Short-time work in search and matching models: Evidence from Germany during the Covid-19 crisis

Peltonen, Juho

University of Helsinki, Université Paris-Saclay

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Juho Peltonen *

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Abstract

This paper estimates the extent to which unemployment in Germany would have been increased during the Covid-19 recession without a short-time work (STW) labor-market policy which enables employers to reduce temporarily the working hours of full-time workers. A Bayesian estimation of a general equilibrium model with a STW policy, and a simulation of a counterfactual model without STW, show that the German unemployment rate would have been 4.2 percentage points higher without the policy. These results indicate that the STW participates in preventing excess job destruction during economic downturns, and in stabilizing unemployment fluctuations over business cycles.

Keywords: Search and matching, short-time work, Bayesian estimation.

JEL: E24, E32, J63.

*University of Helsinki, Helsinki Graduate School of Economics, P.O. Box 17 (Arkadiankatu 7), 00014, University of Helsinki, Finland and Université Paris-Saclay, Univ Evry, EPEE, 91025, Evry-Courcouronnes, France. Email: juho.peltonen@protonmail.com. I thank Marlène Isoré, Antti Ripatti, and Fabien Tripier for supervision. I also acknowledge, Christian Merkl, Thepthida Sopraseuth and participants at the 2022 Paris-Saclay economics doctoriales for helpful discussions. This work is supported by the "ADI 2019" project funded by the IDEX Paris-Saclay, ANR-11-IDEX-0003-02, and by the OP Group Research Foundation's grant 20220090.

1 Introduction

Broadly defined, short-time work (STW) is a job retention policy, which aims at preserving employed workers during recessions, and at preventing unemployment increases. This policy saves jobs by allowing and incentivizing employers to reduce working hours of full-time workers instead of laying them off. A key element of the policy is that a government pays workers in STW benefits from hours not worked. In Germany, this policy, named Kurzarbeit, has a long tradition, since it was first established already in the 1920s (Müller & Schulten, 2020). Furthermore, during the Great Recession of 2007–2009, the German labor markets experienced a deep recession period with a very moderate unemployment increase compared to that the US.

During the Covid-19 recession of 2020, the German government supported unprecedented participation in the STW program. Up to 19% of employed workers were in STW in Spring 2020, which is a larger share than ever before. As a comparison, the same figure was 4% during the Great Recession (Organisation for Economic Co-operation and Development (OECD), 2020) and the average is 0.78% over the past 20 years.[1] In addition, the working time of workers in STW was reduced on average by almost 50% during the Covid-19, while the average reduction is approximately 30%, and furthermore the reduction during the Great Recession was not higher than the average (Herzog-Stein, Nüß, Peede, & Stein, 2021).

This paper estimates what the level of the unemployment rate Germany would have experienced during the Covid-19 crisis without the short-time work program. To answer this question, I estimate Balleer, Gehrke, Lechthaler, and Merkl (2016)'s labor-market model with STW using Bayesian techniques. Estimation quantifies the model parameters, and yields series of shock innovations. These estimated shock processes account for fluctuations in labor market variables over the sample period, including the Covid-19 pandemic. Then, I consider the same model without STW and simulate it using the estimated shock series, in order to obtain counterfactual labor market outcomes without the

[1] Source: Bundesbank (`https://www.bundesbank.de/en/statistics`) and author's calculations.

STW policy. Finally, the two sets of results are compared, which concludes, for instance, that the materialized 1.4 percentage points increase in the unemployment rate would have been 5.6 percentage points without STW.

The contribution of this paper is quantitative and twofold. First, I estimate a structural general equilibrium model with STW, using Bayesian techniques. Second, I simulate a counterfactual model without STW, in order to evaluate the impact of STW policy on unemployment stabilization. To the best of my knowledge, Bayesian techniques have not been used for this purpose so far. STW is generally quantified either from cross-country comparisons, for instance in Hijzen and Venn (2011) and Boeri and Bruecker (2011), or by exploiting microdata, for instance in Cahuc, Kramarz, and Nevoux (2021) and Kopp and Siegenthaler (2021). However, both approaches face challenges. First, the cross-country comparisons are hampered by the fact that countries are different. Even if the STW programs are comparable, many other dimensions such as institutions, administrative practices, or cultural traits differ which complicates the identification of STW from the other country-specific characteristics. Second, utilizing microdata at a firm or an establishment level within a single country cannot capture general equilibrium effects on employment or consumption from the demand side. The method of estimation and simulation in this paper has the additional benefit that it allows for the construction of a counterfactual of an identical economy without STW in a general equilibrium framework.

In general, using a novel method, this paper complements the existing literature about the effectiveness of STW in stabilizing unemployment, and preventing job destruction. Indeed, the simulation results over the last two decades of the German economy show that the variance in unemployment is 2.3 times higher, and the variance in job separations is 2.1 times higher without STW. In turn, this paper also detects some of the trade-offs of the policy. For instance, when firms are subsidized in keeping workers employed in STW, the low productive jobs are preserved. The simulations in this paper result in up to approximately 30% higher firm-level productivities during recessions in the economy without STW. Furthermore, another issue of the policy is detected from the parameter estimates of the model. They suggest that the number of workers in STW has been higher than the number of jobs which are saved from separation, which in turn implies deadweight costs for the society. This result is affected by the generous STW policy during the large recessions in the sample, but it also shows that the STW program is vulnerable to moral hazard issues, and further suggest the need for research about the optimal level of the policy.

Finally, this paper provides support for the decisions of governments that incentivized exceptionally high levels of STW during Covid-19. Without these policy extensions, the firms would have needed to adjust the labor costs through costly job destruction and re-creation, resulting in high volatility in unemployment. Moreover, as argued by Näf, Stucki, and Thomet (2022), job destruction and creation are especially costly in Continental European countries, where the role of STW has indeed been essential during the Covid-19. However, since this paper also detects the trade-offs of STW, it suggests that the policy expansions, should be limited in duration, for instance in coverage, eligibility and generosity during economic downturns.

