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ABSTRACT

The German Labor Market during the Great Recession: Shocks and Institutions*

This paper analyzes Germany's unusual labor market experience during the Great Recession. We estimate a general equilibrium model with a detailed labor market block for post-unification Germany. This allows us to disentangle the role of institutions (short-time work, government spending rules) and shocks (aggregate, labor market, and policy shocks) and to perform counterfactual exercises. We identify positive labor market performance shocks (likely caused by labor market reforms) as the key driver for the "German labor market miracle" during the Great Recession.

JEL Classification: E24, E32, E62, J08, J63

Keywords: Great Recession, search and matching, DSGE, short-time work, fiscal policy, business cycles, Germany

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1 Introduction

The German labor market experience during the Great Recession in 2008/09 has received a lot of attention. While real GDP dropped by more than in other industrialized countries, such as in the United States, unemployment barely increased (see Figure 1). This development was dubbed as the German labor market miracle (Burda and Hunt, 2011). The existing literature has pointed to various shocks and institutions that may account for this unusual labor market development (e.g., Balleer et al., 2016, Boeri and Bruecker, 2011, Burda and Hunt, 2011, Boysen-Hogrefe and Groll, 2010, Möller, 2010, see Section 6 for a review). Potential explanations include labor adjustment along the intensive margin, e.g., using short-time work (STW, henceforth),[1] labor market reforms or reluctant hiring in the preceding boom.

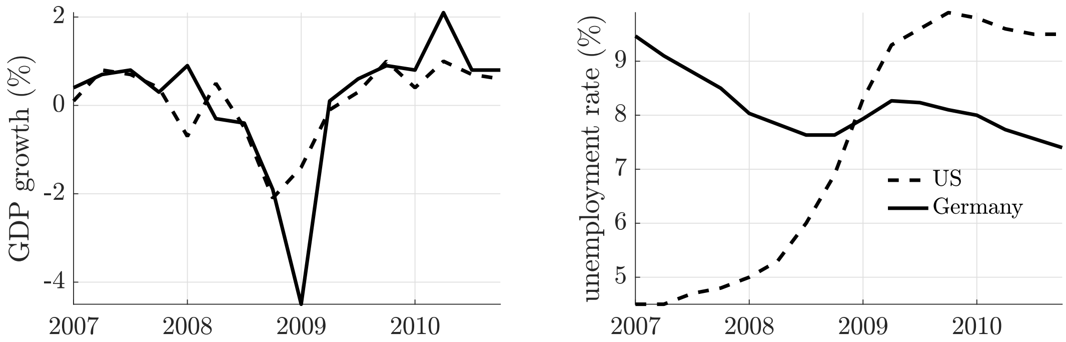

Figure 1: US and German GDP growth and the unemployment rate during the Great Recession (all data is seasonally adjusted).

Our paper is the first to jointly analyze the role of different shocks (e.g., aggregate shocks and labor market shocks) and institutions (e.g., short-time work and government spending rules) during the Great Recession in Germany through the lens of an estimated dynamic general equilibrium model with rigid prices and unemployment.[2] These models are commonly used for policy analysis (Christiano et al., 2011, Cogan et al., 2010) but have thus far not been adapted to explain the German labor market in the Great Recession. In order to analyze the labor market response in the Great Recession, we incorporate a search and matching labor market (Diamond, 1982 and Mortensen and Pissarides, 1994) with endogenous separations and the possibility for firms to use STW as in Balleer et al. (2016).

[1]Short-time work (in German: *Kurzarbeit*) is a government subsidized scheme to reduce the working time at the firm level if firms are in financial difficulties. This instrument was used in various OECD countries during the Great Recession (see, e.g., Cahuc and Carcillo, 2011). In Germany, in 2009, more than 1.5 million workers were affected by STW. Figure 7 in Appendix A shows that total hours worked decreased much more compared to employment in Germany in the Great Recession. Further, labor force participation and hourly wages did not fall in this time period (see also Figure 7).

[2]The role of shocks and institutions for unemployment has received a lot of attention in the literature. However, a large part uses cross-country data to analyze this issue (e.g., Blanchard and Wolfers, 2000). Krause and Uhlig (2012) provide a quantitative analysis of the German labor market in the Great Recession in a labor market model without any interaction with government spending or fiscal rules. Casares and Vázquez (2018) compare labor market dynamics in Germany and Spain. Their work is complementary to ours. They use a completely different labor market model and provide the comparison between these two countries. By contrast, we provide a richer institutional structure for Germany (e.g., modeling STW explicitly). Sala et al. (2012) also look at Germany during the Great Recession from a DSGE perspective. Again, their model does not feature STW and relies purely on exogenous separations.

Our model is extremely rich along the labor market dimension because we aim to focus on explaining the German labor market response in the Great Recession. The eligibility of STW follows a rule that adjusts to the business cycle. Similarly, government spending is assumed to follow a rule. As a consequence, economic agents anticipate that governments typically adjust policy in a rule-based way in recessions. Anticipation affects behavior and may thus generate stabilizing macroeconomic effects. Additionally, there are discretionary policy changes, i.e., unforeseen changes of government spending and STW. These policy changes were major components of the business cycle stimulus packages that the German government implemented in the Great Recession to stabilize the economy (see Appendix A for details). Our model is constructed in a way such that it is flexible enough to allow for large and small effects of policy shocks and institutions (depending on estimated parameters). We let the data speak on this issue and quantify the role of shocks, while disciplining our exercise with the estimation of key model parameters based on German time series data from 1993 to 2013.[3]

Our model-based approach has the advantage that we can perform counterfactual exercises, i.e., we can analyze how the German labor market would have evolved in the absence of certain shocks and institutions. This methodological approach provides a number of interesting results. STW has contributed to the German labor market miracle. Our paper points to a new dimension of rule-based behavior and is thereby complementary to Balleer et al. (2016). In our model, the automatic adjustment of STW, triggered by an explicit and thereby expected rule, reduced the increase in unemployment during the Great Recession by 0.3 percentage points. By contrast, the government spending rule had no strong effects and also discretionary government spending during the Great Recession reduced unemployment by at most 0.03 percentage points according to our estimations.[4]

Our exercise reveals that expectations play an important role for the stabilizing effect of STW. More expected STW in recessions provides an insurance for firms in recessions, i.e., they know that they can use this instrument with higher probability in case of negative aggregate and idiosyncratic shocks. This smooths their present value of an existing match over the business cycle and thereby their hiring and firing activity. By contrast, given that our estimated parameters imply small multipliers for government spending, the stabilization through the government spending rule is quantitatively not very relevant.

What are other key drivers of the German labor market miracle? We detect two important candidates. First, during our observation period output shocks had a relatively small effect on unemployment. GDP and unemployment appear to be less connected than in prior decades. This is consonant with results from other empirical papers (e.g., Klinger and Weber, 2015). Second, the German labor market was hit by a sequence of positive labor market performance shocks in the years before the Great Recession. These positive labor market performance shocks had long-lasting after-effects and thereby lowered the increase in unemployment during the Great Recession by up to 1 percentage points. We

[3]Furlanetto and Groshenny (2016) use a comparable approach to analyze the extreme increase of US unemployment in the Great Recession. Given the different institutional settings, however, their New Keynesian model does not feature STW.

[4]In line with the literature, we focus on direct government expenditure. This does not include transfers such as unemployment benefits.

obtain additional support for this driving source from two other observations. Empirical studies that do not look at the Great Recession through the lens of a structural model find independent evidence for an increase of the matching efficiency starting around 2005.[5] In addition, we can observe a strong decline of the unemployment rate before and after the Great Recession (see Figure 1), which points to a permanent decline of the steady state unemployment rate. This development shows up as positive labor market performance shocks in our estimation. Due to the timing, we interpret these labor market performance shocks as long-lasting after-effects of the German labor market reforms (Hartz reforms) that were implemented between 2003 and 2005. While our DSGE estimation has the major advantage that we can simulate counterfactuals (i.e., switching STW on and off), it comes at the disadvantage that we look at the data through the lens of our structural model and are thereby less flexible than other macroeconometric methods (e.g., structural vector autoregressions). As our approach delivers a broadly similar picture in several dimensions compared to less structural approaches (e.g., Gehrke and Weber, 2018 or Klinger and Rothe, 2012), we are confident that our results are rather driven by the data than our prior modeling assumptions.

What are the policy implications of our results for the next severe German recession? A large part of the German labor market miracle can be attributed to a timing coincidence, namely the labor market reforms, which took place some years before the Great Recession. Thus, our paper sounds a cautionary note on explanations that attribute the German labor market miracle solely to German labor market institutions, such as short-time work and firing costs (e.g., Krugman, 2009).

However, even though STW can not explain the whole German miracle, our results strengthen the previous findings in Balleer et al. (2016) that STW stabilizes business fluctuations to a certain extent, in particular if this policy is used in a rule-based way. In our paper firms anticipate that the rules for STW are business cycle dependent and this provides an additional stabilizing effect. Does that mean that this policy would be equally effective if implemented in other countries? Not necessarily. As discussed in Balleer et al. (2016), the beneficial effects of STW depend on certain labor market characteristics, like rigid labor market flows, collective wage bargaining and high firing costs. Thus, the stabilizing effects of STW can be expected to be smaller in economies with flexible labor markets as the US.

The rest of the paper is structured as follows. Section 2 derives the dynamic stochastic general equilibrium model with search and matching. Section 3 discusses the estimation and properties of the estimated model. Section 4 analyzes the role of different shocks during the Great Recession. Section 5 analyzes the role of different institutions during the Great Recession. Section 6 puts our results in perspective to the existing literature. Section 7 concludes.

[5] See Klinger and Rothe (2012) and Klinger and Weber (2016) for evidence on an increase in matching efficiency after 2005 from reduced-form estimations.

2 The model

To analyze the effects of labor market institutions and shocks, we require a model that is sufficiently rich. For this purpose, we take the search and matching model of Balleer et al. (2016), which contains short-time work, and extend it to a general equilibrium setting. The spirit of our exercise is to have a theoretical model that has enough flexibility to allow the estimation to generate small or large effects of different shocks and institutions depending on the parameter values.

Since we are interested in the effects of traditional government spending, we add price rigidities and consumption habits to our model. Price rigidities lead to counter-cyclical price mark-ups and as a consequence increase the effects of fiscal expenditures. A larger degree of habit formation reduces crowding-out effects (Monacelli and Perotti, 2008). Thus, the habit formation parameter allows for different sizes of the government spending multiplier. Furthermore, we include a government spending rule and an explicit STW rule that allow these institutions to adjust in response to business cycle fluctuations. These rules capture anticipated policy changes in recessions and expansions. The estimated coefficients in these rules will determine the importance of the rule-based stabilization. Our labor market block contains fixed costs of production, which will be estimated. These determine how strongly aggregate productivity shocks are propagated to the labor market in the search and matching model.

