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Transitions in the German labor market: Structure and crisis ☆

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ABSTRACT

Since the so-called Hartz IV reforms around 2005 and during the global crisis of 2008/2009, the German labor market featured mainly declining unemployment rates. We develop a search and matching model with heterogeneous skills to explore the role of structural and cyclical policies for this performance. Calibrating unemployment benefits to approximate legislation before and after the reforms, we find a large reduction in unemployment and its duration, with the transition concluding after about three years. During the crisis, the extended use of short-time labor subsidies that prevent jobs from being destroyed is likely to have prevented strong increases in unemployment.

1. Introduction

The German labor market has undergone remarkable transitions during the past decade. After unemployment had been rising since the 1970s, reaching its peak of almost 11% in 2005, a series of reforms to the unemployment insurance system appears to have induced a reversal. The main focus of the so-called Hartz reforms was on the supply side of labor, to increase unemployed workers' incentives to accept jobs. This was implemented by reducing the level and duration of unemployment benefit entitlements. By 2011, the unemployment rate had fallen to 7.2%.[1] Surprisingly, while many countries (such as the U.S. and Spain) remained stuck with high unemployment two years after the economic crisis of 2008 and 2009, it has barely risen in Germany and the economy has rebounded to an extent that there are even reports of shortages for skilled labor. Some observers speak of a German employment miracle.[2]

It is not clear however, whether this performance is mainly the consequence of the reforms as such, of the stabilization policies adopted during the crisis, or other factors. Gartner and Merkl (2011) emphasize the importance of the reforms and the ensuing wage moderation, arguing that the crisis has only briefly interrupted what is a forceful downward transition to a new steady state with low unemployment. Others argue that short-time work subsidies (*Kurzarbeitergeld*) may have had a significant role in preventing massive employment losses, in Germany and other countries.[3] In contrast, Burda and Hunt (2011) and Dietz et al. (2011), and others argue that instead flexible work arrangements, such as working time accounts, allowed firms to smooth production costs and created incentives to keep workers. Burda and Hunt (2011) also

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[1] We are talking here in terms of the ILO definitions of unemployment, which are lower than the official German Labor Office's measurements.
[2] See, for example, Burda and Hunt (2011) and Gartner and Merkl (2011).
[3] See Hijzen and Venn (2011).

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stress that pessimistic expectations led to a hiring backlog in the pre-crisis boom, and thus subdued firing in the crisis. All of the arguments thus far are largely based on empirical analyses and small illustrative models.

This paper develops a quantitative labor market model to offer a structural perspective on the performance of the German labor market before and during the crisis. Our model is close to those by Ljungqvist and Sargent (2007) and Den Haan et al. (2005), featuring skill heterogeneity of workers along with search and matching frictions as familiar from Mortensen and Pissarides (1994), and endogenous job acceptance and separation rates. To this we add a more detailed description of an unemployment insurance system, with layers of benefits and welfare payments as present before and after the German Hartz reforms. Workers accumulate skills on the job and lose skills when unemployed. It is the interaction of skill loss during unemployment and generous unemployment benefits that depend on previous earnings which generates the higher unemployment rate before the reforms. This is our framework of choice because it allows a unified explanation of the evolution of European and U.S. unemployment since the 1960s, as shown by Ljungqvist and Sargent (1998, 2008). To generate rising unemployment, the standard search and matching model without skill heterogeneity would require counterfactual increases in unemployment benefits and other institutions which historically have undergone only relatively little change.[4]

In the first part of the analysis, we calibrate the model to characterize the German labor market before the reforms, and then simulate the transition after the so-called Hartz IV reform stage in 2005. For our baseline calibration, we find that the reduction of the duration of unemployment benefits, essentially brought about by the removal of the long-lasting earnings-dependent unemployment assistance, accounts for an about 2.8% point reduction in the unemployment rate. Labor market tightness and job acceptance rates both increase, leading to a drop in the fraction of low-skilled workers with high benefits. The number of long-term unemployed workers drops, but since the reforms removed the earnings-dependent unemployment assistance which was only slightly lower than the unemployment insurance benefits, a much larger fraction of those workers is now on welfare. Output is higher not only due to the higher employment rate, but also because workers find jobs faster and jobs last longer. Both factors lead to an overall improvement in the quality of the workforce. Further reductions in the unemployment rate may have been generated by other aspect of the reforms. For example, the earlier stages (Hartz II and III) aimed at improving job matching. Guided by findings of Fahr and Sunde (2009), increasing the match efficiency parameter in the model by 10% yields an additional reduction of more than 0.6% in the unemployment rate.[5]

Most of the transition to the post-reform steady state takes place within the first three years. That is, by 2008, the adjustment would have largely concluded. Returning to the argument by Gartner and Merkl (2011), the 2009 drop in output would then have hit an economy already in the new steady state, so that the employment adjustment to the crisis should have followed normal cyclical patterns. But even if the transition had been still ongoing during the crisis, there is a second issue pertaining to the level of the post-reform steady state. Suppose the steady-state unemployment rate in 2005 was at the 10.8% predicted by the model. Then with an overall reduction of 2.8% points induced by the reforms, apart from match efficiency gains, the new natural rate of unemployment would still be above the roughly 7.4% during the crisis. Only if the natural rate were much lower could the reforms have potentially have mattered for the performance during the crisis. Whether this may actually have been the case requires simultaneous analysis of aggregate shocks and transitions.

We calculate how the model economy responds to an intertemporal preference (or discount factor) shock. The discount factor shock can be regarded as a proxy to financial market turmoil as it affects the interest rate, and thus the long-run incentives to invest in new jobs, and thereby as a simple stand-in for the driver of the 2008/2009 recession. Even fairly small changes in the discount factor induce large changes in unemployment. This is a potential candidate for the large drop in employment in the U.S. and several European economies, but would not help understand the evolution of the German labor market, where unemployment barely changed, unless other factors played a role, such as policy. We focus on short-time work subsidies in particular[6]: in times of exceptionally reduced product demand, firms can apply for such subsidies, inducing the government to finance part of the proportional shortfall in wages that workers would suffer, while allowing firms to cut costs. During the crisis, the German government also increased the maximum duration of the subsidies. We model such subsidies as a transfer payment to those job-worker matches that would otherwise separate after an aggregate shock. To generate the observed drop in German output during the recession while at the same time leaving unemployment roughly constant requires large movements in output-per-worker. On the other hand, a discount factor shock of a size sufficient to force unemployment up by as much as in other European G7 countries, i.e., about 2–2.5% points, can be offset by a relatively moderate subsidy.

The paper is related to a quickly developing literature. The approach followed in our paper is most closely related to the contributions of Ljungqvist and Sargent (2004, 2007) and Nie (2010). In a series of papers, Ljungqvist and Sargent develop

[4] See Costain and Reiter (2008) and Pissarides (2009). The key element originally introduced by Ljungqvist and Sargent (1998) is an increase in the degree of skill obsolescence after workers' job loss, which they term "turbulence". In their model, an increase in turbulence increases unemployment in a European-style welfare state because formerly high-skilled workers maintain high earnings-dependent benefits after job loss, muting job search incentives. Our analysis is thus complementary to theirs in that we analyse changes in labor market institutions while instead leaving the dynamics of skill loss unchanged.

[5] Fahr and Sunde (2009) were the first to present evidence on job matching after the reforms. The relevant reforms were actually conducted in 2002 and 2003, prior to the observed reduction in unemployment.

[6] See Cahuc and Carcillo (2011) and OECD (2010) for a survey and assessment of short-time work subsidies.