The rest of the paper is organized as follows. Section 2 discusses the related literature. Section 3 describes the model. Section 4 presents the estimation and simulation procedure. Section 5 contains the results and analysis. Section 6 concludes.

2 Related literature

This paper investigates the German STW program, named Kurzarbeit. In Germany, Kurzarbeit has a long history, and consequently, the German STW is probably the most researched policy program in the economic literature. Three closely related papers are Cooper, Meyer, and Schott (2017), Gehrke, Lechthaler, and Merkl (2019) and Aiyar and Dao (2021). Cooper et al. (2017) estimate the parameters of a structural heterogeneous-agents search-model using a simulated method of moments and confidential plant-level micro data. Further, the paper imposes a negative productivity shock generating a recession in the model. Finally, the authors compare the impact of the shock with and without the STW policy. The same shock increases unemployment by 4 percentage points without STW, while the increase is 0.5 percentage points when the policy is active. As a comparison, this paper uses a Bayesian estimation which allows for an assessment of the full series of shocks accountable for the Covid-19 fluctuations, and further, for these series to be applied on the counterfactual simulations. However, the stabilization of 4.2 percentage points in unemployment during the Covid-19 recession in this paper is close to the results found by Cooper et al. (2017).

Gehrke et al. (2019) are estimating the impact of STW and other institutional factors on the German labor markets during the Great Recession. They are estimating a model that builds on Balleer et al. (2016) with Bayesian techniques, which makes their paper the closest to this one. However, there are important differences, most notably, this paper focuses on the Covid-19, which is not part of the data in Gehrke et al. (2019). The dataset and structural shock also diverge as Gehrke et al. (2019) have four observables, i.e. the number of short-time workers, the unemployment rate, GDP and government spending, and four shocks, i.e. TFP, matching efficiency, government spending and STW shocks. My paper has the two former series and two former shocks in common, but the third observable is the vacancy rate and the third shock is the unemployment benefit shock. Other differences are, that the data are detrended with an HP-filter and the model is log-linearized in Gehrke et al. (2019), while in this paper a linear trend is removed and the model is linearized as all the observables are rates. Finally, the counterfactual exercises also differ.

Gehrke et al. (2019) estimate that STW had a small stabilizing effect on unemployment during the Great Recession, as they find that the STW program only prevented 0.3 percentage points increase in the unemployment rate. The simulation exercise in this paper finds a more than four times larger impact, since the increase in unemployment would have been 1.3 percentage points higher without STW, during the Great Recession. At least one of the differences is likely to be important in explaining this divergence in the results. Gehrke et al. (2019) implement an STW shock in the model. As the authors show, this shock, that changes the policy criterion for participation in STW, has almost no impact on unemployment, but explains a significant fraction of the increase in the level of STW. In this paper, the exogenous policy criterion is fixed, and hence the volatility of STW is explained by the other shocks, which are also responsible for unemployment fluctuation. In addition, this paper matches the vacancy rate to data. Consequently, the volatility in job creation is restricted to observations, and it cannot prevent excessive fraction of unemployment increase. However, Gehrke et al. (2019) do not report the responses of vacancies, so the comparison of this effect is not possible. In turn, there are also equivalent results. For instance, both papers find that unemployment fluctuations are mostly driven by the TFP and matching efficiency shocks. In addition, both papers argue that STW may generate deadweight costs, since the number of workers in STW can be larger than the number workers that are actually preserved from layoffs.

Aiyar and Dao (2021) investigate the contribution of the STW expansion during the Covid-19 in preventing the unemployment increase. They are exploiting high-frequency regional data from Germany, and OLS-regression to detect that, during the second quarter of 2020, the average unemployment rate would have been 2.9 percentage points higher without the expansion of the program. Furthermore, the regional variation is considerable, for instance the increase would have been almost 4 percentage points in Hamburg. These estimates are in line with this paper, since the 4.2 percentage points higher unemployment found here is the difference between actual and simulated peak monthly values. Moreover, the counterfactual in this paper is an economy without STW, while Aiyar and Dao (2021) compare the effect of the policy coverage expansion with the STW coverage outside the Covid-19 pandemic.

Another interesting aspect of Aiyar and Dao (2021) is that they choose the strategy of analyzing regional data from a single country in order to solve the challenges related to cross-country panels, or country-level micro data. In this paper, these same challenges are solved by estimating and simulating a general equilibrium model. The benefits of the method by Aiyar and Dao (2021) are that it enables the authors to empirically identify the impact of the changes in the STW policy during the Covid-19. In turn, the method here allows this paper to investigate a fully counterfactual case where STW does not exist at all.

The German STW is also researched by Balleer et al. (2016) and Niedermayer and Tilly (2016) related to the Great Recession, Herzog-Stein et al. (2021) who compare the Great Recession and the Covid-19, and Teichgräber, Žužek, and Hensel (2022) who apply a mechanism design approach with a calibration exercise matching the pre-Great Recession Germany. Related to unemployment stabilization, Balleer et al. (2016) find that STW lowers the unemployment fluctuations by 21% and Niedermayer and Tilly (2016) that one job was retained for every four workers on STW. The stabilization during Covid-19 is larger, which is expected as the participation in STW was higher. This fact is documented in detail by Herzog-Stein et al. (2021) who show that the STW program was more expanded, and it also accounted alone for the working hour reductions during Covid-19, whereas during the Great Recession all the working-time instruments contributed to the intensive margin adjustments. The calibration exercise by Teichgräber et al. (2022) finds that the job separation rate decreases by 1.2 – 2.4 percentage points with STW, which is a qualitatively corresponding result with this paper, but difficult to compare exactly, since the Teichgräber et al. (2022)'s calibration targets an outside of recession period.

The model in this paper is from Balleer et al. (2016). They calibrate the model to match the German economy and show that STW stabilizes unemployment, and that a discretionary change in STW policy does not have an impact on unemployment. The model is recently extended by Dengler and Gehrke (2021) to include the precautionary savings of households, which are shown to amplify the stabilization effectiveness of STW.