The model is a New Keynesian setting with Rotemberg (1982) price adjustment costs. Households consume final goods under habit formation, intermediate-good firms produce intermediate goods from labor subject to search and matching frictions and final-good firms produce differentiated final goods using the intermediate goods as inputs. They act under monopolistic competition and set prices subject to price adjustment costs.

2.1 Households

The households maximizes intertemporal utility:

$$U_t = E_t \sum_{t=0}^{\infty} \beta^t \frac{(c_t - h^c c_{t-1})^{1-\sigma}}{1-\sigma}, \tag{1}$$

where β is the household's discount factor, σ is the elasticity of intertemporal substitution and h^c is the degree of external habit formation (see Smets and Wouters, 2007 and Christiano et al., 2005). The habit persistence parameter h^c will be estimated and thereby affect the size of the government spending multiplier.

As is common in the literature, we assume that each household consists of a large number of individuals sharing all income with the other household members. This implies that consumption does not depend on a worker's employment status. Thus, the household maximizes its utility subject to the budget constraint:

$$B_t + \int \frac{P_{it}}{P_t} c_{it} = w_t n_t (1 - \chi_t) + n_t \chi_t w_t^{stw} + b u_t + (1 + r_{t-1}) B_{t-1} + \Pi_t - T_t. \tag{2}$$

Here, B are real bond holdings, $\int \frac{P_i}{P} c_i$ are the expenditures for the consumption of intermediate goods, T are real lump-sum taxes, r is the real interest rate and Π are real aggregate profits which are transferred in lump-sum manner, w is the regular real wage under full time work, χ is the share of employed workers who are on STW, w^{stw} is the average compensation for a worker who is on short-time work[6], n is the employment rate, b the real income of unemployed workers and u the unemployment rate. Intertemporal utility maximization yields the following consumption Euler equation

$$(c_t - h^c c_{t-1})^{-\sigma} = \beta E_t (c_{t+1} - h^c c_t)^{-\sigma} (1 + r_t), \tag{3}$$

and the stochastic discount factor as

$$\Lambda_{t,t+1} = \beta \Big(\frac{c_{t+1} - h^c c_t}{c_t - h^c c_{t-1}} \Big)^{-\sigma}.$$

2.2 Final good firms

Final goods producers indexed by i are monopolistic competitors and price setters that face quadratic price adjustment costs. They produce their output using a linear production function with the intermediate good as the only input, bought at price $p_{z,t} = P_{z,t}/P_t$ from the intermediate goods sector. They face the downwards sloping demand function:

$$y_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\epsilon} y_t,$$

where ϵ is the elasticity of substitution among varieties. Firms solve the following constrained optimization problem

$$\Pi_{it} = \sum_{t=0}^{\infty} \Lambda_{0,t} \left[\left(\frac{P_{i,t}}{P_t} y_{it} - p_{z,t} y_{it} \right) - \frac{\Psi}{2} \left(\frac{P_{i,t}}{P_{i,t-1}} - 1 \right)^2 y_t \right], \tag{4}$$

where $\Lambda_{0,t}$ is the stochastic discount factor and Ψ measures the extent of price rigidity in the Rotemberg (1982) adjustment cost function. Optimizing with respect to P_{it}, and noting that all firms set the same price yields the standard Phillips curve:

$$0 = (1 - \epsilon) + \epsilon p_{z,t} - \Psi (\pi_t - 1) \pi_t + E_t \{ \Lambda_{t,t+1} \Psi (\pi_{t+1} - 1) \frac{y_{t+1}}{y_t} \pi_{t+1} \}, \tag{5}$$

[6]Note that this compensation consists of the wage paid by the employer for the remaining working time and the compensation by the government for the STW part. For analytical convenience (since the full expression contains several integrals and since some variables will be defined later), we summarize these elements as w^{stw}.

where $\pi_t = P_t/P_{t-1}$ is the aggregate inflation rate.

2.3 Intermediate goods producers and the labor market

Intermediate goods producers act at a labor market with search frictions. They have to post vacancies to attract workers. Each firm employs only one worker. Wages are determined according to Nash bargaining. Firms sell their products on a competitive market to the final-goods producers. The labor market closely follows Balleer et al. (2016).

2.3.1 Matching

Matches m_t are determined by a Cobb-Douglas constant returns matching function

$$m_t = \mu_t u_t^{\alpha} v_t^{1-\alpha}, \tag{6}$$

where u_t is unemployment, v_t are vacancies and α is the matching elasticity with respect to unemployment, and $\mu_t > 0$ is the matching efficiency. Time-varying matching efficiency follows an autoregressive process:

$$\frac{\mu_t}{\mu} = \left(\frac{\mu_{t-1}}{\mu}\right)^{\rho_\mu} e^{\varepsilon_{\mu,t}}, \tag{7}$$

where ρ_μ is the persistence parameter of the shock and ε_μ is the matching efficiency shock. The shock process will be estimated.

The worker-finding rate q_t (i.e., the probability of a firm to fill a vacancy) is

$$q_t = \mu_t \theta_t^{-\alpha}, \tag{8}$$

where $\theta_t = v_t/u_t$ is the labor market-tightness. Consequently, the job-finding rate η_t (i.e., the probability of an unemployed worker to find a job) is

$$\eta_t = \mu_t \theta_t^{1-\alpha}. \tag{9}$$

The present value of a vacancy is defined as

$$V_t = -\kappa + E_t \Lambda_{t+1} q_t J_{t+1} + E_t \Lambda_{t,t+1} \left(1 - q_t\right) V_{t+1}, \tag{10}$$

where J_t is the value of a job and κ are the vacancy posting costs. Assuming free entry implies $V_t = 0$ $\forall\, t$ which simplifies the above equation to

$$\kappa = E_t \Lambda_{t,t+1} q_t J_{t+1}. \tag{11}$$

Thus, in equilibrium the vacancy posting cost has to equal the expected payoff of the vacancy, which consists of the value of a successful match weighted with the probability to find a worker.

2.3.2 Separation and short-time work decisions

As is standard in the literature, we endogenize separations by assuming that the profits generated by a worker depend on the realization of an idiosyncratic shock, ε_t (Mortensen and Pissarides, 1994). We assume that the idiosyncratic component is additive and has the interpretation of a cost-shock. This shock ε_t is drawn from the random distribution $g(\varepsilon)$ and is i.i.d. across workers and time. We will first describe the STW decision (which is analogous to Balleer et al., 2016) and then the firing decision in this economy because the latter depends on the former.

The value of a worker with a specific realization of the idiosyncratic shock ε_t, who is not on STW, is given by

$$J(\varepsilon_t) = a_t p_{zt} - w_t - \varepsilon_t - c + E_t \Lambda_{t,t+1} J_{t+1}, \tag{12}$$

where a_t is aggregate productivity, w_t is the wage of the worker, and c is a fixed cost of production. The fixed cost of production c was introduced by Christoffel and Kuester (2008) as a way to generate the large volatility of unemployment over the business cycle found in the data, without resorting to wage rigidity or using a small-surplus calibration. The fixed costs parameter c will be estimated and thereby determine the amplification of aggregate shocks to the labor market.

Aggregate productivity is subject to shocks. As all other shocks, the state of aggregate productivity is revealed at the beginning of the period. We assume that aggregate productivity in the economy follows a first-order autoregressive process:

$$\left(\frac{a_t}{a}\right) = \left(\frac{a_{t-1}}{a}\right)^{\rho_a} e^{\varepsilon_{a,t}}, \tag{13}$$

where ρ_a is the first-order autoregressive coefficient and $\varepsilon_{a,t}$ is the productivity innovation.

We assume that the government defines an eligibility criterion ζ_t for STW such that only workers whose value is below that threshold are allowed to be sent on STW.

$$a_t p_{zt} - w_t - \varepsilon_t + E_t \Lambda_{t+1} J_{t+1} - c < \zeta_t. \tag{14}$$

The variable ζ_t is a policy instrument. By lowering ζ_t, the government makes the eligibility criterion more stringent and, thus, directly reduces the number of workers on STW. In steady state, we assume $\zeta = -f$, where f is the cost of firing a worker. This assures that only those firms are allowed to use STW that would otherwise fire.[7] This corresponds to the German rule that only firms with "unavoidable financial difficulties" can apply for STW (i.e., the loss needs to be sufficiently large that it would lead to a destruction of the worker-firm pair without using the policy).

[7] Note that for $\zeta_t = -f$, equation (14) coincides with the firing condition of an equivalent model without STW.

Based on equation (14) we can define a threshold-level for the idiosyncratic component ε_t

$$v_t^k = a_t p_{zt} - w_t + E_t \Lambda_{t+1} J_{t+1} - c - \zeta_t, \tag{15}$$

such that workers with $\varepsilon_t < v_t^k$ work full-time, while workers with $\varepsilon_t > v_t^K$ are allowed to be sent on STW.

On top of the modeling assumptions by Balleer et al. (2016), we introduce systematic variation of the STW eligibility criterion over the cycle, i.e., the stringency of the STW rule is allowed to react to GDP

$$\frac{1+\zeta_t}{1+\zeta} = \left(\frac{1+\zeta_{t-1}}{1+\zeta}\right)^{\rho_\zeta} \left(\frac{y_t}{y}\right)^{\psi_\zeta} e^{\zeta,t}, \tag{16}$$

where ψ_ζ is the parameter for the reaction of STW to GDP fluctuations, ρ_ζ is the persistence over time and $\varepsilon_{\zeta,t}$ is a discretionary shock. The rule-based reaction to GDP captures that part of STW legislation is adjusted regularly in recessions. For example, the maximum duration that firms are allowed to use STW is typically extended in recessions at maximum up to two years. In turn, in expansionary phases of the business cycle the maximum duration is reduced again (see also Gehrke and Hochmuth (2018)). A discretionary shock can be any surprise change in the eligibility criteria or the costs of STW. We estimate the parameters of the rule and the shocks. Changes in STW due to discretionary shocks and due to the STW rule are conceptually different because the STW rule is common knowledge and thus changes in STW according to the rule are expected, while discretionary changes are by definition unexpected.[8]

Given that a worker is eligible for STW, the firm can choose the optimal working time reduction K subject to convex STW costs $C\left(K\left(\varepsilon_t\right)\right)$, with $\frac{\partial C(K(\varepsilon_t))}{\partial K(\varepsilon_t)} > 0$ and $\frac{\partial C(K(\varepsilon_t))^2}{\partial^2 K(\varepsilon_t)} > 0$ to assure interior solutions.[9] There are several reasons to use convex STW costs. First, convex costs are necessary to replicate the empirical finding that the degree of STW usage varies across firms.[10] Second, although the employer reduces the labor costs with STW, the reduction is not necessarily proportional to the working hours reduction because the employer has to pay the social security contributions for the full time equivalent.[11] Third, the implementation of STW must be approved by the workers' council.[12] As long as there is no approval, workers have the right to obtain their full wage. Workers' councils are generally more willing to approve small working time reductions than larger working time reductions because employees only receive a partial compensation for their wage loss. These STW costs are important also because they prevent that firms use STW as a long-term structural tool to increase their

[8]Note that STW additionally stabilizes the business cycle in an automatic way beyond that captured by the rule in equation (16). In Balleer et al. (2016), we show that according to equation (15), in a recession there are more workers eligible for STW. This provides automatic stabilization over the business cycle.