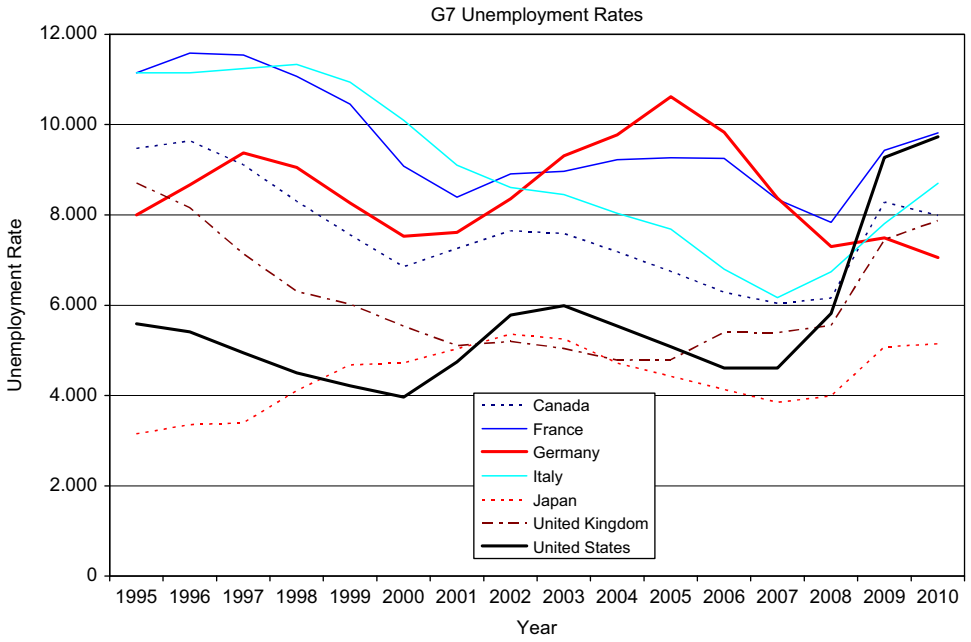

Fig. 1. G7 unemployment rates, 1995–2010 (source: IMF).

models that explain the rising European unemployment as an outcome of increased skill obsolescence upon job loss, which they call 'turbulence'. In contrast, the U.S. labor market, which has low unemployment benefits of short duration, is argued to be able to respond flexibly to higher turbulence. In their 2007 paper, the authors have shown the robustness of their results to the inclusion of matching frictions and firing costs. Nie (2010) uses a similar model to focus on the German labor market reforms and their effects on the incentives to accumulate human capital through training. The only other analysis of the German Hartz IV labor market reforms in a heterogeneous agent model is by Krebs and Scheffel (2011), calculating an unemployment rate decrease of 1.1% points. The authors depart from the risk neutrality assumption that we entertain and focus on the savings decision of workers and welfare implications. An interesting application of dynamic simulations as in our paper is found in Nakajima (2011), who analyses the extension of unemployment benefits during the crisis in the U.S. He focuses on the details of the duration of the extensions and different points in time, and finds an overall additional impact on the U.S. unemployment rate of 1.6%.

The paper proceeds from here as follows. In the next section, we give some institutional background on the German labor market and its reform as well as discuss short-time labor subsidies used extensively during the crisis. In Section 3 we set up the model. We describe our calibration and simulation strategy in Section 4. In Section 5 we present the analysis. First, we compare the quantitative steady state outcomes pre- and post-reform. We then show the transitional dynamics of the unemployment rates. Finally, we subject the model economy to a discount shock during that transition, and discuss the impact of short-term labor subsidies. Section 6 concludes.

2. Background

Since the 1970s, the German labor market experienced an increase in unemployment from about 4% to above 10% in 2005. In particular, since 1995, unemployment fell below 8% only at the height of the so-called dotcom bubble. Fig. 1 shows the evolution of the German unemployment rate since 1995, along with that of major developed countries. Since 2005 however, the unemployment rate has fallen persistently until the 2008/2009 global economic crisis. Surprisingly, while the crisis has led to increases in unemployment in all G7 countries, in Germany it has only taken a temporary dent, and appears to continue on a downward trend. This is in particularly stark contrast with the experience in the U.S. and U.K. Note however that output in Germany fell by similar magnitudes as in other countries.[7]

The very peak of the German unemployment rate in 2005 coincides with the period of the introduction of major parts of the Hartz reforms. These labor market reforms were actually enacted in a sequence of steps from 2002, until on January 1, 2006, the final step, Hartz IV, was implemented to change the benefit system. The first steps were largely concerned with reforming the Federal Employment Agency, as well as developing better tools for improving search and retraining, and

[7] See, e.g., Burda and Hunt (2011).

measures to foster self-employment.[8] The final step was key, as it reduced in the duration of the entitlements to earnings-dependent unemployment insurance.

Before Hartz IV, the German unemployment benefit system consisted of *three* layers: unemployment 'insurance', unemployment 'assistance', and supplementary social assistance (or welfare). Unemployment insurance benefits were (and are) part of the compulsory social security system, and are thus financed through a tax on labor, paid in half by employees and employers. The incomes support from that system typically lasted 52 weeks.

The second component, unemployment *assistance*, was the most distinct feature of the German system, and has been entirely removed with the reforms. Its 'assistance' payments were based on previous net earnings, albeit at a slightly lower percentage than unemployment benefits, and after means testing, but the duration was essentially indefinite. Particularly workers with relatively high earnings before unemployment, but low or depreciated marketable skills, had little incentive to search for jobs and were thus likely to stay long in unemployment assistance. Many of these workers eventually entered early retirement without ever having participated in the labor market again.

Social assistance was also means-tested and paid an indefinite amount of time, but it did not depend on previous employment or earnings. It was mainly meant for non-employable persons, but unemployed workers could receive supplementary payments from social assistance when their benefit income was below a specified existence minimum. Also the number of children was taken into account and subsidies may have been paid for accommodation.

The key innovation of the Hartz IV reforms was to merge unemployment assistance and social assistance, essentially abolishing the former. The newly defined "unemployed income II" (for Arbeitslosengeld II, henceforth ALG II) is a means-tested payment which depends on basic needs, family status, and willingness to work. It thus is much closer to the previous social (welfare) assistance than to unemployment assistance. Refusal to work may lead to cuts in the benefit level, at the discretion of local employment agencies. Notably, a person is employable if he or she is capable of working at least 3 hours a day. It can also be paid to employed persons or those on what is now called ALG I, whose income is below a certain level. The design of ALG I remained largely unchanged from the former unemployment benefits, and is based on previous earnings, but paid for about one year only.[9]

In spite of these – for Germany – rather fundamental changes, the new system carries in it some exceptions that may reduce its effectiveness. For example, a supplementary temporary benefit is paid after transiting into ALG II, for up to two years. This mitigates the incentives to start searching for jobs early during an unemployment spell. Further, in ALG II, additional support is granted for housing and heating, and it depends on the number of dependents.

Several empirical studies focus on the incentive problems in the German unemployment benefit system. Ochel (2005) finds that high unemployment benefits result in higher reservation wages and, therefore, adversely affect the transition from unemployment to employment. Schäfer (2003) concludes that the evidence shows that the duration of unemployment benefits is largely responsible for increases in unemployment duration. Correspondingly, Christensen (2005) finds that higher reservation wages lead to a higher unemployment duration. According to OECD (2006), the German unemployment insurance system still provides disincentives to supply labor. Especially a lower level of support for the low-skilled would increase the transition to employment.