More generally, this paper contributes to the empirical research about STW, which investigates whether the STW policy can prevent job losses and stabilize unemployment fluctuations. Related papers using cross-country analysis include Abraham and Houseman

(1994) comparing the Belgian, French, and German economies with the US, and Hijzen and Venn (2011), and Boeri and Bruecker (2011) investigating OECD and developed economies respectively. Furthermore, related country-specific research includes Cahuc et al. (2021), Benghalem, Cahuc, and Villedieu (2023) and Albertini, Fairise, Poirier, and Terriau (2022) who analyze France, Kopp and Siegenthaler (2021) and Hijzen and Salvatori (2022) Switzerland, and Osuna and Pérez (2021) Spain. In general all this literature supports the contribution of STW in stabilizing unemployment over business cycles. However, to the best of my knowledge, this paper is the first to use a Bayesian estimation and simulation method to quantify the impact of STW policy during the Covid-19 pandemic.

3 Model

The model is the search and matching model by Balleer et al. (2016), who extend Mortensen and Pissarides (1994) with a STW policy. The model is composed of households, firms and a government. The households supply labor, consume and save. Furthermore, all household members are either employed or unemployed, and the latter ones are searching for a job. The firms are producing homogeneous consumption good using labor as the input of production. In order to hire workers, the firms are posting vacancies with a fixed cost. Unemployed workers and open vacancies are matched according to a matching function as in canonical search and matching models. The government collects a lump-sum tax to finance unemployment benefits. As an addition in this model, these unemployment benefits are also paid to the workers in STW for hours not worked.

Workers in the model are ex-ante identical. In turn, job-specific productivity is determined by an idiosyncratic shock, drawn each period for all the existing job matches. If the job-specific productivity is low, the worker may generate profit losses. In this case, the firm has two choices. One, it can separate with this worker as in Mortensen and Pissarides (1994). Two, it can participate in STW and reduce working hours.

The timing of the events is the following. First, unemployed workers search for jobs and firms post vacancies. These two are matched according to a matching function. Second, an exogenous proportion of matches dissolve without decisions from any of the agents, i.e. exogenous separation occurs. Third, wages are negotiated, resulting in a surplus sharing rule, which is dependent on the aggregate state of the economy. Fourth, exogenous total productivity is realized, and all employed workers draw an idiosyncratic shock from a time-invariant distribution. Fifth, firms make a decision about endogenous separations and STW. These decisions depend on the aggregate and idiosyncratic states, as well as the wage rule. Finally, production is done and surplus is shared.

The following section presents the essential ingredients of the model, details of the full model and derivation are in Appendix A.

3.1 The firm

An idiosyncratic shock ε_t, is drawn from a time-invariant distribution with PDF $g(\varepsilon)$. This shock is transitory and drawn again each period. The value of a job with the idiosyncratic productivity ε_t is given by

$$J_t(\varepsilon_t) = a_t - \varepsilon_t - w_t - c_f + \beta E_t J_{t+1}(\varepsilon_{t+1}), \tag{1}$$

where a_t is a TFP, w_t is a wage, c_f is a fixed cost of production and β is the household's subjective discount factor.

First, the firm chooses a condition for STW. However, it cannot benefit unconditionally from the policy, hence the government sets a criterion under which the firm can participate in STW. Formally, this criterion is given by

$$J_t(\varepsilon_t) < \bar{J}, \tag{2}$$

in which $\bar{J}$ an exogenous threshold parameter. More specifically, if the value of a job is smaller than $\bar{J}$, the working hours of worker in job $J_t(\varepsilon_t)$ can be reduced in STW.

Criterion (2) also implies a threshold value of an idiosyncratic shock. On the threshold, the condition (2) holds in equality, i.e. the threshold value identifies the lowest productive job, which is not applicable for STW. The threshold value of shock is named v_t^k and solved as

$$J_t(v_t^k) = \bar{J} \quad \Leftrightarrow \quad v_t^k = a_t - w_t - c_f - \bar{J} + \beta E_t J_{t+1}(\varepsilon_{t+1}). \tag{3}$$

Noticing that the idiosyncratic shock is subtracted from the TFP in equation (1), i.e. it has a negative impact on the job value, the interpretation of the threshold v_t^k is that all the jobs with $\varepsilon_t > v_t^k$ are applicable to STW, while the jobs with $\varepsilon_t \leq v_t^k$ are full-time jobs.

After the firm has chosen the STW threshold, it decides about the optimal working-hours of workers participating in the program. The full working time is normalized to one, and the firm decides a fraction, which is reduced from the full-time. The working-time condition is a result of a maximization problem given by

$$\max_{K(\varepsilon_t)} \ (a_t - \varepsilon_t - w_t)(1 - K(\varepsilon_t)) - c_f - C(K(\varepsilon_t)), \tag{4}$$

where $K(\varepsilon_t) \in [0, 1]$ is the share of hours not worked, and $C(K(\varepsilon_t))$ is a convex cost of hour reduction. The convex cost ensures an interior solution, which enables the situation in the German labor markets to be captured, where for instance during the Covid-19 the hour cut was approximately 50% of full working time according to Herzog-Stein et al. (2021). As a comparison, a linear cost would result in a corner solution, in which the firm cuts either all the working hours or none in STW.

The optimization problem in equation (4) is solved by assuming a quadratic from for cost function $C(K(\varepsilon_t))$, which results in an optimal hour reduction as

$$K(\varepsilon_t)^* = -\frac{a - \varepsilon_t - w_t}{c_K}, \tag{5}$$

in which c_K is a fixed cost of hour cut.

Next, the firm makes a decision about endogenous separation. A difference from the canonical search and matching model is that the firm is now aware of the optimal conditions under which it participates in STW. Consequently, the optimal STW outcome is considered in a separation decision. More specifically, the firm compares the value of a job with optimal working time in STW, i.e. $(1 - K_t(\varepsilon_t)^*)$, with the cost of separation. If it is more costly to separate, the firm retains the job in STW. The separation condition is given by

$$J_t(\varepsilon_t, K(\varepsilon_t)^*) < -f, \tag{6}$$

where $J_t(\varepsilon_t, K_t(\varepsilon_t))$ is the value of STW job with optimal working time reduction K_t^* and $-f$ is a fixed separation cost. The intuition of separation condition (6) is that, if the worker with optimal working time in STW is still generating more profit losses than the separation cost $-f$, it is beneficial for the firm to separate.