[9]Assuming a linear cost function would imply corner solutions, i.e. workers either work full time or reduce hours by 100%.

[10]From 1993-2010, 44% of all employees who used STW in Germany reduced their working time up to 25%, 33% between 25 and 50%, 8% between 75-99% and 8% to 100% (Source: Federal Employment Agency).

[11]See Bach et al. (2009) who show that these institutional features generates a convexity in the cost of STW.

[12]German labor law makes it mandatory for firms from a certain size onwards to allow their employees to elect representatives ("Betriebsrat" in English: workers' council).

competitiveness (see also the discussion in Boeri and Bruecker (2011)).

The firm chooses the optimal level of K by maximizing its contemporaneous profit of having a worker on STW in the firm

$$\max_{K(\varepsilon_t)} \pi_t = (a_t p_{zt} - w_t - \varepsilon_t)(1 - K(\varepsilon_t)) - c - C(K(\varepsilon_t)). \tag{17}$$

Note that the reduction in working time does not only reduce the output of the worker but also reduces the wage payments and the idiosyncratic cost. However, it does not reduce the fixed cost which is independent of the production level. Imposing a quadratic functional form for the costs of STW

$$C(K(\varepsilon_t)) = c_K \frac{1}{2} K(\varepsilon_t)^2 \tag{18}$$

gives the optimal degree of STW for a given ε_t

$$K^*(\varepsilon_t) = -\frac{a_t p_{zt} - w_t - \varepsilon_t}{c_K}. \tag{19}$$

Naturally, the lower the profitability of a worker, i.e., the higher the realization of ε_t, the higher the working time reduction. We can now describe the firing decision of the firm, which depends on the working time reduction K. Workers are fired if the losses they generate are higher than the firing cost:[13]

$$(a_t p_{zt} - w_t - \varepsilon_t)(1 - K(\varepsilon_t)) - C(K(\varepsilon_t)) - c + E_t \Lambda_{t+1} J_{t+1} < -f. \tag{20}$$

This defines a firing threshold v_t^f at which the firm is indifferent between firing and retaining the worker:

$$v_t^f = a_t p_{zt} - w_t - c + \frac{E_t \Lambda_{t+1} J_{t+1}}{1 - K\left(v_t^f\right)} + \frac{f}{1 - K\left(v_t^f\right)} - \frac{C\left(K(v_t^f)\right)}{1 - K\left(v_t^f\right)}. \tag{21}$$

Thus, the endogenous separation rate is

$$\phi_t^e = \int_{v_t^f}^{\infty} g(\varepsilon_t)\, d\varepsilon_t, \tag{22}$$

and the rate of workers on STW is

$$\chi_t = \int_{v_t^k}^{v_t^f} g(\varepsilon_t)\, d\varepsilon_t. \tag{23}$$

All the workers above the threshold v_t^k are eligible for STW, but workers above v_t^f are so unproductive that they are fired nevertheless. Note that STW exists in this economy if $v_t^f > v_t^k$. This is the case as long as STW costs are not prohibitively high. Then, STW will allow firms to reduce the losses generated by an unproductive worker which reduces the firing rate. If c_K approaches infinity, then from equation (19) it follows that $K = 0$, i.e., firms do not use STW. In this case the STW cutoff

[13] Note that workers close to the firing threshold are always eligible to STW.

and the firing cutoff are identical: $v_t^f = v_t^k$. This limiting case provides us with the model that we use for counterfactual analysis in the numerical part. If c_K is smaller than $a_t - w_t - \varepsilon_t$, the firm optimally reduces hours worked for those on STW to zero. In that case, no firing occurs in this economy.

The expected value of a worker before the realization of ε is known is

$$\begin{aligned} J_{t+1} &= (1-\phi^x)\int_{-\infty}^{v_{t+1}^k} (a_{t+1}p_{zt+1} - w_{t+1} - \varepsilon_{t+1})\, g(\varepsilon_{t+1}) d\varepsilon_{t+1} \\ &+ (1-\phi^x)\int_{v_{t+1}^k}^{v_{t+1}^f} \left[(a_{t+1}p_{zt+1} - w_{t+1} - \varepsilon_{t+1})(1-K(\varepsilon_{t+1})) - C(K(\varepsilon_{t+1}))\right] g(\varepsilon_{t+1})\, d\varepsilon_{t+1} \\ &- (1-\phi_{t+1})\, c - (1-\phi^x)\,\phi_{t+1}^e f + (1-\phi_{t+1})\, E_{t+1}\Lambda_{t+1,t+2} J_{t+2}. \end{aligned} \tag{24}$$

Here,

$$\phi_{t+1} = \phi^x + (1-\phi^x)\,\phi_{t+1}^e, \tag{25}$$

is the overall rate of job destruction, which depends on the endogenous rate of job destruction defined in (22) and on the exogenous rate of job destruction ϕ^x. The first integral in equation (24) is the expected revenue of workers who work full-time. The second integral is the expected revenue of workers on STW. Here, we need to take into account that these workers have reduced working time, but that the firm has to incur the cost of STW. The fixed cost has to be paid for all employed workers. The firing cost has to be paid only for endogenous, not for exogenous separations.

2.3.3 Employment evolution

The evolution of the employment rate n_t in this economy is described by

$$n_t = (1-\phi_t)\, n_{t-1} + \eta_{t-1}(1-\phi_t)(1-n_{t-1}). \tag{26}$$

Note that workers on STW are treated as employed, corresponding to the official German employment statistics (although they only work part-time).

2.3.4 Wage bargaining

Finally, we specify wage formation. We assume that wages are set collectively, i.e., at each period there exists one wage which is relevant for each employed worker and which does not depend on the realization of ε_t. Specifically, we assume that the wage is bargained between a representative firm and a representative incumbent worker for whom the realization of the operating costs equals its expectation of zero. The median firms' profit[14] (with operating costs zero) of a match is

$$F_t = a_t p_{zt} - w_t - c + E_t\Lambda_{t+1}(1-\phi_{t+1})\, J_{t+1}. \tag{27}$$

[14] Note that the median firm does not use STW (empirically, only 0.7% of German firms use STW on average).

In case of disagreement, production will come to a halt, and bargaining will resume in the next period. This bargaining setup is described in more detail in Lechthaler et al. (2010). It is especially plausible under collective bargaining since it is unlikely that all workers become unemployed in case of disagreement. Thus, the fall-back option of the firm is

$$\tilde{F}_t = -c + E_t \Lambda_{t+1} (1 - \phi_{t+1}) J_{t+1}. \tag{28}$$

The median workers' surplus W_t from a match is

$$W_t = w_t + E_t \Lambda_{t+1} (1 - \phi_{t+1}) W_{t+1} + E_t \Lambda_{t+1} \phi_{t+1} U_{t+1} \tag{29}$$

where U_t is the value of unemployment. The workers' fall-back option under disagreement is:

$$\tilde{W}_t = b + E_t \Lambda_{t+1} (1 - \phi_{t+1}) W_{t+1} + E_t \Lambda_{t+1} \phi_{t+1} U_{t+1}. \tag{30}$$

This means that in case of no production, workers are assumed to obtain a payment b, which is equal to the unemployment benefits in the economy.

Defining γ as workers' bargaining power and maximizing the Nash product yields the following wage equation:

$$w_t = \gamma a_t p_{zt} + (1 - \gamma) b. \tag{31}$$

Finally, the average compensation of a worker on STW is given by

$$w_t^{stw} = \int_{v_t^k}^{v_t^f} \frac{(1 - K(\varepsilon_t)) w_t + b K(\varepsilon_t) g(\varepsilon_t)}{\chi t} d\varepsilon_t. \tag{32}$$

Here, depending on the realization of ε_t the worker is sent on STW for a share of $K(\varepsilon_t)$ of her working time. For that fraction she only receives unemployment benefits. For the remainder she receives the collectively bargained wage. Since being on STW is a convex combination of full employment and unemployment, workers always prefer STW to being laid-off.

2.4 Government sector

The government has a balanced budget and finances STW expenses, unemployment benefits and traditional government spending (expenses for infrastructure, government consumption or staff) through a lump-sum tax:[15]

$$b n_t \int_{v_t^k}^{v_t^f} K(\varepsilon_t) g(\varepsilon) d\varepsilon_t + b u_t + g_t = T_t. \tag{33}$$

Government spending follows a first-order autoregressive process and may react to the business

[15] Introducing government debt would leave our results completely unaffected given that we assume lump-sum taxes and Ricardian equivalence holds. This may change with distortionary taxation. However, the effects of STW will not be affected much given that STW is a very cost efficient stabilizer (see Balleer et al., 2016 for a detailed discussion).

cycle.[16]

$$\frac{g_t}{g} = \left(\frac{g_{t-1}}{g}\right)^{\rho_g} \left(\frac{y_t}{y}\right)^{\psi_{gy}} e^{\varepsilon_{g,t}}, \tag{34}$$

where ρ_g is the first-order autoregression coefficient and ψ_{gy} shows the reaction of government spending to output deviations from steady state. $\varepsilon_{g,t}$ is a discretionary government spending shock. Again, we estimate the parameters of the rule and the shocks.

Monetary policy is modeled as a Taylor rule that targets the inflation rate

$$\frac{i_t}{i} = \pi_t^{\psi_\pi},$$

where i is the nominal interest rate, and ψ_π is the weight that the monetary authority puts on stable prices. Real and nominal interest rates are connected via the Fisher-equation $1 + i_t = (1 + r_t)(1 + \pi_{t+1})$.

