is constant), a long-term unemployed would live in a stationary world and the value of being a long-term unemployed would be stationary as well. With a negative spell-effect, the job finding rate - taking optimally chosen effort into account - goes down and the value of being unemployed approaches a lower limit determined by the lower limit of $\eta(s)$.

The optimal reaction of the unemployed worker is shown by the lower left panel. Effort increases during the first 9 months but then starts falling before entitlement to unemployment insurance ceases at $\bar{s} = 12.2$ months. Optimal effort is the outcome of the interplay of the spell-effect (lower $\eta(s)$ reduces optimal effort) and the incentive-effect, i.e. the potential gain from finding a job. As gains increase due to a falling value of being unemployed, this second effect tends to increase effort. This can be seen from the first-order condition in (6) or, more directly, from (A.1) in the appendix. The initial increase of effort clearly reflects the rising incentive to search harder the closer $\bar{s}$. After around 9 months, however, the increase in the gain of finding a job is no longer strong enough to compensate the "discouraging" spell-effect. Search effort falls and approaches a constant. The fact that unemployed workers finally "give up" is ultimately the effect of the exogenous negative spell-effect.

The exit rate shows paths for $b_{UA} = 0$, average $b_{UA}$ and $b_{UA} = b_{UI}$. Average $b_{UA}$ is the one in our pre-reform steady state, we will return to the other ones in our analysis of the reform.

## 5.2 The effects of the reform

Labour market reforms were characterized by a reduction in UA benefits $b_{UA}$ and entitlement length $\bar{s}$. Benefits decreased on average by 7%, average entitlement length dropped from 12.2 to 11.4 months, i.e. by 6.6%. We present here the effect of the reform, i.e. a joint decrease of both $b_{UA}$ and $\bar{s}$. Afterwards, we will briefly discuss which of the effects is the stronger one, both in a quantitative and qualitative way. For more details, see Launov and Wälde (2010).

The horizontal axis of fig. 3 plots "Hartz-units". The "1" represents the situation before the reform. The "0" represents the situation after the reform and "-1" to "-4" shows the effects of stronger reforms, i.e. of reducing $b_{UA}$ by another 7% and $\bar{s}$ by another 6.6%. The vertical axes plot changes relative to the pre-reform steady state which is normalized (levels were reported in tab. 2 above) to 1. The pre-reform steady state is therefore always given by the point $(1, 1)$. The solid line shows the changes as predicted by our estimated model. The dashed lines above and below provide a 95% confidence interval for the statistic in the middle. This confidence interval is constructed using parametric bootstrap where draws are made from the multivariate normal distribution of the maximum likelihood estimates. For every new draw we recompute the equilibrium solution at each Hartz-unit. Due to the high numerical complexity of the equilibrium solution, confidence intervals at each Hartz-unit are currently based on 80 replications.[24]

[24] To the best of our knowledge, we are the first to explicitly show confidence intervalls for our policy analysis and experiments - even though it turns out that not all of our experiments have a significant effect.

Concerning results, we find - generally speaking - very weak effects of the reform. The qualitative effects of the reform are as intended by policy makers. Effort $\phi(0)$ when becoming unemployed rises the stronger the reform, i.e. the further we are to the right of the upper left figure. Labour market tightness $\theta$ and the average job finding rate $\bar{\mu}$ from (9) rise as well. The increase in $\theta$, i.e. the number of vacancies per unemployed worker, is pretty important for what follows. Understanding this effect is simple, however: More effort by unemployed workers makes opening a vacancy more attractive. Hence, lower benefits induce a higher number of vacancies per unemployed worker. The quantitatively weak effect of the reform becomes visible when looking at the unemployment rate. It decreases from the pre-reform steady state "1" to the reform level at "0" to (more than) 97% only. Starting at an unemployment rate of around 10.4%, the effect of the reform would be to decrease the unemployment rate to 10.1%, i.e. by 0.3 percentage points only.