Analogically with the STW threshold in equation (3), the separation threshold for the idiosyncratic productivity is named v_t^f and derived from condition (6) as

$$\begin{gathered} J_t(v_t^f, K_t(v_t^f)^*) = -f \\ \Leftrightarrow \\ v_t^f = a_t - w_t - c_f + \frac{1}{(1 - K(v_t^f)^*)}\Big[f + \beta E_t J_{t+1}(\varepsilon_{t+1}) - C(K(v_t^f)^*)\Big], \end{gathered} \tag{7}$$

where $K(v_t^f)^*$ is the optimal working hour reduction of a job with the threshold idiosyncratic productivity v_t^f, and $C(K(v_t^f)^*)$ the cost of the corresponding hour cut. The interpretation of threshold is also analogical with the STW threshold, such that the jobs with idiosyncratic productivity $\varepsilon_t > v_t^f$ are separated, and the jobs with $\varepsilon_t \leq v_t^f$ are preserved in STW. Figure 1 illustrates how the firm's choice of STW and separation thresholds divides workers into three groups.

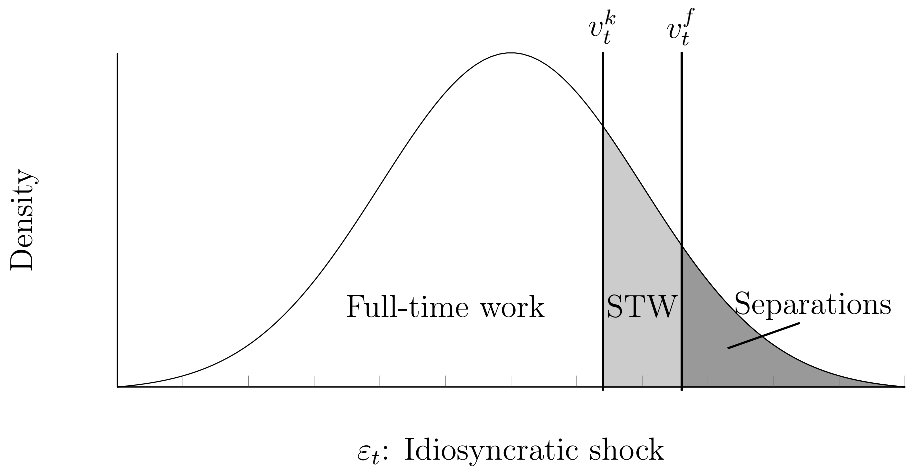

Figure 1: The idiosyncratic productivity is drawn from a time-invariant distribution. The firm chooses two thresholds for the idiosyncratic shock: STW threshold v_t^f and separation threshold v_t^k. These thresholds divide workers in three groups: separations, STW, and full-time work.

The STW and separation conditions above are dictated by exogenous parameters $\bar{J}$ and $-f$. In order to investigate further the relationship between these two parameters, let us first consider a case without STW, i.e. the case where hours are not reduced. More specifically, this means $K(v_t^f)^* = 0$ and $C(K(v_t^f)^*) = 0$ in the separation threshold equation (7). In this case, the separation threshold (7) would collapse to correspond the STW threshold in equation (3), with the difference that the former has f and the latter $-\bar{J}$ on the RHS. Consequently, setting $\bar{J} = -f$ would imply $v_t^k = v_t^f$. Next, if we keep the assumption that $\bar{J} = -f$, and consider the case where the firm cuts hours in STW, i.e. $K(\varepsilon_t)^* > 0$ the two thresholds diverge such that $v_t^k < v_t^f$. Furthermore, this implies that the jobs are preserved from separation, only if the firm benefits from hour reductions in STW. In other words, if $\bar{J} = -f$, STW is saving jobs which would be destroyed without the policy.

The productivity distribution $g(\varepsilon)$ and the thresholds v_t^k and v_t^f define the share of workers in STW, named χ_t, and given by

$$\chi_t = \int_{v_t^k}^{v_t^f} g(\varepsilon)d\varepsilon, \tag{8}$$

and the rate of endogenous separations, named ρ_t^e, and given by

$$\rho_t^e = \int_{v_t^f}^{\infty} g(\varepsilon)d\varepsilon. \tag{9}$$

Finally, the total separation rate is a sum of exogenous and endogenous shares, following Den Haan, Ramey, and Watson (2000), as

$$\rho_t = \rho^X + \left(1 - \rho^X\right) \rho_t^e, \tag{10}$$

where ρ_t is the total separation rate and ρ^X is an exogenous separation rate.

Job creation is more standard and follows canonical search and matching models. More specifically, new workers are not hired directly to STW, since the idiosyncratic productivity is not known at the moment of vacancy posting. The firm is posting vacancies with a fixed cost to hire unemployed workers. The free entry condition of vacancies is assumed to hold, i.e. an open vacancy does not have any value. As a result, the job creation condition equates the cost of hiring with the expected value of a filled job, and is given by

$$\frac{\kappa}{q(\theta_t)} = \beta E_t J_{t+1}(\varepsilon_{t+1}), \tag{11}$$

where κ is a fixed vacancy posting cost, θ_t is labor market tightness and $q(\theta_t)$ is a vacancy filling rate.

The employment evolution is also standard

$$n_{t+1} = (1 - \rho_{t+1})(n_t + q(\theta_t)v_t), \tag{12}$$

in which n_t is employment and v_t is a number of vacancies. As is common in the literature the labor force is normalized to one, yielding unemployment, u_t, as $u_t = 1 - n_t$.