2.5 Equilibrium and aggregation

The general equilibrium is defined by the bond market equilibrium (equation (3)), the labor market equilibrium (equations (22), (20), (15), (21), (22), (23), (26) and (31)) and the product market equilibrium. The latter requires that private consumption plus government spending equals production minus frictional costs, i.e.,

$$\begin{aligned} c_t + g_t &= (1-\phi^x)\left[n_t^B \int_{-\infty}^{v_t^k} (a_t - \varepsilon_t)\, g(\varepsilon_t)\, d\varepsilon + n_t^B \int_{v_t^k}^{v_t^f} (1 - K(\varepsilon_t))\,(a_t - \varepsilon_t)\, g(\varepsilon_t)\, d\varepsilon\right] \\ &\quad - n_t^B (1-\phi_t)\, c - (1-\phi^x)\, n_t^B \phi_t^e f - v_t \kappa - \frac{\Psi}{2}(\pi - 1)^2 y_t. \end{aligned} \tag{35}$$

with $n_t^B = n_{t-1} + \eta_t (1 - n_{t-1})$. Aggregate consumption equals production minus resource costs. When determining production we need to take account of the reduction in working time of workers on STW and the idiosyncratic shock. The resource costs include vacancy posting costs, firing costs, price adjustment cost and fixed costs of production.

3 Data, estimation, and impulse response functions

We fit the model to German data on GDP, government spending, the number of short-time workers and the unemployment rate from 1993Q1 to 2013Q4. The choice of these time series is led by our aim to analyze the role of institutions and shocks during the Great Recession. Government spending and the number of short-time workers capture the role of these institutions on German GDP and unemployment. Note that we focus on these series because we are interested in the real and labor market outcomes during the Great Recession.

[16]Among others, Leeper et al. (2010) have shown that government spending responds in a rule-based way to the business cycle.

The series of government spending is cash data that reflects actual cash payments. We focus on government direct expenditure, i.e., personnel expenditure, other operating expenditure and capital formation (see Tenhofen et al., 2010 for details).[17] Transfer spending is not included in the government spending series. We start our analysis after the German reunification to avoid to have to deal with the huge structural changes in the German labor market due to reunification.

Our model is perturbed by four structural shocks: shocks to aggregate productivity, government spending, short-time work and matching efficiency. A few words on the interpretation of these shocks are in order. In our setting, the productivity shock should not be interpreted in the literal sense because it captures all disturbances to output that cannot be explained by the other shocks. Obviously, the Great Recession was not (purely) driven by a decline of total factor productivity. Note, however, that aggregate demand and supply shocks would have the same qualitative effects on the time series we use (output, STW and unemployment). The decline of German net exports has for example contributed substantially to the fall in output. This would be captured by our productivity shock because we observe an unexpected decline in output. Thus, we refer to output shock instead of productivity shock henceforth. In a similar vein, the matching efficiency shocks should be interpreted as labor market performance shocks that capture all changes that cannot be explained by the other three shocks. We will use the corresponding terminology henceforth.

Given that the data is subject to long run trends, we detrend our time series with the one-sided HP filter before estimation. We estimate the log-linearized model with Bayesian techniques (e.g., An and Schorfheide, 2007). The mode of the posterior distribution is obtained using numerical maximization and the full posterior is explored with the Random Walk Metropolis Hastings algorithm.[18]

Table 1 summarizes the steady state targets and the fixed parameters. The calibration replicates the German economy and is fully in line with Balleer et al. (2016). For several parameters, we impose standard values. We normalize steady state inflation to one and the Rotemberg price adjustment costs to 128.16. This value correspond to a Calvo price stickiness of 0.75. The elasticity of substitution is 10 and the parameter for household's relative risk aversion is 1. The Taylor rule weight on inflation is 1.5.

We estimate all the parameters that determine the effects of the policy institutions and the shocks. Most importantly, we estimate the fixed cost of production c. This parameter is known to govern the amplification towards the labor market (Christoffel et al., 2009). Using a Gamma prior with mean 0.2 and standard deviation 0.15, we ensure that this parameter remains positive. For STW usage, one crucial parameter is the cost of using STW c_K. We specify again a Gamma prior with mean 20 and standard deviation 10 (see Balleer et al., 2016). Note that these two parameters affect the steady state of our model. To match the targets, we thus adjust the firing costs, the scale parameter of the profitability distribution and the costs of posting a vacancy while estimating. The effects of government spending depend on the degree of habit formation in the economy. To estimate this

[17] See Appendix for the detailed data sources.

[18] We ensure convergence of the Markov chain by diagnostic tools such as CUSUM and trace plots (see Figure 9 in the Appendix).

Parameter		Value
β	discount factor	0.99
ϵ	elasticity of substitution	10
σ	relative risk aversion	1
Ψ	Rotemberg price adjustment costs	128.16
α_π	Taylor weight on inflation	1.5
α	matching elasticity w.r.t unemployment	0.60
μ	matching efficiency	0.43
b/w	replacement rate	0.65
a	productivity	1
Steady state targets		**Value**
q	worker finding rate	0.70
ϕ	overall job destruction rate	0.03
	endogenous 1/3, exogenous 2/3	
η	job finding rate	0.31
u	unemployment rate	0.09
χ	short-time work rate	0.007
Π	inflation	1

Table 1: Calibration.

parameter, we specify a loose Beta prior with mean 0.5 and standard deviation 0.2. We also estimate the parameters that determine the behavior of the policy rules. We specify a Normal prior centered at zero with a standard deviation of 1. For the shock processes, we set a Beta prior on the autoregressive parameters with mean 0.5 and standard deviation 0.2. The variances have an inverse Gamma prior centered at 0.05 for productivity and at 0.1 for the other shocks with a large variance. Table 2 provides an overview.

The data is informative for our parameters of interest. The estimation moves the posterior away from the prior (see also Figure 8 in the Appendix). The STW costs c_K are slightly reduced compared to the prior mean, but the posterior distribution is more precise. The fixed cost of production c increase relative to the prior mean, generating more amplification towards the labor market. Habit formation is not an important property in our model. The posterior mean of this parameter is only 0.36. The STW rule turns out be very important, whereas the government spending rule is not significantly different from zero. Except for government spending, the shocks are largely persistent and the posterior distributions of the shock variances are tight. In the following we discuss the reaction of the estimated model to output shocks to highlight the mechanics of the model and the effects of STW in particular.

Figure 2 shows the impulse responses of selected variables in the estimated model in response to a negative autocorrelated output shock.[19] The negative output shock lowers the demand for labor.

[19]Impulse responses to the other shocks can be found in the Appendix E. Positive government spending shocks, STW and matching efficiency shocks all decrease unemployment.

			Prior		Posterior	
			Mean	Std.dev.	Mean	90% interval
Model parameters						
Costs of STW usage	c_K	G	20.0	10.0	19.4018	$[12.709; 26.252]$
Fixed cost of production	c	G	0.2	0.15	0.2164	$[0.1789; 0.2411]$
Degree of habit formation	h^c	B	0.5	0.2	0.3695	$[0.1160; 0.7005]$
STW rule	ψ_{Co}	N	0	1	2.4745	$[1.3482; 3.5562]$
government spending rule	ψ_G	N	0	1	-0.1546	$[-0.4226; 0.1185]$
Parameters to match targets						
linear firing costs	f				2.72	
scale parameter of the profitability distribution	s				0.97	
cost of posting a vacancy	κ				0.85	
Shock parameters						
AR(1) productivity	ρ_a	B	0.50	0.2	0.9118	$[0.8670; 0.9671]$
AR(1) matching efficiency	ρ_u	B	0.50	0.2	0.8063	$[0.70530.9151]$
AR(1) government spending	ρ_g	B	0.50	0.2	0.4189	$[0.22650.6026]$
AR(1) STW	ρ_{Co}	B	0.50	0.2	0.7668	$[0.6792; 0.8603]$
Std.dev. productivity	σ_a	IG	0.05	1	0.0089	$[0.0066; 0.0114]$
Std.dev. matching efficiency	σ_u	IG	0.1	1	0.0268	$[0.0223; 0.0312]$
Std.dev. government spending	σ_g	IG	0.1	1	0.0202	$[0.0175; 0.0227]$
Std.dev. STW	σ_{Co}	IG	0.1	1	0.0805	$[0.0503; 0.1114]$

Table 2: Posterior distributions of the estimated model parameters. The posterior is explored using the Random Walk Metropolis Hastings algorithm with $400,000$ draws. We discard the first $200,000$ draws. The average acceptance rate is 0.3577.

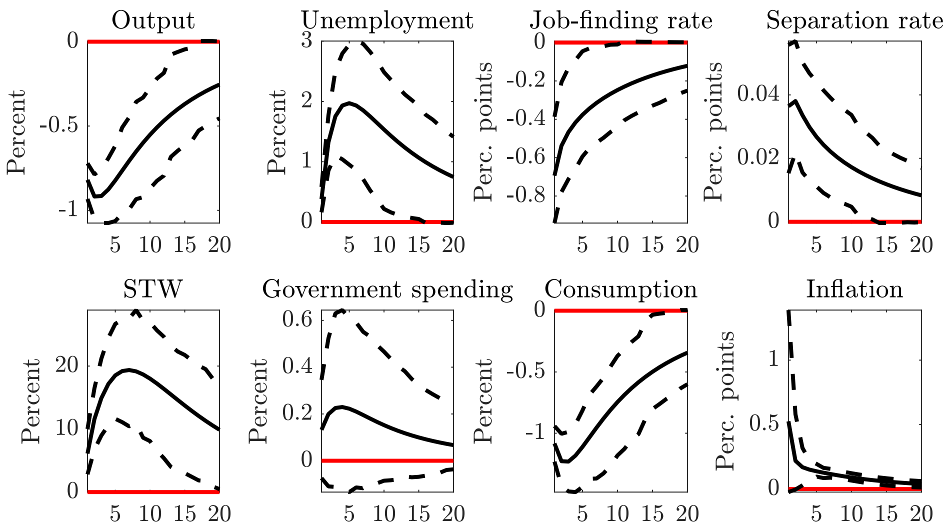

Figure 2: Estimated IRFs to output shock. The solid line shows the impulse responses at the posterior mean; the dashed lines at the 5 percent and 95 percent posterior intervals. The impulse horizon is measured in quarters.

Thus firms post fewer vacancies and fire more workers. Consequently, the probability of unemployed workers to find a job goes down, while the probability of employed workers to lose their job goes up. Both effects raise the unemployment rate. Note that the increase in the unemployment rate is substantially larger than the decrease in output (measured in percent deviations from steady state). This is due to the fixed cost of production which increases the sensibility of unemployment to output shocks and thereby circumvents the Shimer (2005) puzzle.

The two fiscal instruments, government spending and short-time work, react to the output shock in a stabilizing way. The estimated parameters of the government spending rule in equation (34) prescribe a mild increase in government spending in response to a decrease in output. The number of workers on STW goes up for two reasons. First, the reduction in demand lowers the value of a worker in equation (12). Consequently, more workers fulfill the requirement to use STW in equation (15), even without any policy changes. Second, the estimated parameters of the STW rule in equation (16) prescribe a loosening of the STW-criterion and thus a further increase in the use of STW.