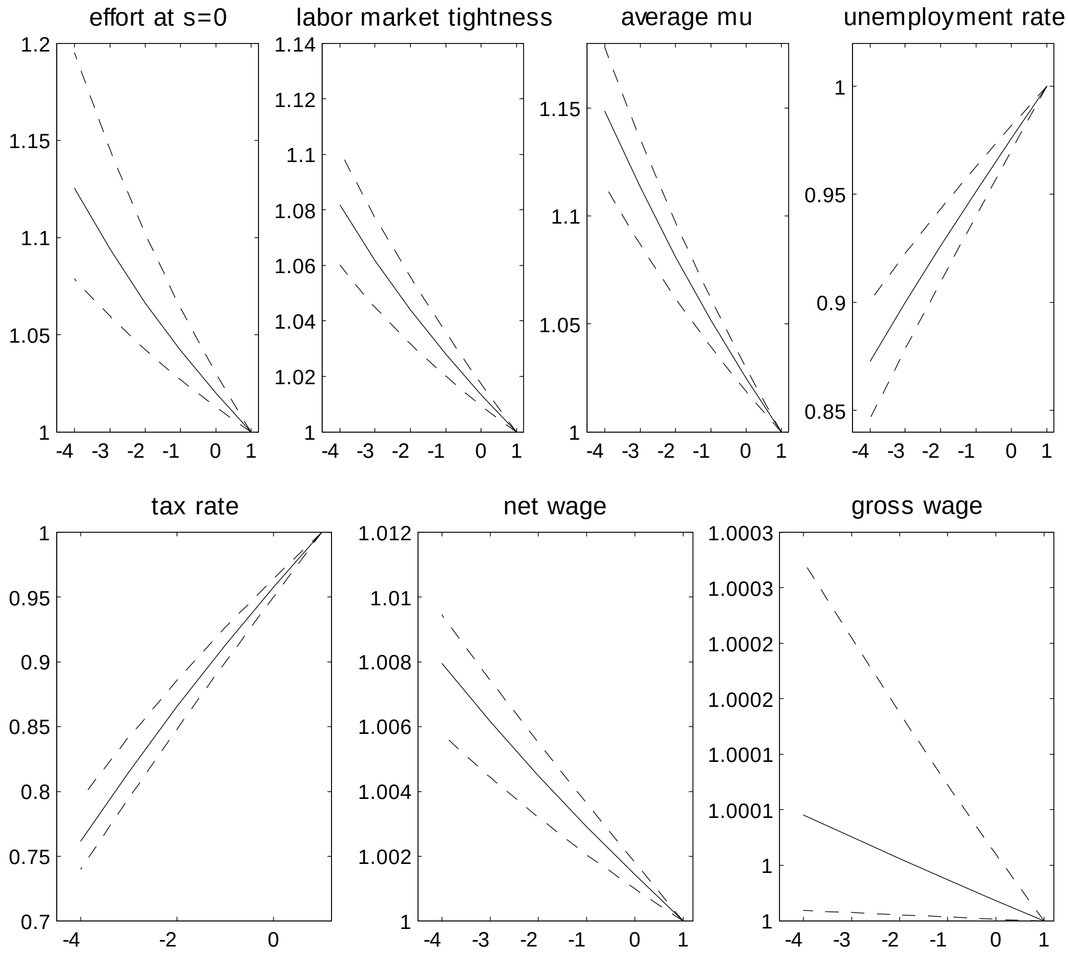


**Figure 3** *Aggregate effects of UA payments $b_{UA}$ and entitlement length $\bar{s}$*

The lower figures show that the tax rate falls. This has various reasons: Lower benefit payments and a lower number of recipients reduce overall expenditure. This reduced expenditure is paid by more workers who earn higher gross wages.

One of the most surprising results is the increase in the net and gross wage. This increase is also the basis for the rise in social welfare which we will discuss later. The increase in the net wages becomes clear from the wage equation (11) when taking into account that the positive tightness effect dominates the negative effort effect. This is an interesting feature of this wage bargaining setup with endogenous effort and is in strong contrast to perfectly competitive setups, to bargaining setups with exogenous effort and to search setups where the reservation wage is a simple decreasing function of the outside option. Here, the outside option (utility from being an unemployed worker) decreases as well but this is overcompensated by the positive effect of more vacancies per unemployed worker.

Confidence intervals for all the statistics in fig. 3 show that the changes induced by the reform are statistically significant, as both the upper and the lower bound lie strictly above (or strictly below) unity. Summarizing and ignoring distributional effects, the reform has the qualitatively desired effects but is quantitatively of hardly any importance: While the reduction of unemployment is statistically significant, economically, it is not.

When we look at welfare measures in fig. 4, we see the distributional nature of the reform. Employed workers gain from the reform. This might not appear surprising given that the net wage rises. Employed workers do also anticipate, however, the potential loss from the reform as they have a certain risk of becoming unemployed. If the value of being unemployed falls, the value of having a job could fall as well.

When we look at the value of being unemployed at $s = 0$, i.e. right after having lost the job, this value slightly *increases* as well due to the reform. This is entirely due to the anticipation effect of having a job. The short-term unemployed clearly loses as benefits will fall earlier and by more due to the reform. But the short-term unemployed also gains as he will gain more due to the reform in case he finds a job. More formally, the value of unemployment depends negatively on search effort and positively on exit rate, which can be seen from equations (5) and (17). As both search effort and the exit rate go up, each effect could dominate. In our case, the positive exit-rate effect is the stronger one for the short-term unemployed. For the long-term unemployed worker, to the contrary, the value of having been unemployed for one year falls due to the reform.

Considering the 95% confidence intervals for each of these three statistics, though, we can see that despite the predicted wins and losses, all these wins and losses are not statistically significant. The confidence bounds lie above and below unity. What is significant, however, are the losses of the firms, i.e. a drop of $J$ when benefits $b_{UA}$ are reduced.

The loss of firms is a surprising qualitative result of our analysis and is a direct consequence of the rise in the gross wage. Rewriting (8) slightly shows that the value of the firm $J$ decreases in the gross wage, hence firms dislike the reform. Is this a strong disadvantage of our model given that employers generally were in favour of the reform in public discussions? We do not think so. The wage can rise or fall in our theoretical setup. Whether the worse outside option of employed workers reduces the wage more than the higher job-finding rate due to higher $\theta$ is theoretically an open question. Given our estimates, the "$\theta$-effect" dominates. While firms urged the unemployed to search harder and the government to pay them lower benefits, they might not have seen that higher vacancies per unemployed worker finally makes workers stronger, wages rise and profits fall.