Wages are bargained collectively, meaning that the labor union is bargaining the same wage for all workers. In addition, the outside option in the bargaining process is a strike. During a strike production does not occur, and wages are not paid, but the workers remain employed, and the firm holds the value of job matches. In addition, it is assumed that the workers receive a strike allowance, which is equivalent to an unemployment benefit. In this setting, the wage becomes dependent only on the aggregate productivity and the reservation wage. Due to the assumption of the strike allowance, the latter equals the unemployment benefit as is standard in the wage bargaining models. The wage bargaining result is then given by

$$w_t = \gamma a_t + (1 - \gamma) b_t, \tag{13}$$

where γ is the bargaining power of workers, and b_t is an unemployment benefit, which is subject to an exogenous shock, and hence time varying. This shock is added for the estimation purposes and specified later.

Finally, the aggregate output is a combination of outputs by full-time and STW workers net of fixed costs, as

$$Y_t = \underbrace{\frac{n_t}{1-\rho_t^e}}_{\text{Employment}} \underbrace{\int_{-\infty}^{v_t^k} (a_t - \varepsilon_t) g(\varepsilon_t) d\varepsilon_t}_{\text{Full-time workers' output}}$$

$$+\frac{n_t}{1-\rho_t^e} \underbrace{\int_{v_t^k}^{v_t^f} [(a_t - \varepsilon_t)(1 - K^*(\varepsilon_t)) - C(K^*(\varepsilon_t))] g(\varepsilon_t) d\varepsilon_t}_{\text{STW workers' output}} \tag{14}$$

$$\underbrace{-n_t c_f - \frac{n_t}{1-\rho_t^e} \rho_t^e f - v_t \kappa}_{\text{Fixed costs of production, separations, vacancies}} \quad .$$

The stock of employees in equation (14) is derived from employment evolution equation (12) and the definition of total separation rate (10).

3.2 The household, the government and closing the model

The household in the model supplies labor, consumes and saves to risk-free government bonds. The members of the household are either employed or unemployed. The household's income consists of wages and unemployment benefits. As usual, the unemployed household members earn only unemployment benefits and the employed workers, who are working full working hours, earn full wages. In turn, as a difference from canonical labor market models, the STW workers earn wages from hours worked, and unemployment benefits from hours not worked. Hence, the household budget constraint is

$$\begin{aligned} C_t + B_{t+1} = & \underbrace{w_t \frac{n_t}{1-\rho_t^e} \int_{-\infty}^{v_t^k} g(\varepsilon_t) d\varepsilon_t}_{\text{Wages of full-time workers}} + \underbrace{w_t \frac{n_t}{1-\rho_t^e} \int_{v_t^k}^{v_t^f} (1 - K^*(\varepsilon_t)) g(\varepsilon_t) d\varepsilon_t}_{\text{Wages of STW workers}} \\ & + \underbrace{b_t \frac{n_t}{1-\rho_t^e} \int_{v_t^k}^{v_t^f} K^*(\varepsilon_t) g(\varepsilon_t) d\varepsilon_t}_{\text{Unemployment benefits of STW workers}} + b_t u_t + R_t B_t + \Pi_t - T_t, \end{aligned} \tag{15}$$

in which C_t is consumption, B_t a government risk-free bond, R_t a gross return of the bond, Π_t the profits from firms which the household owns, and T_t a lump sum tax.

The household derives utility from consumption. The utility function is named $U(C_t)$, which the household maximizes over time, by choosing consumption C_t and the government bond purchases B_{t+1} subject to a budget constraint in equation (15). The first order conditions for consumption and bonds yield to standard consumption Euler equation as

$$\frac{1}{R_{t+1}} = \beta E_t \frac{U'(C_{t+1})}{U'(C_t)}, \tag{16}$$

where U' is the derivative of utility function w.r.t consumption.

Respectively, the government pays unemployment benefits not only to unemployed workers, but also for hours not worked to workers in STW. The benefits are financed by lump sum tax and borrowing. The government runs a balanced budget, with budget constraint given by

$$b_t \frac{n_t}{1-\rho_t^e} \int_{v_t^k}^{v_t^f} K^*(\varepsilon_t) g(\varepsilon_t) d\varepsilon_t + b_t u_t + R_t B_t = T_t + B_{t+1}. \tag{17}$$

All output which is left after the frictional costs, is consumed. The frictional costs are subtracted in equation (14). Hence, the aggregate budget constraint is simply

$$Y_t = C_t. \tag{18}$$

3.3 Shocks and functional forms

This section defines the exogenous shock processes which are estimated later in the paper. In addition, the functional forms which are not presented before in the model section are specified here.

The matching function is defined to take Cobb-Douglas form, given by

$$m_t = \mu_t u_t^{\alpha} v_t^{1-\alpha}, \tag{19}$$

where m_t is the number of matches, μ_t a matching efficiency, and α the elasticity of matches w.r.t. to unemployment. The matching efficiency is subject to an exogenous shock. Moreover, the matching function implies a vacancy filling rate as

$$q(\theta_t) = \mu_t \theta_t^{-\alpha}. \tag{20}$$

The second function which is specified, is the household's utility function. It is assumed to take CRRA form as

$$U(C_t) = \left(\frac{C_t^{1-\sigma} - 1}{1-\sigma} \right), \tag{21}$$

in which σ is a risk-aversion parameter.

There are three exogenous shocks in the model, productivity shock, workers' outside option shock, and matching efficiency shock. These shocks are selected such that they can be identified, since they generate distinct responses of the variables of the model. Furthermore, all of the shocks are assumed to take $AR(1)$ form.

Productivity shock is imposed on the common productivity component, for instance in output equation (14), and given by

$$a_t = (1-\rho^a)\bar{a} + \rho^a a_{t-1} + \epsilon_t^a, \qquad \epsilon_t^a \sim \mathcal{N}(0, \sigma^a), \tag{22}$$

where ρ^a is the persistence parameter, $\bar{a}$ a steady-state value of the common productivity a_t, and ϵ_t^a an independently and identically distributed shock with standard deviation σ^a.