STW stabilizes the labor market through two channels. On the one hand, STW allows a reduction in the working time of unproductive workers and thus lowers the separation rate. A stronger use of STW during recessions implies that the separation rate increase by less. On the other hand, the possibility to use STW raises the expected profitability of firms, which tends to indirectly raise vacancy posting and lower separations. Note that firms anticipate the reduced stringency of the STW-requirement during a recession which adds to the stabilizing effect of STW. In the following two sections, we will explore the quantitative importance of different shocks and government spending as well as STW rules during the Great Recession.

4 The role of shocks during the Great Recession

Figure 3 depicts the role of the different shocks for the dynamics of German GDP, unemployment, STW and government spending around the Great Recession (in percent deviation from the one-sided HP trend) using a historical variance decomposition of the estimated model.[20] The upper left panel of Figure 3 shows that most of the GDP variation during the Great Recession is explained by a series of negative output shocks. This is unsurprising because Germany was hit by the after-effects of the global financial crisis.

There is some spillover from the labor market to GDP. Labor market performance shocks stabilize GDP during the Great Recession.[21] Government spending and STW shocks have only very small effects on the GDP dynamics. Note that the historical decomposition only shows the effects of the discretionary policy changes. We will discuss the role of policy rules in the next section using counterfactual model simulations, where the government spending and STW rules are switched off.

German unemployment during the Great Recession is mainly determined by output shocks and labor market shocks (see upper right panel of Figure 3). Output shocks generate an increase of unem-

[20]For a variance decomposition for the entire observation period, see Appendix E.

[21]We will provide a more detailed discussion for the sources and effects of labor market shocks in the next section.

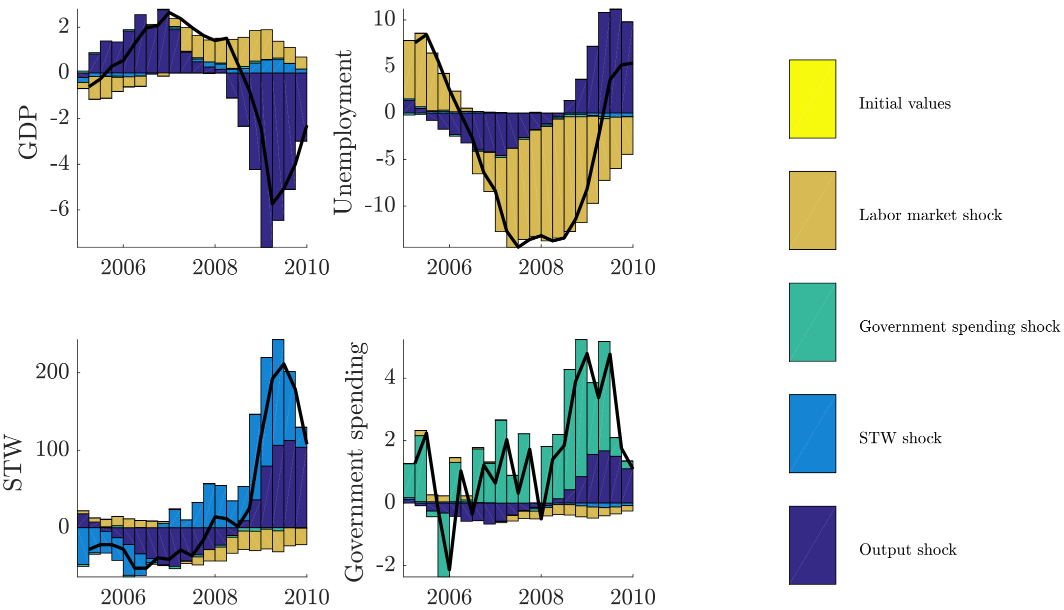

Figure 3: Historical variance decomposition of GDP, unemployment, STW, and government spending during the Great Recession. The solid line shows the time series (% deviation from HP trend).

ployment from 2009 onwards, reflecting the after-effects of the financial crisis. Note, however, that the maximum increase of unemployment due to output shocks is relatively moderate, namely about 10 percent from steady state (with a steady state unemployment rate around 9 percent at the time). Thus, according to our estimated model, unemployment increases by roughly one percentage point due to the sequence of output shocks.[22]

As discussed in the previous section, we allow our model to generate large effects of output shocks on unemployment (due to the fixed costs of production for firms). The estimation indeed chooses a specification where unemployment is more volatile than output. Although stronger amplification of output shocks would be possible in our model, this is not supported by the data. We interpret this finding in terms of a decoupling of the German labor market from GDP (see Klinger and Weber, 2015 for a similar observation).

The upper right panel of Figure 3 shows that the negative implications of the output shocks on unemployment were to a large extent offset by positive labor market shocks. We will discuss this phenomenon in more detail in the next section.

Short-time work and government spending both increased in discretionary manner during the Great Recession. This can be seen in the left lower panels in Figure 3 for STW (STW shock) and in the right lower panel in Figure 3 for government spending (government spending shock). There is some stabilizing effect of discretionary STW shocks and government spending shocks on unemployment (see upper right panel in Figure 3). However, these effects are moderate, despite substantial additional spending in these two dimensions. Discretionary government spending lowered unemployment by at

[22]Note that this statement is true for the given set of institutions, which will be varied in the next section.

most 0.03 percentage points and discretionary STW by at most 0.02 percentage points. What are the underlying reasons for these surprising results?

Government spending exhibits very small multipliers in the estimated model. This is due to the fact habits play a limited role in the estimated model. In different words, the data does not ask for an important macroeconomic role of discretionary government spending during the Great Recession.

The discretionary component of STW is largely ineffective because under the existence of a STW system, unprofitable worker-firm pairs can already be sent on STW. Thus, the extra spending by the government generates large deadweight effects. This means that extra workers are sent on STW that would not have been fired in the absence of discretionary STW measures. The intuition is similar to Balleer et al. (2016) where discretionary STW spending has zero effects. The tiny extra-effects compared to Balleer et al. (2016) are due to a larger estimated persistence of the STW shocks and general equilibrium effects.

The two lower panels in Figure 3 show the importance of the short-time work rule and the government spending rule. As can be seen in the Figure, the sequence of negative output shocks automatically increases government spending and STW (most remarkably for the latter). This is due to the estimated coefficients in these two rules (see equations (16) and (34)). The macroeconomic and labor market implications of these rules will be analyzed in more detail in the next section.

5 The role of institutions during the Great Recession

One of the major advantages of our structurally estimated model is that we can switch on and off certain institutions to analyze their effects on the aggregate outcome. Germany was hit by a major GDP decline in the Great Recession in 2008/09, but unemployment barely increased. What are the key drivers of this development, which is substantially different from other crises such as the oil price shocks in the 1970s and 80s? In order to shed light on this question, we disentangle the role of institutions based on our estimated parameters and shocks.[23]

Starting in the second quarter of 2008, the first negative output shock realization has hit the German economy. This was followed by a sequence of three additional negative output shocks in the next quarters. Figure 4 depicts the reaction of unemployment to these four negative output shocks. For illustration purposes, we do not include the recovery shocks that hit from the second quarter of 2009 onward.[24]

The solid line at the top of Figure 4 illustrates how unemployment would have evolved if this sequence of negative output shocks had hit the German economy and if there had been no other shocks and institutions. To be more precise, it shows the reaction for the counterfactual scenario where both the government spending rule and the STW rule are switched off ($\psi_\zeta = 0$ and $\psi_G = 0$). Even absent any government spending rule, STW rule and other shocks, our model simulation predicts

[23] We simulate the model at the posterior mean and feed in the filtered shocks in the Great Recession. The counterfactual exercise is based on a first-order Taylor approximation.

[24] This is the reason why unemployment and GDP do not recover in our counterfactual exercises.

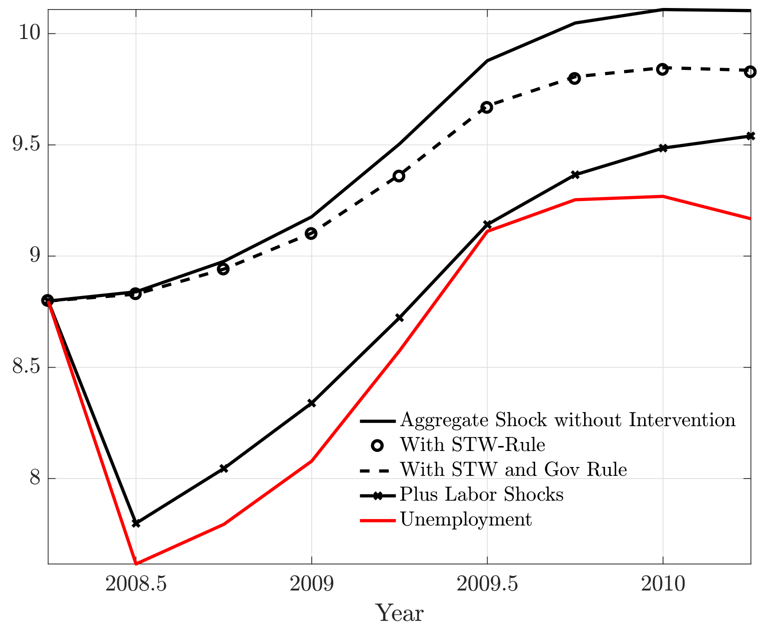

Figure 4: Counterfactuals for cyclical unemployment (black lines) and actual development (red line).

a relatively modest increase of unemployment from less than 9 percent to more than 10 percent (an increase of roughly 1.5 percentage points), despite a decline of GDP of about 7 percent in the same counterfactual scenario (see Figure 6). Compared to the reaction of unemployment in the 1980s and 90s, this appears moderate and shows that even absent other shocks and institutions, our estimated model only generates a small increase of unemployment relative to the size of the GDP movement.

The rest of Figure 4 explains why unemployment has basically not increased at all during the Great Recession. Switching the STW rule on and setting the parameter to the estimated value $\psi_\zeta = 2.47$ reduces the effects of the sequence of recessionary shocks on unemployment by at maximum 0.3 percentage points. Firms' expectations are key for this effect. With a positive value for ψ_ζ, firms know that STW can be used more extensively in the case of recessionary shocks. This initiates additional labor hoarding (less firing) and the hiring behavior drops by less than without the STW rule.

The dots in Figure 4 show what happens when the government spending rule is switched on ($\psi_G = -0.15$) in addition. As can be seen, there is virtually no difference compared to the dashed line without the government spending rule. This is unsurprising for two reasons. First, the estimated coefficient in our government spending rule is very small (and the posterior bands overlap with zero). This limits the possibility to have strong effects from the government rule. Second, government spending multipliers per se are small in our estimated model. The reason is that an increase in public spending crowds out private consumption to a large extent. This also limits the possibility for a government spending rule to be powerful. Compared to government spending, the fiscal burden of STW is smaller given that STW is a very cost-effective instrument that directly targets the labor market (Balleer et al., 2016).