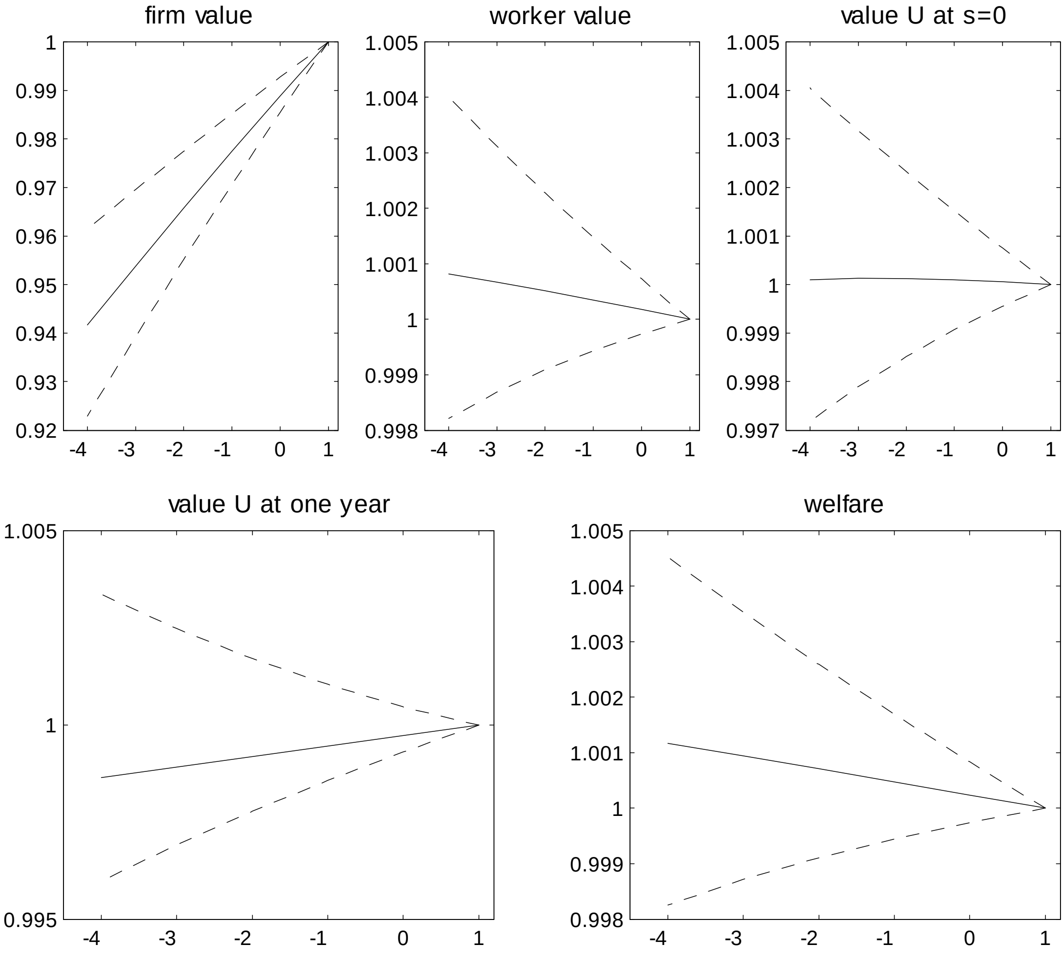


**Figure 4** *Distributional effects of UA payments* $b_{UA}$ *and entitlement length* $\bar{s}$

What is also surprising - despite the lack of statistical significance - is that overall welfare increases. We measure welfare as in (12). It is identical to expected utility of a worker who does not yet know in which state he is. Apparently, the gains of employed workers and of short-term unemployed workers are stronger than the losses of long-term unemployed workers.

## 5.3 Understanding the effects of the reform

- The magnitude of the effects

Generally speaking, we find very weak effects of any type of reform. This can be made plausible with a back-of-the-envelope calculation. As the unemployment rate is approx. 10% and only 1/3 becomes long-term unemployed, only 3.3% of the entire labour force are affected. In an intertemporal sense, income is reduced only during 3.3% of ones' lifetime. The duration of unemployment insurance payments is reduced by 6.6%, the level of the payments by 7%. Let this add up - to make this simple - to 14%. If 3.3% of lifetime income is reduced by 14%, my overall lifetime income reduces by 3.3%*14% $\approx$ .5%. No surprise that quantitative effects are weak.

- The reform and economic growth

Real GDP in Germany grew by 0.8 percent in 2005 and by 2.9 percent in 2006. The question arises whether the drop in unemployment in Germany is not due mainly to economic growth. From January 2005 to January 2007 unemployment in Germany fell from 12.3% to 10.2%. When the growth effect is taken into account here by letting $A$ increase by this amount when evaluating the effects of the reform, the unemployment rate falls from 10.4% to 9.65% (instead of 10.1%). If we attribute 0.3% to the reform and the remaining 0.45% to economic growth, economic growth was more successful in reducing unemployment than the reform (see app. B.4.7for a figure).

- Unemployment assistance $b_{UA}$ and entitlement length $\bar{s}$ individually

When reducing $b_{UA}$ and $\bar{s}$ individually, the results are qualitatively similar. Quantitatively, the individual effects are smaller than the joint effects. The only qualitative difference consists in the value of being a long-term unemployed. While it falls when $b_{UA}$ is reduced, it rises when $\bar{s}$ is reduced. (See the companion policy paper by Launov and Wälde, 2010, for a more explicit discussion.)