Workers' outside option, i.e. the unemployment benefit b_t in the wage rule (13), is subject to the workers' outside option shock as

$$b_t = (1-\rho^b)\bar{b} + \rho^b b_{t-1} + \epsilon_t^b, \qquad \epsilon_t^b \sim \mathcal{N}(0, \sigma^b), \tag{23}$$

in which ρ^b is the persistence parameter, $\bar{b}$ a steady-state value of the unemployment benefit b_t, and ϵ_t^b an independently and identically distributed shock with standard deviation σ^b.

Finally, the matching efficiency shock is imposed on the matching efficiency μ_t in the matching function (19), and given by

$$\mu_t = (1-\rho^\mu)\bar{\mu} + \rho^\mu \mu_{t-1} + \epsilon_t^\mu \qquad \epsilon_t^\mu \sim \mathcal{N}(0, \sigma^\mu), \tag{24}$$

where ρ^μ is the persistence parameter, $\bar{\mu}$ a steady-state value of the matching efficiency, and ϵ_t^μ an independently and identically distributed shock with standard deviation σ^μ.

4 Estimation and simulation

The model is estimated using Bayesian techniques. The model is linearized around a deterministic steady state. I choose the prior distributions for the estimated parameters and use the Metropolis-Hastings algorithm to estimate their posterior distributions. Furthermore, the estimation yields shock processes which are accountable for the fluctuations in the model. These shock series are used to simulate a counterfactual model without the STW policy. The estimation, numerical solution of the model, and the simulation of counterfactual model are done using Dynare software version 5.0 (Adjemian et al., 2022).

4.1 Data

The estimation uses monthly data from Germany between January 2000 and November 2021. The observed variables are the unemployment rate u_t, the vacancy rate v_t, and the STW rate χ_t. All the data is retrieved from the Bundesbank statistics database, and provided there by the Federal Employment Agency. The unemployment rate is available as such, but the vacancy rate and STW rate are calculated from the levels, by using an additional data series of employed workers. For vacancies, we should note, that the Federal Employment Agency has data about the official vacancies opened through the public employment agencies, and hence lacks vacancies which are only available through private search channels (Merkl & Sauerbier, 2023). (Details in appendix B.1).

A peculiarity of the data is, that the German unemployment series has a strong declining trend between mid-2005 and mid-2019. This trend is attributed to a series of labor market reforms, known as the Hartz reforms (see Krause and Uhlig (2012), Krebs and Scheffel (2013), Launov and Wälde (2013) and Hochmuth, Kohlbrecher, Merkl, and Gartner (2021) for the details of the reform). Since this paper studies cyclical fluctuations, with the primary time-period of interest being the Covid-19, the trend is removed in a following way. First, the linear trend between the beginning of the sample and the beginning of the Covid-19 in February 2020 is removed. Then, the Covid-19 period is attached at the end of the detrended series. Finally, the new observation series is demeaned. The described approach to process the unemployment data is used, in order to capture precise fluctuations during the Covid-19, which is at the very end of the sample. For instance, HP-filter results in a significant boom before a bust of the Covid-19, which is counterfactual, as the German unemployment rate remains completely stable between 4.9–5% for 16 months preceding the Covid-19 pandemic. (See also appendix B.2).

In addition, the Hartz reforms have resulted in an increasing trend in vacancy rate series. The vacancy rate trend is less considerable, and also more stable throughout the whole sample as compared with the unemployment rate data. Hence, the linear trend is removed from the whole series. Furthermore, the vacancy rate series is also demeaned. The STW series is not detrended or demeaned, since the participation in the policy is very low outside recessions. More precisely, clearly less than 1% of employed workers are in STW during expansions, and the average STW rate over the whole sample, including the Great Recession and the Covid-19 is only 0.78%. In turn, the increases in STW participation during the two big recession periods are significant, as approximately up to 4% and 14% of employed workers were in STW during the Great Recession and the Covid-19 respectively. This is clearly visible in Figure 2, which depicts the data series used in estimation.

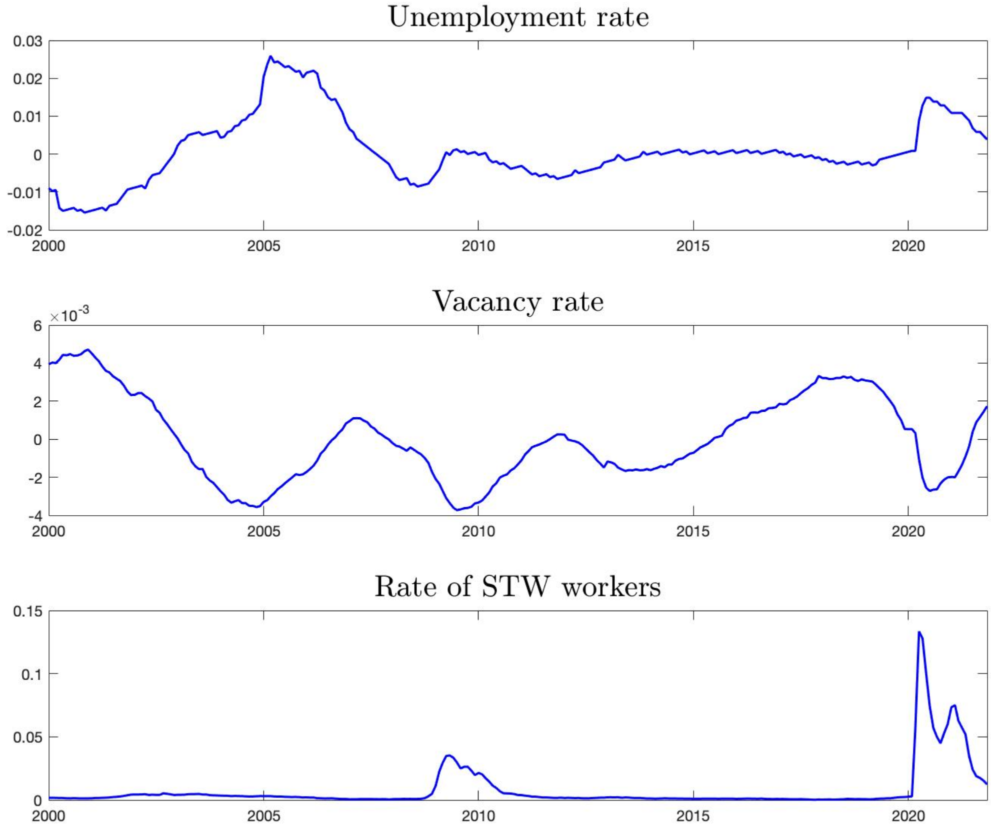

Figure 2: Observed variables in estimation. The unemployment and vacancy rate detrended and demeaned cyclical components.