A stunning feature of the evolution of the German labor market during the crisis is the absence of a significant increase in unemployment, as visible in Fig. 1. At the same time, output fell in 2009 by 4.7%. Correspondingly, labor productivity sharply declined.[10] Also job openings fell only by a quarter during the crisis and have returned now to pre-crisis levels. This is in stark contrast to the U.S. experience, where unemployment almost doubled, while productivity increased. So the question is: why did many German employers choose to keep most of their workers? A tool used by the German government to stabilize employment is a short-time work subsidy, which allows firms to cut hours worked and reduce monthly wage payments to workers. The government matches part of the gap between the regular monthly pay of its workers, and the reduced pay under short-time work. Fig. 2 shows the numbers of workers affected by short-time work allowances, which reached a peak of almost 1.5 million in May 2009.[11]

Before the crisis, the short-time work subsidy was available for up to six months. Essentially, firms are eligible if the reduction in work-time is due to economic circumstances or unavoidable events, and if it is temporary. A minimum requirement is that the reduction in work-time would lead to a loss of at least 10% of monthly earnings, and at least a third of the employees must be affected. In the crisis, there have been successive extensions by ordinance. First, in 2009 and limited to applications to December 31st of that year, the duration of the eligibility was increased to 24 months. At the end of 2009, the duration was set at 18 months for new applications, and finally, for 2011, an extension to 12 months above the standard six months was decided. Under such circumstances, the German Labor Agency pays at least 60% of the gap between normal pay, and the pay under reduced work time. Furthermore, at least part of the social security contributions regularly paid by the employer is reimbursed. From July 2009, 100% of social security contributions were paid to employers.[12]

[8] See Ebbinghaus and Eichhorst (2009) and Eichhorst and Marx (2011) for a detailed description of German labor market policies.
[9] Workers above 55 years of age have an entitlement to 18 months of ALG I.
[10] See Burda and Hunt (2011).
[11] For more details on short-term labor allowances in Europe during the crisis, see European Commission (2010).
[12] Please see Bundesbank (2010) for more detail.

Fig. 2. Number of workers affected by short-time labor subsidies (source: Bundesagentur für Arbeit).

3. The model

Our model builds on the Mortensen and Pissarides (1994) search and matching model with endogenous job destruction, enriched with heterogeneous dynamics of workers' skills, as in Ljungqvist and Sargent (2007), and a more detailed institutional structure of the labor market. Unemployed workers search for jobs, while vacant jobs search for workers.[13] In this framework, the familiar matching function generates contacts between workers and firms, but matches are formed only if an idiosyncratic productivity draw for the job exceeds an optimal threshold. A match continues until it separates exogenously or after either a new productivity draw or an improved outside option of a worker makes separation a mutually agreed outcome. On the job, a worker's skill may improve over time and potential entitlements to unemployment benefits may change, based on labor market experience. During unemployment, skills and benefits may decrease over time. Wages are determined by sharing the surpluses of worker and job over their respective outside options. A government taxes firms' revenue to finance its budget which includes the costs of the unemployment insurance system. Now we turn to the formal details.

3.1. Workers

Time is discrete and the workforce is of measure one. At each point in time, risk-neutral workers have a level of general human capital, or skill, indexed by quality $i=1,\ldots,I$, with $i=1$ being the highest quality. Employed workers with $i>1$ receive stochastically arriving skill upgrades (representing, for example, learning-by-doing), which arrive at a constant Poisson rate. When unemployed, workers with skill higher than the minimum skill may suffer a loss in skill, which also follow a Poisson process.

Workers without jobs receive unemployment benefits of one of several possible levels b_j, indexed $j=1,\ldots J$. The unemployment benefit of a worker separated from his or her job depends on the entitlement built up during employment, which in turn depends on the skill level of the worker. This dependence indirectly captures the dependence of the benefits on wages, as the latter also depend on the skill level: the advantage of this more indirect approach is the computational tractability. Unemployed workers experience benefit reductions that arrive over time according to a Poisson rate.

3.2. Firms and jobs

There are a large number of potential firms with a single job that are free to enter the matching market at a cost V_f. A job-worker pair produces total output $y=az$ where a is an aggregate productivity or revenue measure and z is a match-specific, idiosyncratic, productivity drawn from a skill-specific distribution $z\sim v_i(dz)$. New draws for z arrive with probability γ^s, which thus governs the persistence of idiosyncratic productivity. Draws from $v_i(dz)$ are taken for both new contacts between workers and jobs and for existing matches, and a critical threshold for z exists below which a match is either not consummated in the first place or an existing match is destroyed. Since the thresholds depend on the skill level

[13] Jobs can be treated as one-worker firms, due to a constant-returns assumption for production.

and benefit entitlement were the worker unemployed, endogenous separations may take place either after a new productivity draw or if an increase in benefit entitlement makes continuation of the match inefficient.[14]

Worker and firm bargain over the surplus of the match, with a share π going to the worker and the share $(1-\pi)$ going to the firm. While the worker's fallback option in wage negotiations depends on his benefit entitlement and reemployment probabilities as determined by current skills, the firm's fallback is given by the entry cost V_f. We assume that workers discount future income with a factor β. Assuming perfect capital markets, firms use the same factor when discounting profits.

3.3. Labor market

Each period, the number of contacts between unemployed workers and vacant jobs is determined by an aggregate matching function, $m(v,u)$, where m is the number of contacts that can become matches in the next periods, v is the measure of vacancies, and u is the measure of searching workers, the unemployment rate. The function is constant returns to scale in v and u, so that the contact, or job-finding rate, for workers, $\lambda^w = m(v,u)/u$, and the worker-finding rate for vacancies, $\lambda^f = m(v,u)/v$, can be expressed as functions of labor market tightness $\theta = v/u$.

For jobs, the probability of contacting a worker with a particular skill–benefit mix i,j depends on the relative masses of the different unemployed worker types, that is,

$$\lambda^f(i,j) = \lambda^f \frac{u(i,j)}{u},$$

where $u(i,j)$ is the mass of unemployed workers with skill level i, and benefit entitlement j. After contacts are determined, the rate at which productive matches are formed depends on the idiosyncratic productivity draw z for that job. Below a critical threshold, production is not efficient, and firm and worker continue searching.[15]

3.4. Government

Output y is taxed at a proportional rate τ, so that net output $(1-\tau)y$ remains to be shared for the parties to a match. The government's expenses for the welfare state are the benefit payments to the various types of unemployed workers. Thus the budget identity is

$$\chi + \sum_j \sum_i b_j u(i,j) = \sum_j \sum_i e(i,j) \int_{\underline{z}_{i,j}}^{\overline{z}_{i,j}} \tau a z v_i(dz), \tag{1}$$

recalling that $y = az$. Expenditure on unemployment benefits depends on the masses of workers in the different unemployment states, $u(i,j)$ while the tax revenue depends on aggregate productivity a and the distribution of the productivity levels z for the various types of productive employment relationships $e(i,j)$. The expenditure component χ represents either a lump-sum transfer to households and/or government purchases. We assume that unemployment benefits b_j are proportional to the *average* wages earned by workers in the different skill groups. That is, we take average earnings capacity as the determinant of unemployment benefit entitlements.[16] More details are given in Appendix.

3.5. Equilibrium

The decisions of workers and firms are guided by the discounted present values. As described, the decision problems of workers are to accept or quit a job, contingent on her current skill level i, the current unemployment benefit entitlement j, and the current job-specific productivity z. Firms choices are to enter the matching market and to decide whether to accept a new match or to separate from a worker. The surplus from a job producing $y = az$ and to be shared between the worker and the firm is given by

$$S(i,j,y) = (1-\tau)y + G(i,j,y) - V_f - V(i,j),$$

where $(1-\tau)y + G(i,j,y)$ is the sum of the flow product net (of taxes) and the present value of the job, and $-V_f - V(i,j)$ is the sum of the outside options of the firm and worker, respectively. $G(i,j,y)$ is the continuation value of the match and $V(i,j)$ is the present value of unemployment to the worker.