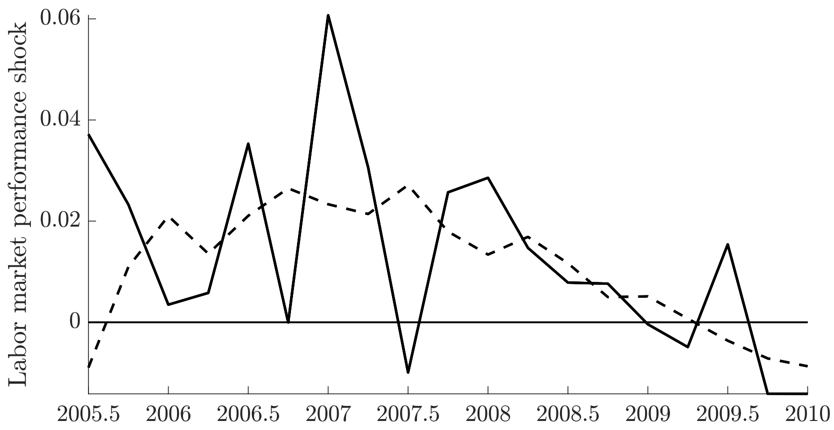

Figure 5: Labor market performance shocks (solid line) and a 4-quarter moving average of the shock series (dashed line).

Finally, Figure 4 shows that the most important reasons for the German labor market miracle were the labor market performance shocks. They bring the dynamics of unemployment very close to the red solid line, which shows the true dynamics of unemployment during the Great Recession.[25]

As illustrated by Figure 5, the German labor market was hit by a sequence of positive labor market performance shocks prior to the Great Recession.[26] According to our estimation, the labor market performance shocks have an autocorrelation of 0.81. Thus, each of these shocks had long-lasting after effects on the German labor market. In intuitive terms, the German labor market was moving to a lower steady state unemployment rate before the Great Recession hit. This downward movement of unemployment also showed up in the cyclical unemployment rate. See Figure 1 in Section 1 for a visual representation of the unemployment rate dynamics in Germany. For illustration, we show a counterfactual for how the unemployment rate would have evolved in case the negative output shocks of the Great Recession would not have occurred in Figure 13 in the Appendix. We further switch of all government intervention. This exercise illustrates how unemployment would have evolved without the crisis (and the corresponding government intervention). Interestingly, we find that the German labor market would have seen a maximum decline of unemployment by one additional percentage point in the Great Recession.

We connect these labor market performance shocks to the after-effects of the labor market market reforms that were implemented in Germany from 2003-2005 (known as the Hartz reforms), which constituted a major reform of the German unemployment benefit system as well as the Federal Employment Agency and thereby its labor market institutions. Importantly, the identification of these shocks rests on the structural DSGE model and is not causal in a microeconomic sense. However, a number of other studies document a comparable increase in matching efficiency after the reforms

[25]For consistency with the estimated model, we start from the realized level of the unemployment rate in the second quarter 2008 and add the cyclical dynamics of unemployment as used in the estimation.

[26]To be more precise: there was a series of six positive labor market performance shocks before the sequence of negative output shocks started hitting the economy.

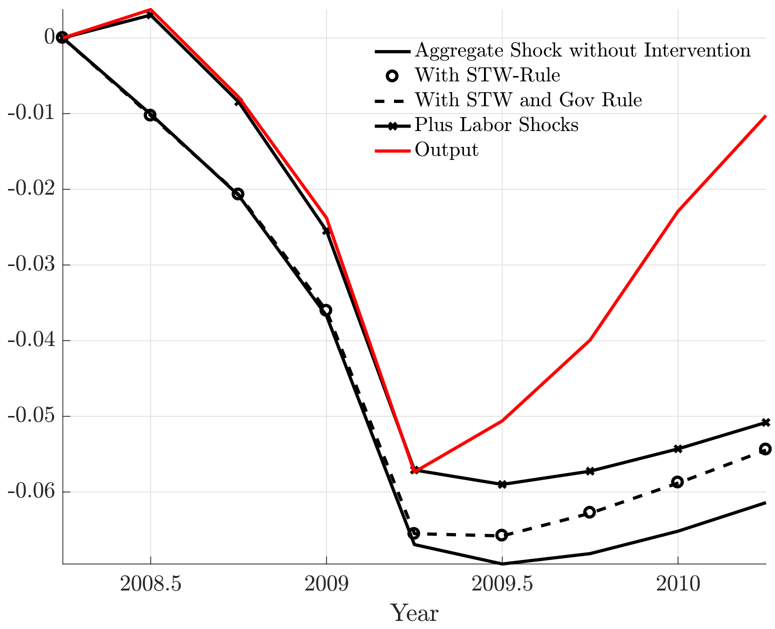

Figure 6: Counterfactuals for output (black lines) and actual development (red line). Log deviations from steady state/trend.

in Germany. Among others, Fahr and Sunde (2009), Klinger and Rothe (2012), Klinger and Weber (2016) and Gehrke and Weber (2018) come to this conclusion from matching function estimations on German data. It is reassuring that our approach yields similar outcomes, even though it is based on a very different method.

To sum up, the key driver of the German labor market miracle is the sequence of positive labor market performance shocks that have hit prior to the Great Recession. Without recessionary shocks, unemployment would have declined further. The negative aggregate output shocks and the prior positive matching efficiency shocks roughly offset one another on the labor market during the Great Recession.

What was the role of the government spending rule, the STW rule and labor market shocks for output? Figure 6 shows that the series of output shocks alone would have lead to a decline of GDP of roughly 7 percent. The STW rule lead to a stabilization of output of around 0.5 percentage points in the middle of the recession (when STW was used most). The STW rule stabilized employment and thereby the production level in the economy. Again, the expected adjustment of STW to the business cycle acts as a stabilizer. As for unemployment, the government spending rule did not have any effects on output. Finally, the labor market performance shocks stabilized output substantially. As they generated more employment, this also lead to more production. Overall, the sequence of positive labor market performance shocks that hit the German economy prior to the Great Recession, and that was most likely caused by the Hartz reforms, was an excellent business cycle stabilizer.[27]

[27] Our counterfactual simulation does not include the positive output shocks (recovery shocks) that hit after the Great Recession. For this reason, the actual development of output and the counterfactual differ from mid-2009 onwards.

6 Relation to the literature

Our paper is the first to analyze the role of different shocks and institutions during the Great Recession through the lens of an estimated dynamic stochastic general equilibrium model with search and matching and thereby builds on the work by Balleer et al. (2016). According to our estimations, the labor market performance shocks prior to the Great Recession play an important role for explaining the German labor market miracle. Thereby, our paper is both related to papers on the macroeconomic effects of the Hartz reforms and to papers that analyze sources of the German labor market miracle.

The papers on the macroeconomic effects of the Hartz reforms (Krause and Uhlig, 2012, Krebs and Scheffel, 2013, Launov and Wälde, 2013, Launov and Wälde, 2016) agree that these reforms lead to a downward shift of the steady state unemployment rate in Germany. This is in line with out estimated positive labor market performance shocks after these reforms and prior to the Great Recession. However, these papers disagree about the order of magnitude of different reform packages. Krause and Uhlig (2012) and Krebs and Scheffel (2013) find that the Hartz IV (reform of the unemployment benefit system), lead to a decline of unemployment of 2.8 and 1.4 percentage points respectively. By contrast, Launov and Wälde (2013) only find an unemployment decline of 0.1 percentage points due to Hartz IV. In a follow-up study, Launov and Wälde (2016) identify Hartz III (reform of the Federal Employment Agency) as the key driving force for the decline of unemployment. Our approach is silent on the issue which of the reform packages was most important for the decline in unemployment. However, it is reassuring that different macroeconomic studies also find an important role of the Hartz reforms on unemployment. This provides a stronger structural underpinning for the positive labor market performance shocks that we estimate in our paper prior to the Great Recession.

Boysen-Hogrefe and Groll (2010) and Boysen-Hogrefe et al. (2010) were early contributions that pointed towards the potential role of the German Hartz reforms for the German labor market miracle. However, given that these papers did not use an estimated structural framework, they are unable to perform counterfactual exercises as we do in our paper.

Möller (2010) has pointed towards the role of internal flexibility (i.e., the use of the intensive instead of the extensive margin of labor adjustment). Our paper has quantified the role of short-time work rules for stabilizing unemployment in the Great Recession and is thereby complementary to Balleer et al. (2016). Burda and Hunt (2011) argue that German firms were overly pessimistic during the 2005-07 upturn and thereby had to fire fewer workers during the subsequent downturn. We cannot test this argument directly in our framework. But we find indirect support for it in terms of the relatively moderate estimated effects of GDP on unemployment (although our framework would be flexible enough to allow for larger effects). Recent empirical evidence by Klinger and Weber (2015) points into the same direction.

This literature review shows that our paper provides value added in terms of the quantitative analysis for the underlying sources of the German labor market miracle. The existing previous results appear to be well in line with our findings. However, our paper allows for a more systematic evaluation, in particular in terms of shocks and counterfactual exercises that would be infeasible without a structural framework.

One structural paper on the interaction of the Hartz reforms and the Great Recession we are aware of is Bauer and King (2018). Their paper focuses on the puzzling fact that reallocation across occupations was very stable over time, although steady state unemployment declined very strongly. The authors argue that the Hartz reforms and the Great Recession had offsetting effects in the reallocation dimension. Although Bauer and King (2018) focus on a completely different dimension of the data, it is reassuring that (similar to us) they show an important interaction between Great Recession and Hartz reforms. Sala et al. (2012) and Casares and Vázquez (2018) investigate the German economy and labor market through the lens of estimated DSGE models and compare the Germany economy to the experience in other countries. However, in both papers, the German labor market institutions are represented in less detail compared to our approach (e.g., there is no STW).

7 Conclusions

Our paper has shown that a large part of the German labor market miracle in 2008/09 can be attributed to a series of positive labor market performance shocks some years prior to the Great Recession. Due to the timing of events, we argue that the Hartz reforms are a likely candidate to have caused these labor market shocks. In addition, we have shown that the rule-based use of short-time work has contributed to the favorable German labor market experience, although its quantitative importance was smaller than that of the labor market performance shocks. Rules are particularly powerful for short-time work because expectations are key for this instrument. If firms anticipate that more short-time work can be used in recessions, this smooths their hiring and firing behavior over the business cycle. For future work, it might be interesting to investigate in more detail the interaction of policies such as STW and uncertainty or financial constraints. Both margins are abstracted from in this paper.