The shift in trend which follows the Hartz reforms can be dated to begin around year 2005. The choice to remove the linear trend from the beginning of the sample, which is earlier than the shift can then result in overemphasizing the fluctuations in early 2000s. On one hand, this may lead to parameter estimates which exaggerate the tightness of criterion to participate in STW policy, since there is no significant volatility in the STW participation in the early 2000s. On the other hand, the higher volatility in the sample improves identification. Furthermore, the lower volatility at the beginning of the sample could increase the relative magnitudes of estimated shocks affecting the Great Recession and the Covid-19 fluctuations, which would then lead to an even larger increase in unemployment in counterfactual simulations. Hence, this filtering method is not likely to result in an overestimation of the stabilization effect of STW during the large recessions.

4.2 Calibration

This section presents the calibrated parameter values. As the number of observables in the estimation is limited, and these observables are related to labor markets, there is insufficient information to identify all parameters in the Bayesian estimation. Hence, a number of parameters are calibrated. In addition, the steady-state targets for variables are chosen.

Table 1 summarizes the calibration, which closely follows the original article by Balleer et al. (2016). The subjective discount factor is chosen to match annual risk-free interest rate of 4.5%. I follow Balleer et al. (2016) in setting the fixed cost of production, as there is not enough information in the data to estimate this cost. The same applies to the bargaining power of workers, and to the household's risk aversion parameters. The former is set to a neutral value of 0.5, which equalizes the surplus sharing between workers and firms. The latter is set to a non-informative value of 1.

The monthly vacancy rate in the data is 0.0111, which further implies the steady-state separation rate. Following the arguments in Den Haan et al. (2000), approximately two-thirds of the total separations are assumed exogenous and one third endogenous, i.e. here 0.01 and 0.006 respectively. Moreover, the distribution of idiosyncratic productivity is assumed to be a logistic distribution, which is the definition in Balleer et al. (2016). The benefit of the logistic distribution is that it is close to normal distribution with thicker tails but allows for analytical solutions. The unconditional mean of the distribution is set to zero, and the standard deviation, also named a scale parameter in a logistic distribution case, is set to 1.029 following Balleer et al. (2016). Moreover, the chosen calibration results in profit losses from the workers in STW, while the full-time jobs are creating positive profits.

Parameter	Description	Value	Source
β	Discount factor	0.996	Annual risk-free rate 4.5%
c_f	Fixed cost of production	0.225	Balleer et al. (2016)
γ	Workers' bargaining power	0.5	Balleer et al. (2016)
σ	Risk aversion	1	Balleer et al. (2016)
ρ^X	Exogenous separations	0.01	Monthly vacancy rate 0.0111
s	STD of idiosyncratic distribution	1.029	Losses in STW and profits in FT
μ^g	Mean of idiosyncratic distribution	0	Losses in STW and profits in FT
g	Idiosyncratic distribution	Logistic	Balleer et al. (2016)
Steady-state target			
$\bar{\mu}$	Matching efficiency	0.433	Monthly $q = 0.70$, $v = 0.0111$
$\bar{u}$	Unemployment rate	0.078	Average 2000-2021
$\bar{\rho^e}$	Endogenous separations	0.006	Monthly vacancy rate 0.0111
$\bar{\chi}$	Rate of STW	0.0078	Average 2000-2021
$\bar{K^*}$	Working time reduction	0.33	Balleer et al. (2016)
$\bar{A}$	TFP	1	Standard in the literature
$\bar{b}$	Unemployment benefit	0.65	Replacement rate 65%

Table 1: Calibration

The steady-state target of unemployment rate is set to 7.8% which is the mean in the data. Jointly, the aforementioned vacancy rate and unemployment rate imply a steady-state labor market tightness. Further, the matching efficiency in the steady state is set to 0.433, in order to target a vacancy filling probability around 0.7 and job finding probability around 0.2. We should note here that the matching efficiency is subject to an exogenous shock which is estimated later, lowering the significance of the steady-state calibration.

The steady-state rate of workers in STW is set to 0.78% of employment, which is the average in the data. This is 0.1 percentage points higher than the estimate in Balleer et al. (2016) due to the impact of the Covid-19 recession. However, the working hour reduction is set to one-third of full working time as in Balleer et al. (2016). One third, is approximately the long-term average that applies also during the Great Recession, even if the hour reduction is momentarily higher during the Covid-19 (Herzog-Stein et al., 2021).

Finally, the steady state of common productivity component $\bar{A}$ is set to one, which is standard in the macro-literature. The steady-state target of unemployment benefit is set to 0.65 which implies approximately 65% replacement rate. Both these variables are subject to an exogenous shock processes, which are estimated later.

4.3 Priors

The parameters for estimation are the separation cost f, the STW policy criterion $\bar{J}$, the elasticity of matching function α, the vacancy posting cost κ, and hour reduction cost c_k. The costs are estimated as they cannot be directly observed from the data. Especially, the parameters of interest are the separation cost f and the STW criterion $\bar{J}$, since these two dictate the choices between job destruction and STW.