[14] Separations potentially occurring after new productivity draws is the familiar mechanism in Mortensen and Pissarides (1994) that generates endogenous job destruction rates. The feature that productivities are drawn also after first contact between worker and firms adds the notion of stochastic job match quality as in Pissarides (2000, Chapter 6). In the original Mortensen–Pissarides model, new jobs are always created at the highest productivity possible.

[15] Note that search is not directed but random, that is, firms cannot target vacancies at a particular type of worker. Instead, they post vacancies on the basis of the expected skills and entitlements of the workers they may contact. Ljungqvist and Sargent (2007) explore the implications of assuming multiple matching functions for the different skill–benefit types.

[16] To be exact, one would have to take account of a worker's earnings of a certain number of previous periods as the basis for benefit entitlements, as mandated by legislation. Doing so would vastly expand the state space and thus the computational burden, without too much additional insight. Ljungqvist and Sargent (2007) and Den Haan et al. (2005) follow the same strategy.

The continuation value G of the match depends on changes in the exogenous and endogenous states that occur from one period to the next, and, indicating future values with primes, $'$, is given by

$$G(i,j,y)=\beta\left[\sum_{i'j'}Q(i',j',1;i,j)\max\{S(i',j',y),0\}+\sum_{i'j'}Q(i',j',2;i,j)\int_{z\geq z_{i'j'}}S(i',j',az)v_{i'}(dz)+\sum_{i'j',n'}Q(i',j',n';i,j)(V_f+V(i',j'))\right],$$

where the $Q's$ are the transition probabilities between different skill and benefit states, defined as follows. There are three cases $n'=1,2,3$ in the next period. The first term on the right hand side is the expected present value of the match for unchanged z, which is the first case $n'=1$. That is, no new draw for the idiosyncratic productivity has arrived. However, states i and j may have changed, possibly leading to a negative surplus, and consequently a separation, so that only the outside options would be earned. The second term denotes the expected present value of the match for the case $n'=2$, in which idiosyncratic productivity in fact has changed. The expectation over the draws of z is taken, conditional on the match not separating endogenously. This is the case when

$$z\geq z_{i,j}=\min\{z\mid S(i,j,y)>0\}. \tag{2}$$

The third case $n'=3$ is exogenous separation. Finally, the third term reflects the values of the outside options. This is part of the continuation value for any $n'=1,2,3$.

The present value of unemployment to the worker is

$$V(i,j)=b_j+\beta\sum_{i'j'}P(i',j';i,j)\left(\lambda^w\pi\int_{z\geq z_{i'j'}}S(i',j',az)v_{i'}(dz)+V(i',j')\right). \tag{3}$$

With probability λ^w, the worker is matched to a new job, and, conditional on i',j' and $z\geq z_{i'j'}$, earns a share π of the surplus in addition to her outside option. If not matched, with probability $(1-\lambda^w)$, the worker earns only the outside option $V(i',j')$.

3.6. Wages and firm entry

Given our surplus sharing rule, the contract can be implemented with a wage corresponding to the flow of the match value accruing to the worker. This wage $w(i,j,y)$ is given by

$$w(i,j,y)+G^W(i,j,y)-V(i,j)=\pi S(i,j,y),$$

where

$$G^W(i,j,y)=\pi[G(i,j,y)-\beta V_f]+(1-\pi)\beta\sum_{i'j',n'}Q(i',j',n';i,j)V(i',j')$$

is the (gross) continuation value for a worker on a job characterized by i, j, and z. This value is a weighted average of the worker's share of the job's net value plus the worker's outside option.

In equilibrium, the fallback option of firms, V_f, must equal the cost of creating jobs. New jobs enter the market whenever the benefit of posting a vacancy exceeds its cost, V_f. Thus[17]

$$V_f=\sum_{i,j}\lambda^f(i,j)(1-\pi)\beta\int_{\underline{z}_{i,j}}^{\infty}S(i,j,y)v_i(dz)+\beta V_f.$$

4. Calibration and solution

Since the model does not have an analytical solution it must be solved numerically. First, we discuss here the calibration, and then explain the solution and simulation methods.

4.1. Calibration

An overview of our parameterization is in Table 1. Sources that guide our choices of values are the benefit rules from German legislation before and after the reforms, facts on labor market flows, and parameters used in related work. We draw on specifications in Ljungqvist and Sargent (2004), Den Haan et al. (2005) and Nie (2010), who estimated with German data the process that governs the accumulation and decumulation of skills.

The model period is set to be quarters of a year, with a discount factor $\beta=0.99$, corresponding to an annual interest rate of about 4%. We allow for three skill levels: high and robust ($i=1$), high and fragile ($i=2$) as well as low ($i=3$). The match specific productivities z are uniformly distributed $z\in[\underline{z}(i),\overline{z}(i)]$: for low skilled workers, z is drawn from [0.5,1.5], while they are drawn from [1.5,2.5] for both types of high-skilled workers.

[17] See also Den Haan et al. (2005, p. 1368).

Table 1
Calibrated parameters.

Parameter	Pre-reform (baseline)	Post-reform if change
Discount factor, β	0.99	
Distr. of low skill productivities, uniform	$v_3 \sim [0.5,1.5]$	
Distr. of high skill productivities, uniform	$v_1, v_2 \sim [1.5,2.5]$	
Match efficiency, m	0.3	
Match elasticity, μ	0.5	
Exogenous separation probability, ρ_x	0.02	
Probability of skill upgrade, ψ_f	0.025	
Probability of productivity change, γ_s	0.075	
Probability of skill downgrade, γ_d	0.25	
Turbulence (skill loss upon separation), γ_x	0.5	
Entitlements changes during employment		
High skill worker, from low benefit, ψ_{lh}	0.25	0.2
Low skill worker, from high benefit, ψ_{hl}	0.125	
High skill worker, from welfare, ψ_{ah}	0.25	0.2
Low skill worker, from welfare, ψ_{al}	0.25	0.2
Entitlement changes during unemployment		
Transition γ_l from b_1 or b_2 to b_3 or b_4 (pre-reform)	0.2	n.a.
Transition γ_a from b_3 or b_4 to b_a (pre-reform)	0.025	n.a.
Transition γ_a from b_1 or b_2 to b_a (post-reform)	n.a.	0.25
Policy parameters		
Tax rate, τ	0.3	
Replacement rate for high benefits, ϕ_h	0.6	0.6
Replacement rate for low benefits, ϕ_l	0.53	n.a.
Welfare, relative to low benefit, ϕ_a	0.8	0.8

The difference between robust and fragile high skills will affect the likelihood of a skill loss when unemployed, thereby allowing us to introduce some persistence in the skill process. Transitions take place with the following probabilities. During employment, low skills become fragile high skills with probability $\psi_f = 0.025$ each quarter. Fragile high skills become robust high skill with probability 1 next period. During unemployment, robust high skills become fragile with probability 1 and fragile high skills become low skills with $\gamma_d = 0.25$. Thus, workers with fragile high skills would still be more productive if they found a new job, but they face a higher risk of skill depreciation during unemployment. Were they to find a job soon enough, their skills would immediately turn robustly high again. Finally, we assume that highly skilled workers immediately become low-skill workers with a "turbulence" probability $\gamma_x = 0.5$.

New productivities are drawn from v_i, $i = 1,2,3$ either when a match between worker and firm is newly formed or during employment with arrival frequency $\gamma_s = 0.075$. Thus on average, productivity changes only every three years and three months. This induces persistence in idiosyncratic productivity levels. Exogenous separations take place with probability $\rho_x = 0.02$ per quarter.