From a policy perspective, our paper sounds a cautionary note on the ability of the German labor market to repeat a similar experience during the next severe recession. Although labor market institutions have contributed to the German labor market miracle, a large part of it was due to a timing coincidence, namely the strong labor market performance shocks prior to the Great Recession (likely caused by the Hartz reforms).[28] The next severe German recession will put this result of our paper to a test.

[28]This view receives additional support from the observation that the German labor market reacted much more strongly during the two oil price crises, although labor market institutions (e.g., short-time work) were not that different at the time.

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Appendix

A Germany in the Great Recession

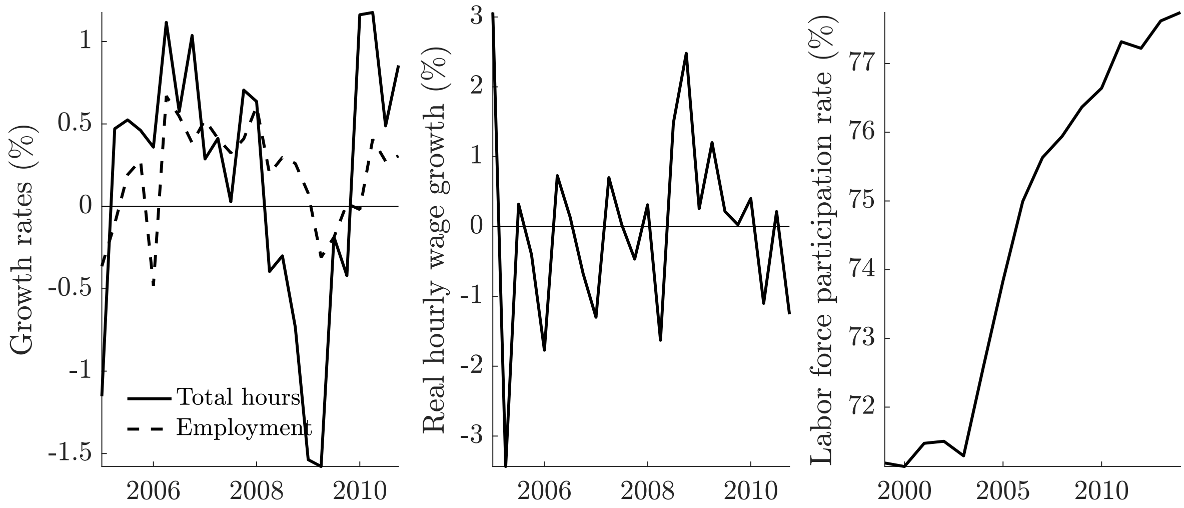

Figure 7: Hours, employment, wage and labor force dynamics in Germany before and during the Great Recession. Total hours worked, employment and hourly wages (deflated with the CPI) are from the German national accounts. The labor force participation rate (relative to working age population) is provided by the OECD.

Policy measures implemented by the German government in the Great Recession (see among others, Barabas et al., 2011, in German):

- Business cycle stimulus package I (November 2008)
  - Volume: approximately 12 billion Euro
  - Tax deductions for firms
  - Investment into infrastructure (restoration of buildings, transport, ...)
  - Increase in the maximum period that firms can use STW for
- Business cycle stimulus package II (January 2009)
  - Volume: approximately 50 billion Euro
  - Investment into education, infrastructure, IT
  - Reduction of social security contributions
  - Income tax cuts and transfers to families with children
  - Additional STW subsidies (for social security contributions) and simplification of application procedure
  - Car scrappage program ("cash for clunkers")

– Extension of qualification programs

In 2008/2009, Germany had no nationwide minimum wage. For that reason, no adjustments were made along this margin.

B Data sources

Series	Description	Source
GDP	real quarterly GDP	National Statistical Office (national accounts)
Unemployment	unemployment rate relative to dependent civilian labor force	Federal Employment Agency
Short-time work	number of short-time workers	Federal Employment Agency
Employment	number of employees covered by social security	National Statistical Office (national accounts)
Government spending	Cash data (see, Tenhofen et al., 2010)	Deutsche Bundesbank (Finanzstatistik)

Table 3: Data sources.

C Model summary

Labor market with STW:

$$n_t = (1-\phi_t)(n_{t-1} + \eta_{t-1}u_{t-1}) \tag{36}$$

$$u_t = 1 - n_t \tag{37}$$

$$q_t = \mu_t \theta_t^{-\alpha} \tag{38}$$

$$\eta_t = \mu_t \theta_t^{1-\alpha} \tag{39}$$

$$\kappa = \Lambda_{t,t+1} q_t E_t J_{t+1} \tag{40}$$

$$\begin{aligned} J_{t+1} = &(1-\phi^x) \int_{-\infty}^{v_{t+1}^k} (a_{t+1}p_{zt+1} - w_{t+1} - \varepsilon_{t+1})\, g(\varepsilon_{t+1}) d\varepsilon_{t+1} \\ &+ (1-\phi^x) \int_{v_{t+1}^k}^{v_{t+1}^f} \left[(a_{t+1}p_{zt+1} - w_{t+1} - \varepsilon_{t+1})(1 - K(\varepsilon_{t+1})) - C(K(\varepsilon_{t+1})) \right] g(\varepsilon_{t+1})\, d\varepsilon_{t+1} \\ &- (1-\phi_{t+1})\, c - (1-\phi^x)\, \phi_{t+1}^e f + (1-\phi_{t+1})\, E_{t+1}\Lambda_{t+1,t+2} J_{t+2} \end{aligned} \tag{41}$$

$$v_t = \theta_t u_t \tag{42}$$

$$w_t = \gamma a_t p_{z,t} + (1-\gamma) b \tag{43}$$

$$\phi_t^e = \int_{v_t^f}^{\infty} g(\varepsilon_t)\, d\varepsilon_t \tag{44}$$

$$\phi_t = \phi^x + (1-\phi^x)\phi_t^e \tag{45}$$

$$v_t^f = a_t p_{z,t} - w_t - c + \frac{E_t \Lambda_{t,t+1} J_{t+1}}{1-K_t} + \frac{f}{1-K_t} - \frac{c_K K_t^2}{2(1-K_t)} \tag{46}$$

$$v_t^k = a_t p_{z,t} - w_t - c + E_t \Lambda_{t,t+1} J_{t+1} + f + \zeta_t \tag{47}$$

$$\chi_t = \int_{v_t^k}^{v_t^f} g(\varepsilon_t)\, d\varepsilon_t \tag{48}$$

$$K_t = -\frac{a_t p_{z,t} - w_t - v_t^f}{c_K} \tag{49}$$

$$\begin{aligned} c_t + g_t = &(1-\phi^x) \left[n_t^B \int_{-\infty}^{v_t^k} (a_t - \varepsilon_t)\, g(\varepsilon_t)\, d\varepsilon + n_t^B \int_{v_t^k}^{v_t^f} (1 - K(\varepsilon_t))(a_t - \varepsilon_t)\, g(\varepsilon_t)\, d\varepsilon \right] \\ &- n_t^B (1-\phi_t)\, c - (1-\phi^x)\, n_t^B \phi_t^e f - v_t \kappa - \frac{\Psi}{2}(\pi - 1)^2 y_t \end{aligned} \tag{50}$$

New Keynesian part:

$$\lambda_t = (c_t - h^c c_{t-1})^{-\sigma} \tag{51}$$

$$\lambda_t = \lambda_{t+1}\beta(1 + r_t) \tag{52}$$

$$\Lambda_{t,t+1} = \beta\frac{\lambda_{t+1}}{\lambda_t} \tag{53}$$

$$0 = (1 - \epsilon) + \epsilon p_{z,t} - \Psi(\pi - 1)\pi_t + \Psi E_t \Lambda_{t,t+1}(\pi_{t+1} - 1)(y_{t+1}/y_t)\pi_{t+1} \tag{54}$$

$$i_t = (1 + r_t)\pi_t \tag{55}$$

$$\frac{i_t}{1/\beta} = \pi_t^{\psi_\pi} \tag{56}$$

$$y_t = c_t + g_t \tag{57}$$

Shock processes and policy rules:

$$\frac{a_t}{a} = \left(\frac{a_{t-1}}{a}\right)^{\rho_a} e^{\varepsilon_{a,t}} \tag{58}$$

$$\frac{\mu_t}{\mu} = \left(\frac{\mu_{t-1}}{\mu}\right)^{\rho_\mu} e^{\varepsilon_{\mu,t}} \tag{59}$$

$$\frac{g_t}{g} = \left(\frac{g_{t-1}}{g}\right)^{\rho_g} \left(\frac{y_t}{y}\right)^{\psi_{gy}} e^{\varepsilon_{g,t}} \tag{60}$$

$$\frac{1 + \zeta_t}{1 + \zeta} = \left(\frac{1 + \zeta_{t-1}}{1 + \zeta}\right)^{\rho_\zeta} \left(\frac{y_t}{y}\right)^{\psi_\zeta} e^{\zeta,t} \tag{61}$$

D Estimation output

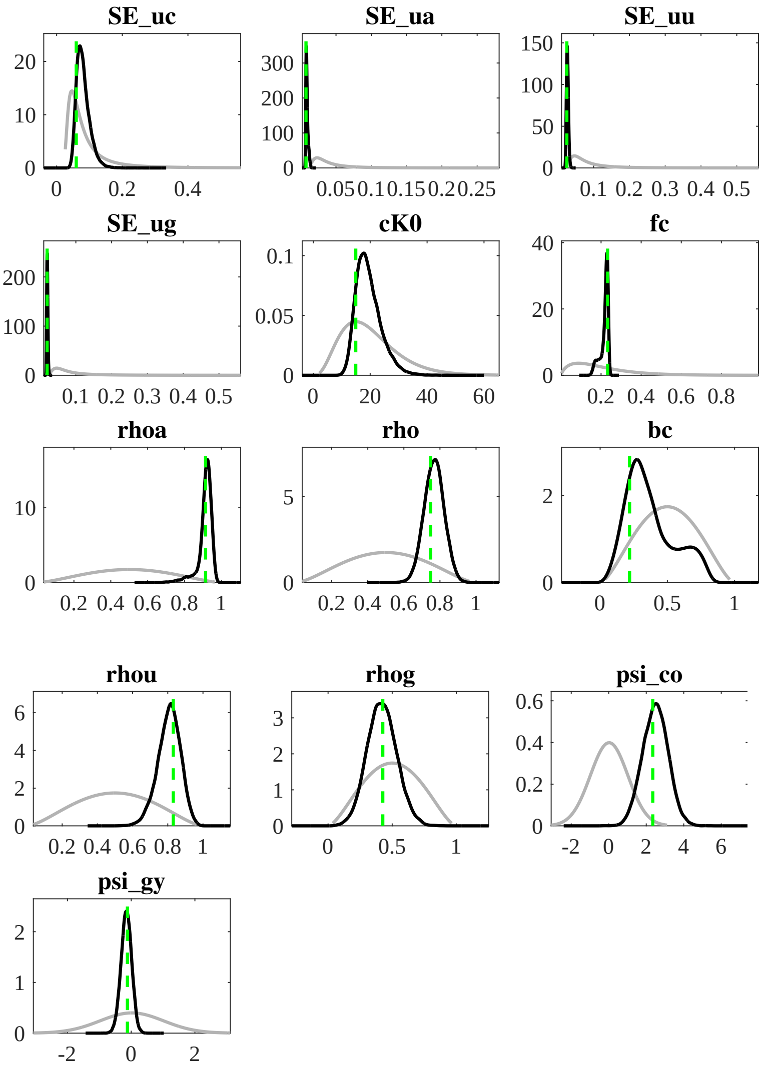

Figure 8: Prior (grey) and posterior (black) distributions.