- Insurance and social welfare

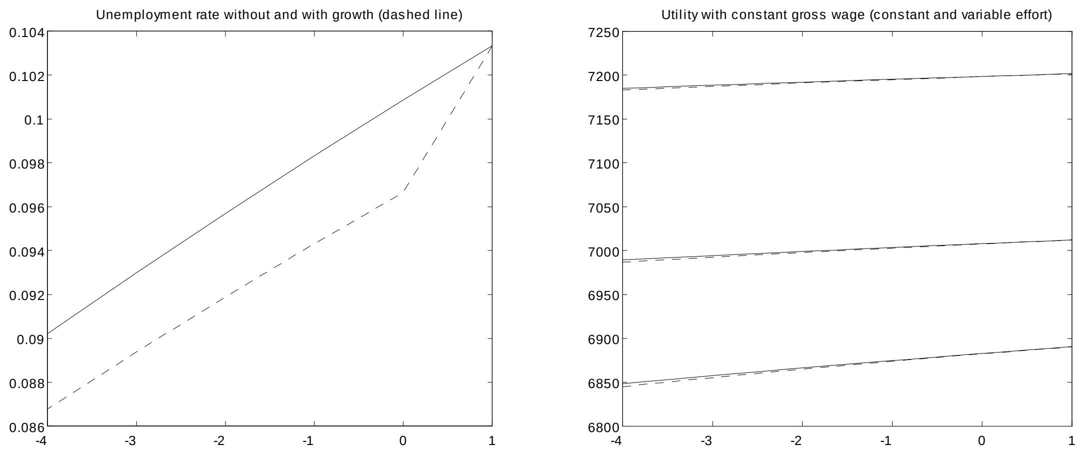


**Figure 5** *The effect of economic growth (left panel) and the pure insurance effect of the reform for employed, short-term and long-term unemployed workers (right panel)*

The most surprising result of our analysis is that workers as a whole gain. This is surprising as one would expect that the insurance mechanism of unemployment benefit payments is reduced following the reduction in $b_{UA}$. Remember that a world without moral hazard unemployment benefits should equal the net wage. Given that a reduction in the length $\bar{s}$ and the level $b_{UA}$ of unemployment benefits moves our economy further away from this setup, one should expect that the insurance mechanism is reduced. Why is it then that social welfare increases?

To understand this, we divide the effects of the reform into two partial effects. The first partial effect is the effect on social welfare when effort and the gross wage are held constant. What would happen if a reduction in $b_{UA}$ implies a reduction in the tax $\kappa$ and thereby an increase in the net wage $w$? The result of this thought-experiment is given in the following figure.

The horizontal axis plots the same Hartz-steps as in previous figures. We clearly see that expected utility falls for worker groups when effort is not affected by benefit levels. This clearly reflects that in a world with constant effort, unemployment benefits should equal the net wage. Any departure from this equality reduces expected utility.

The same result holds when we allow effort to be a function of benefits, i.e. we allow incentives of the reform to play a role. The figure shows (the three dashed lines) that welfare decreases less (as incentives are now improved) but welfare still falls.

As we know that welfare rises in the full general equilibrium, we can conclude that all beneficial effects of the reform come from the increase in the wage due to the higher number of vacancies per unemployed worker. This stresses the importance of two points: Academically speaking, an evaluation of labour market reforms should be undertaken in general equilibrium to provide a complete picture of the effects. More importantly, the Hartz reforms did decrease the insurance mechanism implied by unemployment benefits but - in the end - this was beneficial to the average worker. No need to stress that a more intelligent design of the reform which implies a Pareto-improvement would have been desirable.

# 6 Conclusion

Our project started by inquiring about the effects of the Hartz IV labour market reforms on incentives and insurance mechanisms for the workforce. On a macro level, these questions inquire into the effects on the unemployment rate and social welfare. We have developed an estimable search and matching model with endogenous effort under time-dependent unemployment benefits. The main extension compared to the existing search and matching literature is the endogenous distribution of unemployment duration that arises due to individual choice of search intensity in a nonstationary environment. A link between these micro-dynamics and macro quantities like the unemployment rate was developed using tools from the literature on Semi-Markov processes. The theoretical model provides the density of unemployment duration of an individual being a function of various model parameters. This density provides the basis for structural estimation via maximum likelihood. General equilibrium policy analyses were performed using the parameter estimates of the best fitting specification.

We find that the unemployment rate did decrease due to the reform. Unemployed workers have stronger incentives to search hard. The reduction of the unemployment rate was quantitatively very small, however. While statistically significant, the reduction amounts to 0.3% only. Concerning insurance mechanisms, we find that employed workers and short-term unemployed win but long-term unemployed lose. These results are not statistically significant, however. We also find - much to our own surprise and in contrast to the perception of the public - that generally speaking social welfare increases! As our economy is populated by workers only, this means that workers as a whole gain through the reform.

Looking into the mechanisms in more detail, we find that the gain in social welfare is not due to an improvement in the insurance mechanism. The Hartz IV reform clearly reduced expected utility of a worker - keeping the gross wage constant. As Hartz IV reforms did have general equilibrium effects as well, however, expected utility of a worker did increase as the wages increased. Summarizing, while workers need to search harder, this higher search effort induces firms to open new vacancies. Firms do this so much that the net and gross wage, overall utility for workers and social welfare increases.

These findings clearly give rise to new research questions: Could the reform have been designed in a Pareto-improving way? The old and the low-skilled, i.e. the long-term unemployed, they clearly lose through the reform. Can overall efficiency gains be justified if they are at the cost of one group? There is also a methodological question which should be treated in future work: Are our welfare findings too optimistic given that we have a ex-ante representative consumer? What if we had ex-ante heterogeneity in skill levels? One would expect that social welfare gains would not be as large. All of this is left for future research.

# A Appendix

## A.1 Data

The data comes from the German Socio-Economic Panel (SOEP). The SOEP is a panel surveying households on an annual basis. The survey is coordinated by the Deutsche Institut für Wirtschaftsforschung (Berlin, see www.gsoep.de).

We draw a flow sample of entrants to employment and unemployment at each month of years 1997-98. The choice of the year of sampling is determined by the fact that no changes to either benefit level or entitlement length were made between the 1st of January 1997 and the 1st of January 2005, when Hartz IV reform came into power. With December 2003 being the latest month of our observation period we end up with a sample that describes a stationary entitlement-benefit environment and provides a fairly reliable information on long-term unemployment (only 9.12% of unemployment durations in our sample are right-censored). For each entrant we retrieve the duration of stay in the current state since the moment of entry. Following van den Berg and Ridder (1998), p.1194, we refrain from considering individuals that allow transitions to the states other than full-time employment or unemployment within the above defined 01.97-12.98 window.