The legislation before the reforms entails two replacement rates: high and low, representing unemployment insurance and unemployment assistance, and a welfare benefit (social assistance), as described in Section 2. The high replacement rate is set to $\phi_h = 0.6$ and the low rate to $\phi_l = 0.53$, which are the replacement rate values for single earners without children.[18] Welfare benefits are assumed to be a fraction $\phi_a = 0.8$, or 80%, of the benefits that are received by workers who were low-skill and low-benefit upon job loss.[19] Recall from Section 3.4 that we apply the replacement rates to the wage earned within each skill group. For workers with high benefit entitlement who have just lost their jobs, there are two benefit levels, b_1 and b_2, depending on skill on the previous job and the replacement rate ϕ_h. Likewise, there are two benefit levels for workers who have just transited into the lower unemployment assistance, b_3 and b_4, with replacement rate on previously earned wages ϕ_l. Welfare payments, b_a, are not distinguished by skill. So in total, there are five benefit levels to be tracked in the computations. After the reforms, unemployment assistance is dropped from the system, with only unemployment insurance, b_1 or b_2, and welfare, b_a, and thus three benefit levels remaining. Thus, before the reforms, the welfare benefit is indexed with $j=5$, and after the reforms, it is indexed with $j=3$.

We model the corresponding transitions between entitlements to approximate the institutional details given in OECD (2004, 2009). When unemployed before the reforms, a high benefit level turns into a low benefit level with a Poisson arrival rate of $\gamma_l = 0.2$, corresponding to an average duration of 15 months. The low benefit level turns into welfare with a Poisson arrival rate $\gamma_a = 0.025$ or an average duration of 10 years, capturing the almost infinite duration of the

[18] Using instead the values of 67% and 57% for workers with at least one child leads to slightly higher unemployment rates, but no significant differences in percentage effects of the reforms or the dynamics of the model. See OECD (2004, 2009) for details.

[19] The welfare benefit rate is difficult to pin down, but we wanted to pick a number below, but relatively close to the lowest unemployment benefits. A fraction of unemployed workers did in fact receive welfare benefits that were even higher. Note that the Hartz IV welfare benefit should be a fixed value such as 345 Euros plus allowance for housing, heating, etc. Here we choose to have it endogenously in some relation to the general wage level.

unemployment assistance in the old system. Since for the new system, there is no low benefit level, the high benefit level transits to the welfare benefits at a Poisson arrival rate of $\gamma_a = 0.25$, i.e., after an average duration of one year.

Benefit entitlements change during employment in accordance with the skill level of the worker. The probabilities are motivated by the time it takes by law to be eligible for a higher benefit[20]: under the pre-reform system, a worker became eligible for high benefits after having worked for 12 months out of the last three years in the old system, and achieved full benefits after having worked two years out of seven. As a simplified summary, we thus set the Poisson probabilities of an upgrade to high benefit eligibility for a high-skilled employed worker to $\psi_{lh} = \psi_{ah} = 0.25$ and the upgrade from welfare to low benefit eligibility for a low-skilled employed worker to $\psi_{al} = 0.25$, so that an employed worker becomes eligible for a higher benefit level after one year. A downgrade to a lower benefit for a low-skilled worker occurs with Poisson arrival rate $\psi_{hl} = 0.125$. This may occur when a formerly unemployed worker has high benefit entitlement even though her skills had depreciated. After the reforms, the eligibility criteria have been tightened, which we represent by reducing the probability of an entitlement upgrade to $\psi_{lh} = \psi_{ah} = \psi_{al} = 0.2$.

The average tax rate is set to $\tau = 30\%$. Workers and firms are taxed equally. Since bargaining is efficient, it is irrelevant who pays the tax, so we assume that they bargain over the after tax revenue $(1-\tau)y$. In equilibrium, this implies that expenses for the unemployment insurance system are about 4% of the total government budget, which is roughly in line with the relevant data from the OECD.

The matching function has the functional form $m(v,u) = mv^{1-\mu}u^{\mu}$. The scale parameter is set to $m=0.3$ following Ljungqvist and Sargent (2007). The match elasticity is $\mu = 0.5$. Strictly speaking, these are rates at which firms and workers contact each other, but not match formation rates. The actual rates of match formation depend also on how many contacts are actually profitable after the productivity draw for z. For low-skilled, high-benefit unemployed workers, the likelihood of entering production is much lower for a given draw of z. For the solved model, the finding rates imply a particular present value of a posted vacancy.

4.2. Solution and simulation methods

We solve the model numerically via value function iteration. We use a fine grid instead of a uniform distribution for z. For given labor market tightness and unemployment benefits, the value function iteration finds the optimal values and thus the optimal cutoffs (or decision rules) for z below which matches are either not formed in the first place or destroyed after either unfavorable productivity draws or changes in the economic environment. Along the way, the distribution of workers across skill–benefit types and the employment status is calculated. Based on the distribution of worker across employed types, the average of low-skill and high-skill wages is calculated, based on which the unemployment benefits are determined. Based on the distribution of workers across unemployed types, the expected value of a posted vacancy is calculated and can be compared with the cost of creating a job. In an outer loop, labor market tightness is adjusted until the job creation condition is met. As the distribution of workers and the wages change along the iteration, unemployment benefits need to be recalculated accordingly before entering a new iteration round.

For the calculation of the transition paths between steady states or along a particular simulated realization of shocks, we make again use of the system of value functions used above, in an iterative two-stage procedure. We initialize the procedure per fixing the time horizon T after which the adjustment processes are expected to be concluded, up to desirable numerical precision. We then guess a complete transition path for the endogenous aggregate variables, θ_t and thus the resulting λ_t^f and λ_t^w for each period between the initial and final steady state, and an initial time path for the distribution of workers across types. The first stage is to solve for the optimal values and decision rules backwards, that is, for each period $t = T-1$ to $t = 1$, always using the then known future values and decisions. The second stage uses the recorded decisions to calculate, from period $t=1$ forward, the evolution of the distribution of worker types as it results from agents decisions. We calculate the average wage and thus the resulting unemployment benefits as they prevail at each point in time. We calculate the value of vacant jobs at each point, and update labor market tightness θ_t to ensure the free entry condition is met. Then we return to stage one until convergence.[21]

5. Labor market reforms

In this section we first characterize the labor market before the 2005 Hartz IV reforms, in terms of the skill and benefit composition of the labor force, output, and the duration of unemployment. We conduct the reforms in the model economy, merging the unemployment assistance and welfare benefit system, and changing the duration of benefit entitlements, and compare the new steady state with the previous regime. After showing that the transition dynamics of the model are concluded relatively fast, we turn to the analysis of shocks. One important question is how the reforms may or may not have change the response of the labor market to aggregate shocks, such as intertemporal preference, revenue or technology shocks. The following subsection then turns to the analysis of policy during the crisis.

[20] Again, see Ebbinghaus and Eichhorst (2009), OECD (2004), and OECD (2009).

[21] See Rios-Rull (1999) for solving and simulating heterogeneous agent models and Conesa and Krueger (1999) for an application. Nakajima (2011) gives a particularly clear description of the solution method in a related model.

Table 2
Effects of labor market reforms.