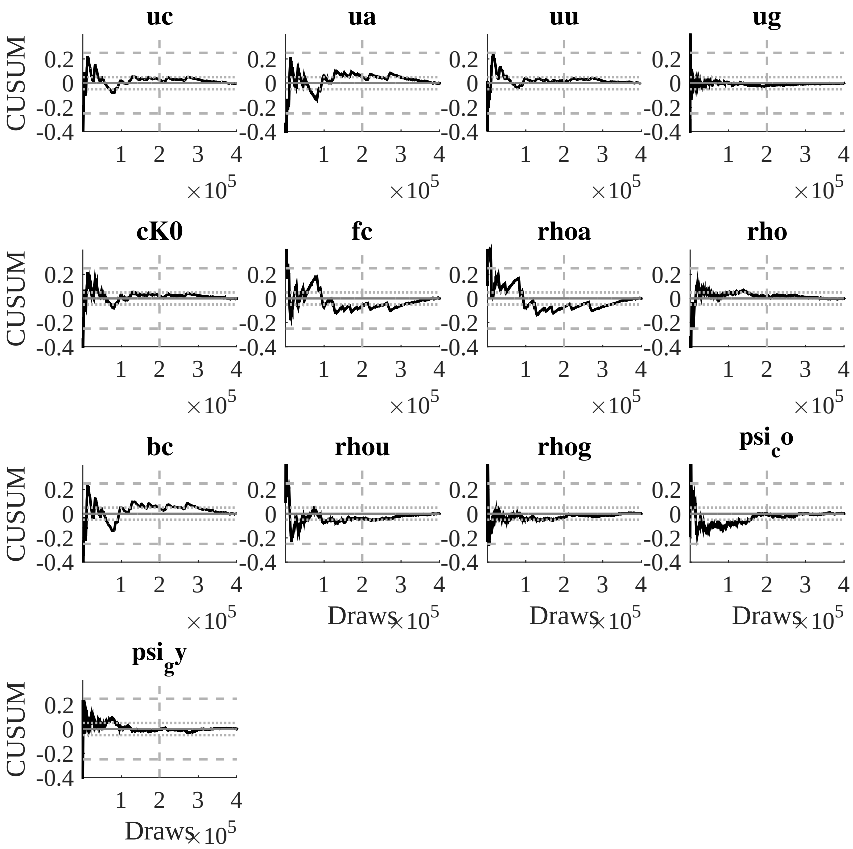

Figure 9: CUSUM statistics.

E Impulse response functions and variance decomposition

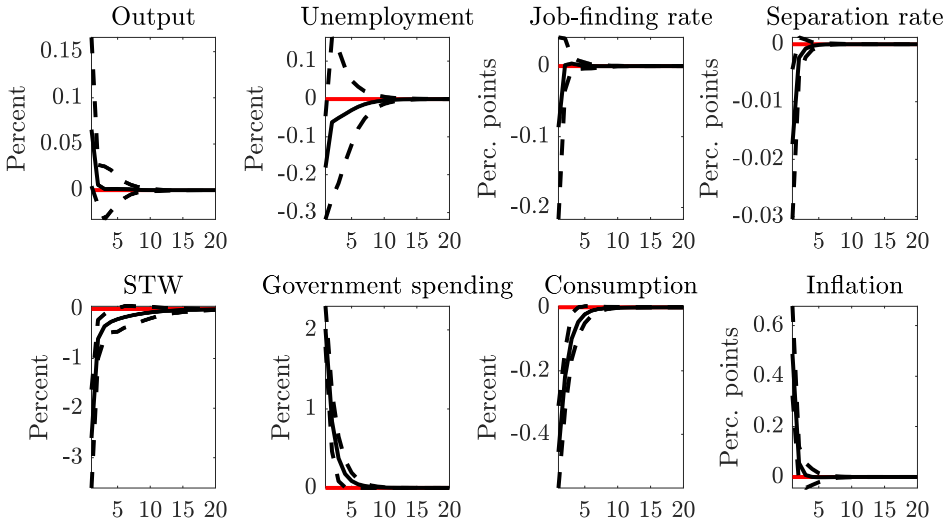

Figure 10: Estimated IRFs to a positive government spending shock. The solid line shows the impulse responses at the posterior mean; the dashed lines at the 5 percent and 95 percent posterior intervals. The impulse horizon is measured in quarters.

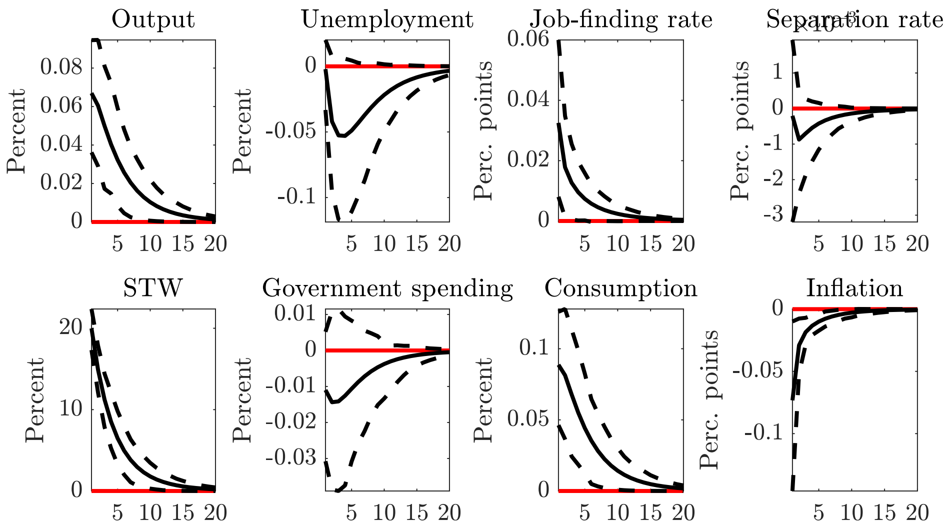

Figure 11: Estimated IRFs to a positive short-time work shock. The solid line shows the impulse responses at the posterior mean; the dashed lines at the 5 percent and 95 percent posterior intervals. The impulse horizon is measured in quarters.

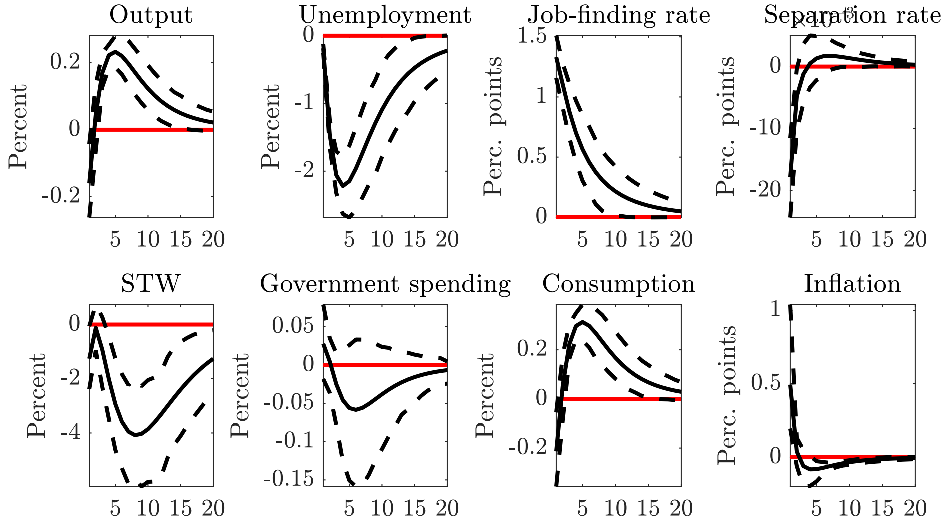

Figure 12: Estimated IRFs to a positive matching efficiency shock. The solid line shows the impulse responses at the posterior mean; the dashed lines at the 5 percent and 95 percent posterior intervals. The impulse horizon is measured in quarters.

Variable/Shock	Output	Labor market	Government spending	STW
GDP	0.85	0.14	0.01	0.01
Unemployment	0.28	0.71	0.01	0
Government spending	0.03	0.01	0.96	0
STW	0.45	0.04	0.01	0.50

Table 4: Unconditional variance decomposition (at posterior mean).

F Additional figures

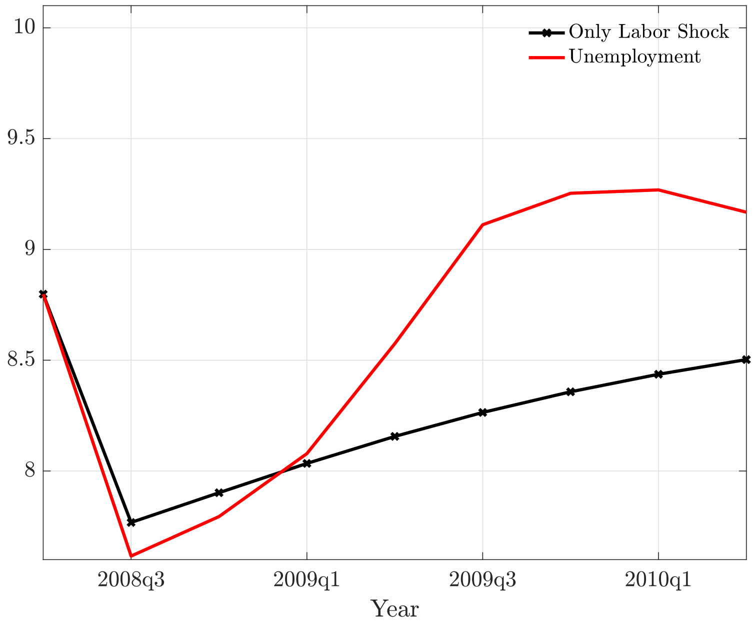

Figure 13: Counterfactuals for cyclical unemployment (black lines) and actual development (red line). Labor market performance shock only.