Units of measurement are months for the duration data and Euros for the wage and benefits data. Wage is the average monthly wage for the months of employment within a year prior to job loss, as these are the wage bases that conform with the observed benefit levels. Price base is that of 1997. Descriptive statistics can be found in tab. 3.

| **Unemployment:** | Mean | Std. Dev. | | Mean | Std. Dev. |
|---|---|---|---|---|---|
| Duration ($s$) | 8.69 | 12.54 | Share of entitled for UI ($\omega$) | 0.5657 | 0.4963 |
| UI benefits ($b_{UI}$) | 727.46 | 294.94 | Share of $\bar{s} = 12$ among entitled | 0.4882 | 0.5010 |
| Entitlement ($\bar{s}$) | 12.18 | 5.48 | Observed share passing the test | 0.1528 | 0.3603 |
| Wage ($w$) | 1166.26 | 538.07 | | | |
| # obs., total / cens. | 373 / 34 | | | | |

| **Employment**: | Mean | Std. Dev. | **Individual characteristics:** | Mean | Std. Dev. |
|---|---|---|---|---|---|
| Duration ($l$), cens. | 57.64 | 25.13 | Share males | 0.5380 | 0.4988 |
| Duration ($l$), all | 40.32 | 29.68 | Share East Germans | 0.4227 | 0.4942 |
| # obs., total / cens. | 694 / 392 | | Share high skilled | 0.2090 | 0.4068 |

**Table 3** *Descriptive statistics (months and EUR)*

It is important to notice that GSOEP data do not contain information on the length of entitlement to UI benefits. There exist, however, strict and relatively simple rules that allow computing the length of entitlement once we know the length of previous job durations and the age of an individual. For this reason, for every person that enters unemployment we also have to retrieve his/her previous job history. In addition to that, previous job history provides us with the record of the latest wages earned.

The mean of the vacancy-unemployment ratio $\theta$ between 1997 and 1999 in Germany is about 0.3 (iab-data, adjusted for underreporting).

## A.2 Steady state solution

We solve for the steady state of the model by separating the model into two "blocks".

- Block 1: Household behaviour

Given the functional forms for utility and the spell-effect in (17) and (19), the first-order condition for effort (6) reads

$$\phi(s) = \{\alpha\eta(s)\theta^{\alpha}[V(w) - V(b(s), s)]\}^{\frac{1}{1-\alpha}}. \tag{A.1}$$

It holds for both short- and long-term unemployed. Plugging this into the Bellman equation for the unemployed (5) and expressing it as a differential equation in $s$ gives

$$\dot{V}(b(s), s) = \rho V(b(s), s) - \frac{b(s)^{1-\sigma}}{1-\sigma} - \frac{1-\alpha}{\alpha}[\alpha\eta(s)\theta^{\alpha}]^{\frac{1}{1-\alpha}}[V(w) - V(b(s), s)]^{\frac{1}{1-\alpha}}, \tag{A.2}$$

which is again valid for both short- and long-term unemployed. As the value of being unemployed an instant before and an instant after becoming a long-term unemployed is identical, we impose $V(b_{UI}, \bar{s}) = V(b_{UA}, \bar{s})$ when solving this differential equation. Finally, since for an infinite unemployment spell, the spell-effect in (19) becomes a constant, $\lim_{s\to\infty}\eta(s) = \eta_2$ and all other quantities are stationary as well, we get the terminal condition for (A.2) by using $\lim_{s\to\infty}\dot{V}(b_{UA}, s) = 0$,

$$\rho V(b_{UA}) = \frac{b_{UA}^{1-\sigma}}{1-\sigma} + \frac{1-\alpha}{\alpha}\left[\alpha\eta_2\theta^{\alpha}\right]^{\frac{1}{1-\alpha}}\left[V(w) - V(b_{UA})\right]^{\frac{1}{1-\alpha}}. \tag{A.3}$$

The Bellman equation for the employed worker (4) can be written with the explicit utility function as

$$V(w) = \frac{1}{\rho+\lambda}\left(\frac{w^{1-\sigma}}{1-\sigma} + \lambda V(b_{UI}, 0)\right). \tag{A.4}$$

Now imagine we insert $V(w)$ from (A.4) into (A.2) and (A.3). Imagine further that we know all parameters and assume, for the time being, some values for $w$ and $\theta$. Then we can solve the differential equation (A.2) starting from some initial value $V(b_{UI}, 0)$ and see whether the solution for $s \to \infty$ is identical to $V(b_{UA})$ from (A.3). If it does not, we need to adjust our initial guess $V(b_{UI}, 0)$ until it does. Hence, with some exogenous $w$ and $\theta$, we have obtained the time path of effort over the unemployment spell, $\phi(b(s), s)$, the spell-path of the value of being unemployed, $V(b(s), s)$, and the value of a job $V(w)$.

- Block 2: Wage, tightness and vacancy filling rate

Given the equilibrium values $\{\phi(b(s), s), V(b(s), s), V(w)\}$ as a function of $w$ and $\theta$, we now endogenize $w$ and $\theta$.

The Bellman equation for the firm and the free entry result, (8) and (10), gives us

$$\frac{A - \frac{w}{1-\kappa}}{\rho+\lambda} = \gamma\frac{\theta}{\bar{\mu}}. \tag{A.5}$$

The bargaining equation (11) reads with an explicit utility function (17)

$$\frac{w^{1-\sigma}}{1-\sigma} + \frac{\beta}{1-\beta}\frac{w}{1-\kappa} = \left[\frac{b_{UI}^{1-\sigma}}{1-\sigma} - \phi(0)\right] + \frac{\beta}{1-\beta}\left[A + \theta\gamma\right], \tag{A.6}$$

where $\phi(0)$ is the optimal search effort at the instant of entry into unemployment, which is given from (A.1). The above two equations require the average exit rate $\bar{\mu}$ and the tax rate $\kappa$.