Variable	Pre-reform (baseline)	Post-reform
Unemployment	10.8%	8.0%
Average wages, skilled workers	0.74	0.74
Average wages, unskilled workers	0.32	0.28
Unemployment benefits		
b_1: high benefit, previously skilled	0.44	0.45
b_2: high benefit, previously unskilled	0.19	0.17
b_3: low benefit, previously skilled	0.39	n.a.
b_4: low benefit, previously unskilled	0.17	n.a.
Welfare benefit, b_a	0.14	0.13
Output	1.63	1.68
Tax revenue	0.49	0.50
Expenditure for welfare system	0.04	0.02
Budget surplus	0.45	0.48
Labor market flows		
Labor market tightness, θ	0.76	1.16
Contact rate, workers, λ_w	0.26	0.32
Contact rate, firms, λ_f	0.35	0.28
Average outflow rate from unemployment	0.16	0.21
Job separation rates ($\rho_x+\rho_i$, $j=h,l,a$)		
Skilled	2%	2%
Unskilled, high potential benefits, ρ_h	5.0%	4.3%
Unskilled, low potential benefits, ρ_l	4.7%	3.5%
Unskilled, potentially welfare, ρ_a	2.0%	3.2%

Note: steady-state values of endogenous variables before and after German labor market reform simulation.

5.1. Steady state before the reforms

An overview of the results is in Table 2. The benchmark calibration implies an equilibrium unemployment rate of 10.8%, which is roughly the actual value in Germany in 2005. In that steady state, average wages earned by experienced high-skilled workers are $\overline{w}_h = 0.74$, and for workers with low skills $\overline{w}_l = 0.32$. Skilled workers earn on average higher than their share of the after tax product $\pi(1-\tau)\overline{z}_h = 0.7$, mainly due to their benefit entitlement which strengthens their outside option. Unskilled workers earn less than $\pi(1-\tau)\overline{z}_l = 0.35$, since their employment relationship also entails the option value of a skill upgrade and commensurate increased benefit entitlement in the future. The implied benefit levels are in Table 2. With the tax rate at $\tau = 0.3$, total tax revenue is 0.49, while total expenses for unemployment benefits and welfare are about 0.04. This leaves a surplus of $\chi = 0.45$ for lump-sum rebates to households or remaining government spending.

The job flows in steady state are as follows. While all jobs are destroyed at the exogenous separation threshold $\rho_x = 0.02$, the endogenous separation rates show some heterogeneity. First of all, jobs with high skilled workers never break up endogenously, so their job destruction rate is 2% per quarter. In contrast, jobs with unskilled workers entitled to benefits break up at about 5% per quarter.

Labor market tightness before the reforms is $\theta = 0.76$, which imply job finding probabilities of $\lambda_w = 0.26$ for workers and $\lambda_f = 0.35$ for firms, close to the values assumed by Ljungqvist and Sargent (2007). These are contact rates and not job filling probabilities for low skilled workers, which are determined in combination with job acceptance probabilities, as implied by the thresholds. For example, a low skilled worker with high benefit entitlement will reject 40% of the job offered after a contact. High-skilled workers accept all jobs they contact. The resulting average outflow rate for unemployed workers is then 0.155, which implies an average unemployment duration of 6.07 quarters, which is about a year and a half.[22]

Workers flow between employment and unemployment, and between the different skill and entitlement types, according to both the exogenously given and the endogenously determined probabilities. The different probabilities determine the stocks of workers that reside in the various categories. Table 3 gives the equilibrium break-up of the skill–benefit composition of the workforce, where the upper half concerns the situation before the reforms. Since high skills become fragile upon job loss, no unemployed worker has robust high skills. The majority of the unemployed is made up of low-skilled workers, of which 37.9% receive unemployment insurance, 43.9% receive unemployment assistance, and only 3.5% welfare payments: prior to the reforms, transition into welfare was simply rather unlikely. Table 4 shows the composition of the employed workers: 93.3% are entitled to the high benefits, and three quarters are high-skilled.

[22] The outflow, or job finding, rate is determined from as the average job finding rate across unemployed workers of skill j and benefit j, as in Table 3, that is,

$$\lambda_w \sum_i \sum_j [1-(z_{i,j}-0.5)]u(i,j)/u.$$

Table 3
Distribution of workers across types, before and after Hartz IV reforms.

Entitlements	Unemployment					Sum
	b_1	b_2	b_3	b_4	b_a	
Before reforms						
Skills						
High-skill, robust	0	0	0	0	0	0
High-skill, fragile	10.8	0.6	2.8	0.2	0.1	14.6
Low-skill	26.4	11.5	36.1	7.8	3.5	85.4
Sum	37.2	12.2	38.9	8.0	3.6	100
After reforms						
Skills						
High-skill, robust	0	0			0	0
High-skill, fragile	13.6	0.9			4.0	18.5
Low-skill	25.9	17.5			38.0	81.5
Sum	39.5	18.4			42.0	100

Note: fractions of unemployed workers in the different benefit and current skill categories, as given by the ergodic steady-state distributions. Benefit levels b_j depend on skill type during last employment.

Table 4
Distribution of workers across types, before and after Hartz IV reforms.

Entitlements	Employment					Sum
	b_1	b_2	b_3	b_4	b_a	
Before reforms						
Skills						
High-skill, robust	71.1	2.4	0.8	0.1	0.1	74.5
High-skill, fragile	0.3	0.9	0.3	0	0	1.5
Low-skill	2.1	16.5	4.1	0.9	0.5	24.0
Sum	73.5	19.8	5.2	1.0	0.6	100
After reforms						
Skills						
High-skill, robust	71.6	2.7			0.8	75.1
High-skill, fragile	0.3	1.0			0.3	1.5
Low-skill	1.4	18.1			3.9	23.3
Sum	73.2	21.7			5.0	100

Note: fractions of employed workers in the different benefit and current skill categories, as given by the ergodic steady-state distributions. Benefit levels b_j depend on skill type during last employment.

5.2. After the reforms

Tables 2–4 also show the corresponding results post reform. Table 2 shows that unemployment drops from 10.8% to 8%. Note that this increase is effectively entirely due to the reduced duration of earnings-dependent benefits, since the level of the initial unemployment insurance benefit remained unchanged. Output increases by 3% to 1.68 from 1.63, due to higher employment and the higher average skill of the workforce. The expenditures for the welfare system drop by (nearly) 50%, reflecting the lower number of unemployed workers as well as the on average lower benefit expenditure per worker. While job separation rates do not change by much, the outflow from unemployment increases substantially from 0.16 to 0.21, due to the increase in labor market tightness. This in turn explains why wages change so little for high-skilled workers. Higher job acceptance probabilities by unemployed workers increase the job-filling probabilities of firms, which in turn induces them to post vacancies. Through bargaining, the improved outside option of workers raises their wages, offsetting the drop in expected benefit income during unemployment.

The lower half of Table 3 shows the new composition of the pool of unemployed workers. While the skill distribution shifts modestly towards the high-skill types, there is a dramatic shift of workers towards welfare. This effect is due to the higher transition rate from unemployment insurance to welfare, since the intervening lower benefit has been removed. It does not mean, however, that there is more long-term unemployment, since the outflow rate from unemployment has increased. Correspondingly, and as the lower half of Table 4 shows, the fraction of employed workers eligible for

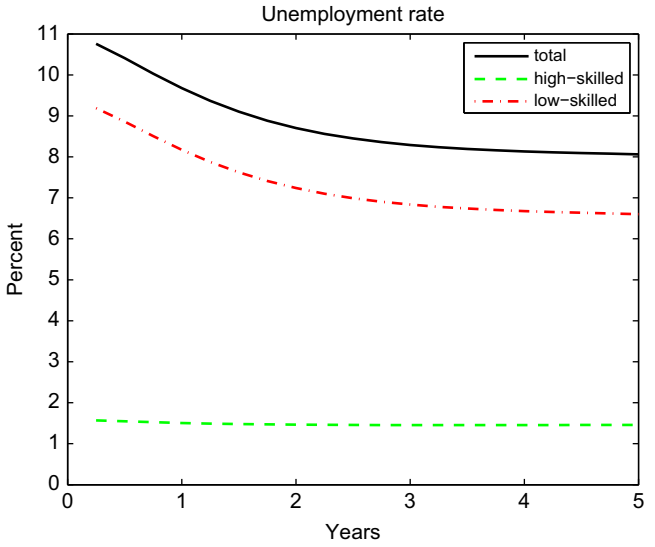

Fig. 3. Adjustment of German unemployment after the Hartz IV reforms. Note: the figure shows the adjustment dynamics from the pre-reform steady state to the post-reform steady state. Total unemployment: solid (black) line, of which low-skilled unemployment: dash-dotted (red) line, and high-skill unemployment, dashed (green) line. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

unemployment benefits drops from over 99 to about 95%. This follows from the larger fraction of worker on welfare in the pool of job searchers.

The reforms to the unemployment offices may have improved match efficiency, but the extent to which is difficult to predict theoretically. An early study that aimed at empirically assessing the success of the reforms in this respect is Fahr and Sunde (2009), who estimate an aggregate matching function using data on worker flows. They find that the reform stages Hartz II and III may have improved match efficiency by between 5% and 10%. Using the latter value to increase the match efficiency parameter in our model lowers the unemployment rate by an additional 0.65% points. Thus the overall effect of the reforms on the unemployment rate would be about 3.45% points.

5.3. *Transitional dynamics*

The transitional dynamics of the economy after the change of the welfare system offers some further insights. To initialize the state from which the transition begins, we merge the masses of workers in the different unemployment benefits before the reforms into the unemployment benefit after the reform, by skill. Fig. 3 shows the adjustment of the unemployment rate, in the aggregate and of its components. First of all, the transition takes place relatively fast. The main impact of the reform to the benefit structure has taken place after about three years, even though the unemployment rate continues to fall further in subsequent periods. Interestingly, the strongest reduction is in the number of unskilled workers, which are those that had lost their skills already, and are thus most likely to be long-term unemployed. Further investigation reveals that the fraction of the low-skilled unemployed with high benefit levels drops particularly strongly.

The model reveals a much larger degree of inertia than the standard search and matching model. In simple versions of that model, one can proxy for cyclical changes by conducting steady-state comparisons, due to the fact that labor market tightness and unemployment instantaneously adjust.[23] In models with heterogeneity this need no longer be true.[24] For example, in our model, the accumulation of skills detaches workers somewhat from movements in labor market tightness, breaking the tight link between their wages and labor market conditions. This explains the protracted adjustment which stretches over a number of years, rather than concluding within a quarter.

5.4. *Shock responses*

It is easy and instructive to calculate the response of the economy to various shocks. We have examined two shocks in particular. The first is a shock to the aggregate productivity level a. It turns out that the response is largely a drop in output, without much interesting labor market dynamics: we thus refrain from reporting the detailed results.[25] While that shock

[23] See Pissarides (2010) and Shimer (2005).

[24] The same may apply in the presence of on-the-job search. See Krause and Lubik (2010) for an illustration.

[25] This is the familiar property search and matching models, where wage flexibility mitigates the response of vacancy creation to shocks. See Hall (2005), Shimer (2005), and Costain and Reiter (2008).

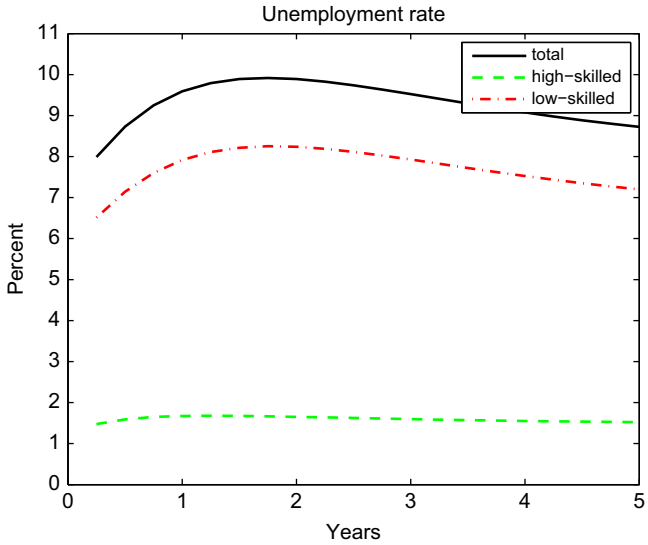

Fig. 4. Impulse response to a discount factor shock. Note: the figure shows the adjustment dynamics after a discount factor shock to the post-reform steady state. Total unemployment: solid (black) line, of which low-skilled unemployment: dash-dotted (red) line, and high-skill unemployment, dashed (green) line. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

may explain the experience of Germany during the financial crisis, it begs the question why other countries did not go through a similar experience. It is therefore more interesting and informative to examine the response to a discount factor shock. Such a shock can proxy a number of things. Literally it is a change in the time preference of households and thus governs the saving motive. In our model the savings motive is mediated through the interest rate into the incentives to invest in new jobs and thus 'accumulate' labor. But the shock can also stand for changes in credit conditions, e.g., increases in risk premia. Finally, it may also reflect unmodelled changes in the expected long-run growth rate of the economy, which affect the incentives to save and invest.

A transitory discount factor shock from $\beta = 0.99$ to $\beta = 0.985$ with persistence $\rho_\beta = 0.9$ induces a strong and persistent increase of the unemployment rate, to a maximum of 9.92 percent (Fig. 4). The intuition is that as firms discount the future more heavily, future returns relative to the job creation cost drop, leading to a drop in vacancies posted and thus flows of workers out of unemployment. Note the hump-shape in the adjustment, which is not the property of the shock process, indicating the propagation mechanism inherent in this heterogeneous agent model. It is also interesting that the unemployment rate does not exhibit a large jump on impact. The corresponding drop in output is almost 2.2%. If this shock indeed played a large role during the crisis, something else must have happened alongside, in order to explain why there was so little movement in unemployment. We therefore consider next what happens when both the transition to the new labor market steady state as well as policy responses are added.

Before doing so, we also conducted a counterfactual experiment, shocking the pre-reform economy with the discount factor shock alone. Starting from the old steady state unemployment rate of 10.8%, and the old system with long-lasting, earnings dependent benefits in place, a shock to the discount factor raises the unemployment rate to a peak of over 13% after about two years. This is an almost 20% increase in the unemployment rate, even lower than the increase that would take place after the reforms, which is about 24%. Thus in absolute terms the reforms have improved the ability of the German labor market to withstand cyclical shocks, as the percentage point change is larger before the reforms, but not in relative terms.

5.5. *Transitions during the crisis*

Our first scenario analysis is one where the economy is hit by a shock while the transition after the reforms is still ongoing. Even though our model predicts that most of the transition would have concluded before the recession began, it is still useful to understand whether the reform transition could have potentially played a role for the German labor market performance during the crisis. To give that story most potential, and to make the effects most transparent, we subject the economy simultaneously to the reforms and to the discount factor shock.[26] Thus both transitions take place at the same time, and show how the argument of Gartner and Merkl (2011) works out in the model.

[26] Bearing in mind that the productivity shock has not much bite.