The average rate $\bar{\mu}$ is given by (9) which can easily be computed given that, after having solved block 1, the exit rates $\mu(.)$ are known from (19) and the density $f(s)$ can therefore be computed from (2). The tax rate $\kappa$ makes the government budget constraint (3) hold and is given by

$$\kappa = \frac{\frac{b_{UI}U_{short} + b_{UA}U_{long}}{wL}}{1 + \frac{b_{UI}U_{short} + b_{UA}U_{long}}{wL}}. \tag{A.7}$$

Given the density $f(s)$, one can compute the number of short-term and long-term unemployed on the right-hand side of this expression from $U_{short} = (N - L)\int_0^{\bar{s}} f(s)\,ds$ and

$U_{long} = N - L - U_{short}$. The number of unemployed in turn follows from (16), using (13a,b) and (14) which we can now solve, given again that exit rates are known from block 1.

Hence, we are basically left with (A.5) and (A.6) to determine the missing endogenous variables $w$ and $\theta$. After having solved block 1 with a guess of $w$ and $\theta$, we verify whether this guess fulfills (A.5) and (A.6). If not, we (matlab) adjusts the guess until we find a solution.

Appendix B.4.3 describes the numerical implementation in matlab. Appendix B.3.7 describes the numerical implementation for the estimation procedure.

## A.3 Transition rates to employment

Transition rates to employment are fully described by the optimal search effort. Using first order condition for search effort (6) and the definition of the exit rate (19) we can therefore express value of unemployment as a function of the optimal exit rate. Inserting this value of unemployment into the Bellman equation for the unemployed (5) and expressing it as a differential equation in $s$ we obtain the time path of the optimal exit transition rate to employment as a result (see app. B.3.3 for derivation). Omitting individual characteristics for brevity, the differential equation that describes the exit rate to employment both for the short-term and the long-term unemployed workers is

$$\begin{aligned} \dot{\mu}_j(s) &= \alpha \left[\mu_j(s)\right]^2 + \left(\frac{\partial \eta(s)/\partial s}{\alpha \eta(s)} + \rho\right) \frac{\alpha}{1-\alpha} \mu_j(s) \\ &\quad - \frac{\alpha^2}{1-\alpha} \left[\eta(s)\theta^\alpha\right]^{\frac{1}{\alpha}} \left[\mu_j(s)\right]^{2-\frac{1}{\alpha}} \left[\rho V(w) - \frac{b_j^{1-\sigma}}{1-\sigma}\right], \end{aligned} \tag{A.8}$$

where, as before, $j$ indicates the regime before ($j = 1$) and after ($j = 2$) expiration of unemployment insurance payments. It can be further shown (see app. B.3.3) that the relevant endpoint conditions are

$$(1-\alpha)\mu_2 - \alpha\left[\eta_0 \theta^\alpha\right]^{\frac{1}{\alpha}} \left[\mu_2\right]^{1-\frac{1}{\alpha}} \left[\rho V(w) - \frac{b_2^{1-\sigma}}{1-\sigma}\right] + \rho = 0 \tag{A.9}$$

for the second regime at $s \to \infty$, and

$$\mu_1(\bar{s}; b_1) = \mu_2(\bar{s}; b_2) \tag{A.10}$$

for the first regime at $s = \bar{s}$.

Once wages and market tightness are observed from the data, $V(w)$ can be obtained from the solution to block 1 in app. A.2. Consequently, under assumption that observed $w$ and $\theta$ are the direct results of the solution to block 2 in app. A.2, we can compute the equilibrium exit rates to without requiring employer-side data.

## A.4 Estimated and predicted survivor functions

Here we show the predicted survivor functions for heterogeneous population groups (solid line everywhere). Along with model predictions we plot the Kaplan-Meier survivor probabilities (zero markers) with corresponding 95% confidence intervals (dash lines connecting the triangles).

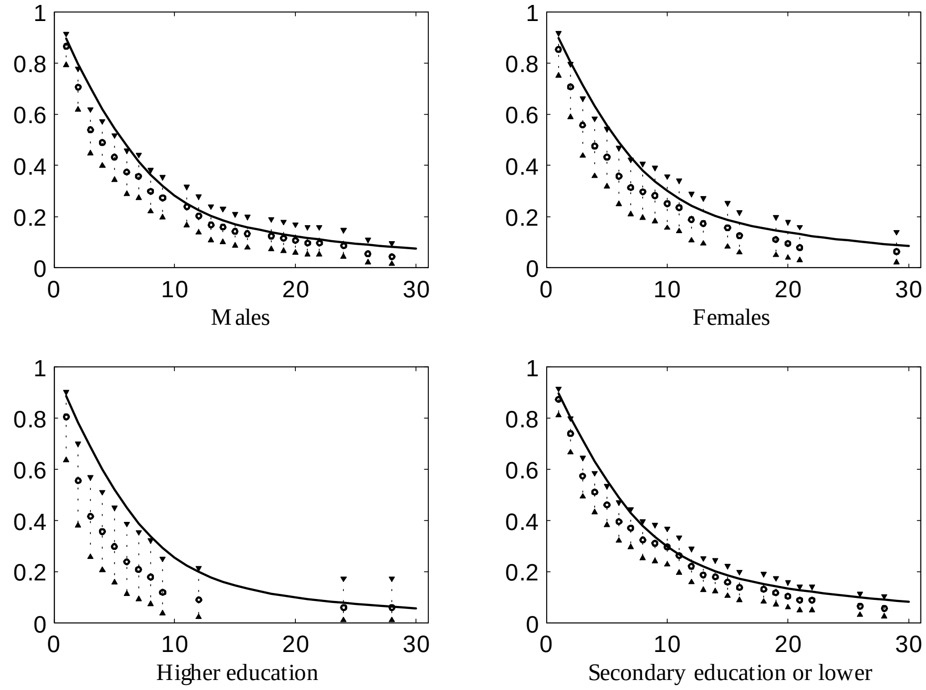


**Figure 6** *Kaplan-Meier and predicted survivor functions: West Germany*

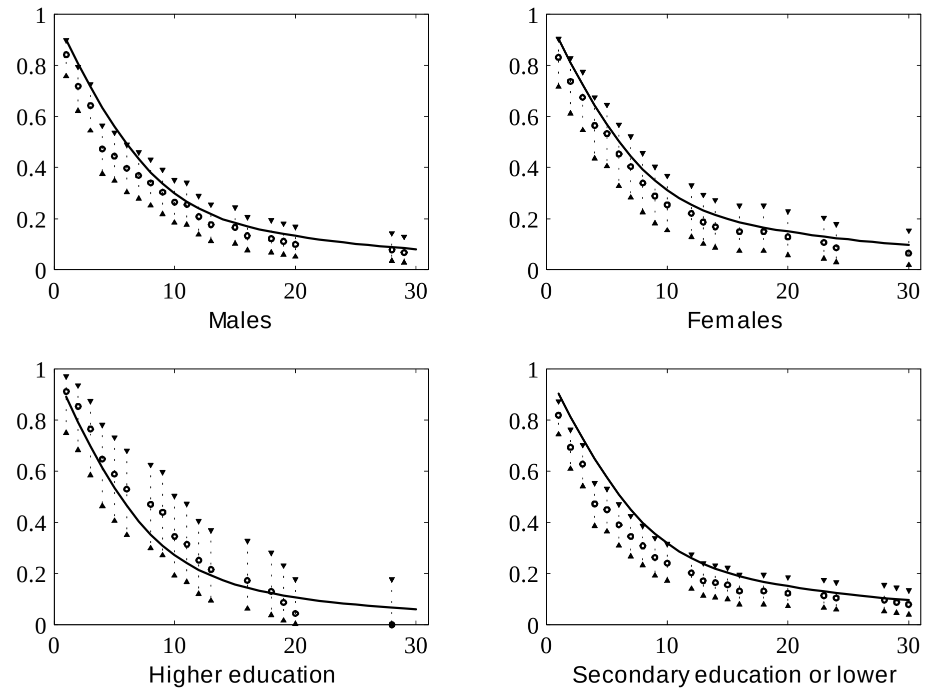


**Figure 7** *Kaplan-Meier and predicted survivor functions: East Germany*

## A.5 A Semi-Markov process

This section provides a short introduction into Semi-Markov processes. For more details, see Schumm (2010, ch. 4). The first subsection describes the general approach to Semi-Markov processes while the second adapts it to our question.

### A.5.1 The general approach

This follows Kulkarni (1995) and Corradi et al. (2004). The original work is by Pyke (1961a,b).[25] Let $Y_n$ denote the state of a system after the $n$th transition. Let this state be $i$. Let the point in time of the $n$th transition be denoted by $S_n$. Define the probability that the system after the next transition is in $j$ and that this transition takes place within a period of length $x$ or shorter, conditional on the system being in $i$ after the $n$th transition, as

$$Q_{ij}(x) \equiv P\{Y_{n+1} = j, S_{n+1} - S_n \leq x | Y_n = i\}.$$

The probability that any transition takes place is then given by summing up the probabilities for each $j$, $Q_i(x) = \Sigma_{j \neq i} Q_{ij}(x)$, not taking into account transitions from $i$ to $i$.[26] The probability that the system will be in $j$ in $\tau$ is given by

$$p_{ij}(\tau) = (1 - Q_i(\tau))\,\delta_{ij} + \Sigma_{k \neq i} \int_0^t p_{kj}(\tau - x)\, dQ_{ik}(x). \tag{A.11}$$

The interpretation of this integral equation is as follows: the first part of the right hand side gives the probability that the system, being currently in state $i$, never leaves state $i$ until $\tau$. In this case $j = i$ and $\delta_{ij} = 1$, so $1 - Q_i(\tau)$ is the survival probability in state $i$. If $j \neq i$, $\delta_{ij} = 0$. The second part of the right hand side collects all cases in which the transition from $i$ to $j$ (which includes $i$) occurred via another state $k \neq i$. First, we take the probability that the process stayed in state $i$ for a period of length $x$ and passed to state $k$ then (captured by $Q_{ik}(x)$). Then we need the probability that the process which is in state $k$ after $x$ will be in state $j$ at $\tau$ (captured by $p_{kj}(\tau - x)$). As the transition from $i$ to $k$ can be anywhere between 0 and $\tau$, we have to integrate over $x$ in order to cover all possible transitions.

Equation (A.11) can slightly be rewritten, provided that $Q_{ik}(x)$ is once differentiable (which holds for our case), as

$$p_{ij}(\tau) = (1 - Q_i(\tau))\,\delta_{ij} + \Sigma_{k \neq i} \int_0^t p_{kj}(\tau - x) \frac{dQ_{ik}(x)}{dx} dx. \tag{A.12}$$

The derivative $dQ_{ik}(x)/dx$ now gives the density of going from $i$ to $k$ after duration $x$. Multiplied by the probability of subsequently going from $k$ to $j$ gives the density of ending up in $j$ after having gone to $k$ after $x$. Integrating over all durations $x$ gives the probability of starting in $i$ and being in $j$ at $\tau$.