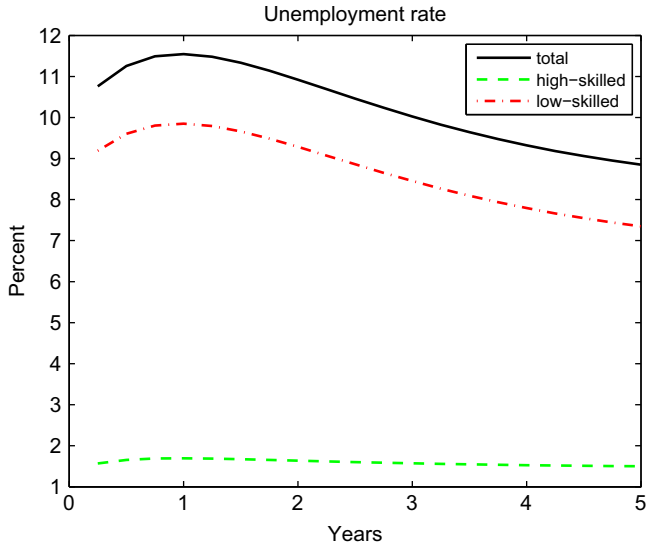

Fig. 5. Impulse response during transition and after discount factor shock. Note: the figure shows the adjustment dynamics from pre-reform steady state with a simultaneous discount factor shock. Total unemployment: solid (black) line, of which low-skilled unemployment: dash-dotted (red) line, and high-skill unemployment, dashed (green) line. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

The impulse response to the discount factor shock immediately after the introduction of the reforms shows basically the same dynamics as the discount factor shock alone (Fig. 5). However, the increase in the unemployment rate is smaller, reaching at the peak 11.6%, an increase of only 0.8% points over the pre-reform steady state. And the peak is already reached after a year. After five years the unemployment rate is still one percentage point above the post-reform steady state. The reason for the protracted adjustment is the large mass of low-skilled workers which are still enjoying high benefits when the shock hits. Of course, a lower persistence of the shock, or the shock hitting when a part of the transition has already concluded, would reduce the peak unemployment rate. None of our simulations exhibit negligible responses of unemployment when the shock hits during the transition. Nevertheless, there may in fact have been a contribution of the reform to reducing the severity of the crisis in Germany. Since a large part of the transitions may already have concluded before the crisis hit, we argue that it cannot be the sole explanation. Subsidies to short-term work must have played an additional and important role.

5.6. The role of labor subsidies

We address the role of labor market subsidies indirectly. The data shows an adjustment that involved only a weak reaction of employment, and a large reaction of productivity and hours per worker. Absent policy, this could be explained solely by the revenue shock. On the other hand, if policy has been actively supporting the labor market, we have to assume what the adjustment would have been without policy. The remaining G7 countries, except the U.S., have experienced increases of unemployment between 2% and 2.5%, so the change in the discount factor that generates 2% may be of the order of magnitude of the shock that has hit Germany. We aim to find the labor subsidy that leaves the unemployment rate roughly constant.

After some experimentation, we find that a tax reduction of 75% for jobs that would otherwise be destroyed, can reduce the impact of the discount factor shock to 0.80%. That is, the unemployment rate rises to only 8.8%, rather than the almost 10% in the absence of this labor subsidy. The government's net revenue drop to 0.499, and the surplus to 0.47, leaving expenditure for the welfare state at 0.01. Thus, compared to the steady state, revenue drops because of the reduction in tax rates for jobs at risk of destruction, but also welfare expenditures drop. Overall, it seems that a relatively moderate expense on subsidizing labor has a rather strong effect on the unemployment rate. Compared to the revenue of 0.505, about 1.1% of revenue is used to subsidize labor.

6. Conclusions

Our main findings can be summarized as follows. In a model that features skill heterogeneity and a stylized description of the German unemployment insurance system before and after the Hartz reforms, the removal of essentially indefinitely paid earnings-dependent unemployment benefits reduces the unemployment rate by 2.8% points. In the new system, the unemployed workers stop receiving earnings-dependent benefits after a little more than a year, so most long-term

unemployment is found among welfare recipients. Overall employment and output are larger, and the average duration of unemployment drops.[27]

To examine the impact of the 2008 financial crisis, we calculated the impact of a shock to the discount factor. By itself, it leads to large adjustments of the unemployment rate, and thus seems a candidate for explaining a significant fraction of movements in employment. Since the adjustments after the reform were likely to have concluded before the crisis hit, we believe that they are not the main factor that kept the unemployment rate as stable as was observed in Germany. Instead, subsidies to jobs deliver a possibility to reduce the impact of aggregate shocks on labor, at moderate costs.

A number of questions surely remain open. We have not documented the impact on the welfare of workers due to various policies, nor have we attempted to solve for optimal labor market policies (and they may be a bit too simplistic in this model, in any case). More detail on modelling the implementation of short-term labor subsidies would be intriguing, adding elements from, say, Nakajima's (2011) analysis. Our workers only differ in productivity: however, they may have been affected differently in the 2008 financial crisis due to non-substitutability of their labor. An extension to more widely dispersed productivities, or even with large firms, would certainly deliver additional and important insights.[28] Deeper thought should also be given to the response of the economy to shocks. The transitions after the reforms and after shocks are likely to be influenced by real wage rigidities, by lumpy hiring, training, and firing costs, and sticky prices, thus giving a role to labor hoarding. We leave all this for future research.

Acknowledgments

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Appendix A

A.1. Further details

After the reforms, the benefits for workers previously with high skills on their last job are given by

$$b_1 = \phi_h \sum_{i=1,2} \sum_j \frac{e(i,j)}{\sum_j e(i,j)} \int_{\underline{z}_{i,j}}^{\overline{z}_{i,j}} w(i,j,y) \frac{\nu_i(dz)}{1-\nu_i(\underline{z}_{i,j})}$$

and for workers with low skills on their last job

$$b_2 = \phi_h \sum_j \frac{e(3,j)}{\sum_j e(3,j)} \int_{\underline{z}_{3,j}}^{\overline{z}_{3,j}} w(3,j,y) \frac{\nu_3(dz)}{1-\nu_3(\underline{z}_{3,j})},$$

where ϕ_h is the replacement ratio, and $y=az$. For the first benefit level, one needs to take account of the different masses of workers who are in the two high-skill classes $i=1,2$ and the various possible benefit entitlements (or flow outside options) $j=1,2,3$ which affect wages. For the second benefit level, only the class $i=3$ for low skilled workers is relevant. Calculating the unemployment benefits thus requires knowledge of the distribution of workers across skills and benefit entitlements (while on the job), and of the conditional distribution of wages across idiosyncratic productivities z.

To reflect the legal arrangement before the Hartz IV labor market reforms in Germany, we introduce the second level of benefit, unemployment assistance. It is slightly lower and paid after the first level has expired, but for a very long period. For previously high-skilled workers, these levels are $b_3=\phi_l(b_1/\phi_h)$ and $b_4=\phi_l(b_2/\phi_h)$, where $\phi_l<\phi_h$. Finally, the welfare benefit earned after income-dependent benefits have expired is b_5. This is assumed to be a fraction of the lowest unemployment benefit level, i.e.,

$$b_a = b_5 = \phi_a b_4,$$

where $0<\phi_a<1$ of low skill benefits, i.e., this formulation makes sure that across simulations welfare entitlements are never larger than unemployment benefits.

Using the wage equation and the definition of the surplus, the wage can be brought into a more familiar form

$$w(i,j,z) = \pi[(1-\tau)y-(1-\beta)V_f]+(1-\pi)(1-\beta)V(i,j)-(1-\pi)\beta\left(\sum_{i',j',n'} Q(i',j',n';i,j)V(i',j')-V(i,j)\right).$$

The wage is a weighted average of the flow product of the firm and the discounted outside option of the firm, on the one hand, and the outside option of the worker, on the other. The last term is the option value of employment, which has a

[27] See Krebs and Scheffel (2011) for related findings concerning how the different worker types fare.

[28] One could imagine that a model like Bachmann (2009) would be the right starting point.

negative effect on the current wage because of the associated chance of higher wages in the future should the worker fall back into the unemployment pool.

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