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[25] We are grateful to Ludwig Fahrmeir for comments on Semi-Markov processes. For an excellent introduction in German, see Fahrmeir et al. (1981).

[26] We differ from the notation in the cited literature in that we explicitly write $j \neq i$ here or $k \neq i$ below. This is equivalent to setting the transition rate from $i$ to $i$ to zero. As our application does not have transitions from $i$ to $i$ (i.e. transition rates from $i$ to $i$ are zero), we find using $j \neq i$ explicitly more intuitive for our purpose.

### A.5.2 Our two-state system

We now need to adjust the notation such that it suits our purposes. We look at a worker who just moved in $t$ (like today) into either employment $e$ or unemployment $u$. Define $Q_{eu}(\tau)$ as the probability that a worker who just found a job in $t$ "jumps" to $u$ in a period of time shorter or equal to $\tau - t$. With a duration $s$ dependent arrival rate $\lambda(s(v))$, this is then simply given by

$$Q_{eu}(\tau|t_e) = 1 - e^{-\int_t^\tau \lambda(s(v))dv}, \tag{A.13}$$

where $s(v) = v - t$ is the duration in her current state. In perfect analogy and using a spell-dependent arrival rate $\mu(s(v))$, we get $Q_{ue}(\tau) = 1 - e^{-\int_t^\tau \mu(s(v))dv}$. For the complementary events - remaining in a given state - the probabilities are simply $Q_{ee}(\tau) = 1 - Q_{eu}(\tau)$ and $Q_{uu}(\tau) = 1 - Q_{ue}(\tau)$. The probabilities that a transition takes place at all in this two state process are

$$Q_e(\tau) \equiv Q_{eu}(\tau), \; Q_u(\tau) \equiv Q_{ue}(\tau). \tag{A.14}$$

With two possible states, we have four transition probabilities for the future: an unemployed (employed) person can either be unemployed or employed at some future point in time $\tau$. Two are redundant as the probability of e.g. an unemployed worker of being employed is complementary to the probability of being unemployed, $p_{ue}(\tau) = 1 - p_{uu}(\tau)$, and similarly $p_{ee}(\tau) = 1 - p_{eu}(\tau)$. Hence, we only focus on $p_{uu}(\tau)$ and $p_{eu}(\tau)$. These probabilities are, using the general equation (A.12),

$$p_{uu}(\tau) = 1 - Q_u(\tau) + \int_t^\tau p_{eu}(\tau - v) \frac{dQ_{ue}(v)}{dv} dv, \tag{A.15a}$$

$$p_{eu}(\tau) = \int_t^\tau p_{uu}(\tau - v|t_u) \frac{dQ_{eu}(v)}{dv} dv. \tag{A.15b}$$

These equations can be most easily be understood by looking at the following figure.

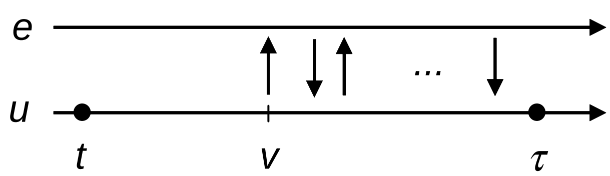


**Figure 8** *Illustrating transition probabilities*

Let's consider $p_{uu}(\tau)$ : An individual unemployed in $t$ can be unemployed in $\tau$ by always remaining unemployed. This is the term $1 - Q_u(\tau)$. The individual can be unemployed in $\tau$ by remaining unemployed until $v$ where she jumps into employment, the density for which is $dQ_{ue}(v|t_u)/dv$. After $v$, the probability of returning to unemployment in the remaining time span of $\tau - v$ is $p_{eu}(\tau - v)$. Note that this probability includes an arbitrary number of transitions larger than zero in this remaining period $\tau - v$. In contrast to integrating over $x$ as in (A.12), we integrate over the point in time $v$ here simply as this is the more intuitive way.

As a last step, we need to determine the two derivatives $dQ_{ue}(v)/dv$ and $dQ_{eu}(v)/dv$. Given duration-dependent arrival rates, the derivatives of (A.13) are,

$$\frac{dQ_{ue}(v)}{dv} = e^{-\int_t^v \mu(s(y))dy} \frac{d}{dv} \int_t^v \mu(s(y))\, dy = e^{-\int_t^v \mu(s(y))dy} \mu(s(v)) \tag{A.16a}$$

$$\frac{dQ_{eu}(v)}{dv} = e^{-\int_t^v \lambda(s(y))dy} \frac{d}{dv} \int_t^v \lambda(s(y))\, dy = e^{-\int_t^v \lambda(s(y))dy} \lambda(s(v)). \tag{A.16b}$$

Given (A.14) and the derivatives, the equations (A.15) become

$$p_{uu}(\tau) = e^{-\int_t^\tau \mu(s(y))dy} + \int_t^\tau p_{eu}(\tau - v)\, e^{-\int_t^v \mu(s(y))dy} \mu(s(v))\, dv,$$

$$p_{eu}(\tau) = \int_t^\tau p_{uu}(\tau - v)\, e^{-\int_t^v \lambda(s(y))dy} \lambda(s(v))\, dv.$$

The final adjustment we need to make is to replace $\lambda(s(v))$ by $\lambda$ as the separation rate is assumed to be constant. This then gives equations (13) in the main text.

# B Appendix

All references to appendices starting with $B$ are available upon request.

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