	Prior			Posterior			
Parameter	Dist.	Mean	Stdev.	Mean	Stdev.	HPD inf	HPD sup
f	gamma	2.400	0.5000	2.681	0.0671	2.5816	2.7899
$\bar{J}$	normal	-2.000	0.2000	-0.874	0.0722	-0.9945	-0.7582
α	beta	0.600	0.1000	0.968	0.0076	0.9552	0.9781
κ	gamma	1.200	0.1000	1.383	0.0161	1.3570	1.4066
c_k	normal	22.000	0.1000	21.984	0.0975	21.8321	22.1433

Table 2: Results from Metropolis-Hastings, parameter priors and posteriors

Table 2 contains the prior distributions and the posterior results from the Metropolis-

Hastings algorithm. Parameters f and κ are costs, so they can only get a positive real value, hence the prior is set to follow a gamma distribution. I choose the prior means of the separation cost f and the vacancy cost κ, based on the calibration in Balleer et al. (2016), as values 2.4 and 1.2 respectively. The standard deviation of the separation cost is set to 0.5, which is relatively loose allow for potentially large moves due the big recessions in the sample, especially the Covid-19 recession. I set the standard deviation of vacancy cost κ to 0.1.

A beta distribution prior is assigned to the matching elasticity parameter α which can only get values on the unit interval. The prior mean is set to 0.6, which is supported by the survey findings by Petrongolo and Pissarides (2001) for large European economies, and in addition is the calibration value in Balleer et al. (2016). A relatively loose standard deviation of 0.1 allows the values from the whole unit interval.

The value of STW criterion $\bar{J}$ can, at least in theoretical sense, be either positive or negative, hence its prior is set to follow normal distribution. As discussed in the model section of this paper, the relationship between the separation cost f and the STW criterion $\bar{J}$ is particularly interesting. More specifically, the situation, in which the STW participation is an efficient option for separations requires that $\bar{J} = -f$. Since, the policy makers have an incentive to change the STW criterion to more generous during the economic downturns, I choose the prior mean of $\bar{J}$ higher than $-f$, and set the value as -2.0. In addition, the standard deviation is set to 0.2, resulting in a wider distribution, in order to allow a significantly more generous criterion, which can be assumed to be a result of the Covid-19 period in the sample.

Finally, the most peculiar parameter for the estimation is the hour reduction cost c_k. Correspondingly with the other costs, it is assumed to be positive. However, the calibration in Balleer et al. (2016) uses rather large value of 22.0 of this parameter. Hence, I choose a normal distribution with a mean of 22.0 and a standard deviation of 0.1. This prior yields to a symmetric distribution between lower and higher values, but simultaneously the negative values of the parameter are extremely unlikely.

	Prior			Posterior			
Parameter	Dist.	Mean	Stdev.	Mean	Stdev.	HPD inf	HPD sup
ρ^a	beta	0.800	0.1000	0.977	0.0048	0.9697	0.9853
ρ^μ	beta	0.800	0.1000	0.995	0.0018	0.9930	0.9987
ρ^b	beta	0.500	0.1000	0.173	0.0252	0.1332	0.2133
σ^a	invg	0.100	Inf	0.017	0.0015	0.0140	0.0187
σ^μ	invg	0.100	Inf	0.042	0.0019	0.0387	0.0446
σ^b	invg	0.100	Inf	0.834	0.0610	0.7438	0.9370

Table 3: Results from Metropolis-Hastings, shocks

Table 3 contains the prior distributions and the posterior results of the shock processes. Priors are chosen following the tradition in the literature about the Bayesian estimation of structural macro models. More specifically, the persistence parameters are set to follow a beta distribution as they can get values on a unit interval, and the standard deviations follow an inverse gamma distribution. Furthermore, the latter parameters have identical priors as the means are set to 0.1 and standard deviations to infinity. For the productivity shock persistence ρ^a, and the matching efficiency shock persistence ρ^μ, the prior means are set to 0.8 and standard deviations to 0.1. In order to allow the estimation of only the shock processes without structural parameters for the simulation purposes later, the third shock, i.e. the workers' outside option shock has a different prior with a mean of 0.5 and a standard deviation of 0.1. This specification of priors avoids problems of symmetricality when estimating only the shocks. In addition, the productivity and matching efficiency shocks are present in the literature with dynamic labor market models, in which they are usually assumed to be persistent. For instance, Lubik (2009) sets a prior persistence to a high value of 0.9 for both shocks in a related model. In turn, the shock on unemployment benefit is less common, which supports a weakly-informative prior.

4.4 Posteriors

The posterior estimates of means, standard deviations, and 5th and 95th percentiles are presented with the priors in Tables 2 and 3. Posterior estimates for the separation cost f, the STW criterion $\bar{J}$, the matching elasticity α, the vacancy cost κ, and all the parameters of structural shocks are not overlapping with the prior implying a good identification of these parameters. In turn, the hour reduction cost c_K seems to be converging to a value following the prior, which suggest that there is insufficient information in the observation series for identification of this parameter value. However, the other estimates seem to be robust, whether the c_K parameter is part of the estimation set or not, hence it is not likely to impact the outcome of the estimation, and simulation exercise later.

The posterior estimate of separation cost f is slightly higher than the prior, more specifically, approximately 2.7 against 2.4 respectively. In turn, the posterior mean of STW criterion $\bar{J}$ is considerably higher than the prior, i.e. approximately -0.9 versus -2.0. The values of both of these posteriors are most likely impacted by the large recession periods in the sample, during which the STW has been specifically incentivized by the government. When the benefits of participation in STW are increased, the relative cost of separation has also increased, which is shown in the estimate of parameter f.

The matching efficiency parameter α has a posterior which is significantly moved from the prior value. The posterior value of 0.97 is very high, suggesting that the increase in unemployment affects the new matches in almost one-to-one relation. This may be a result of the existence of STW in the model, since the policy stabilizes unemployment fluctuations. Since the changes in unemployment are smaller due to STW, the job matches become more reactive to these changes leading to a high elasticity estimate.

Finally, the two remaining parameters, the vacancy cost κ and the hour reduction cost c_K are estimated as being close to their prior values. The vacancy cost increases from a prior value of 1.2 to approximately 1.4 as posterior mean, with a narrow confidence interval, suggesting a good identification. In turn, as mentioned above, the hour reduction cost is not well identified, which is implied by the posterior values that follow closely the prior.

The shock parameters are all well identified. The productivity shock A_t and the matching efficiency shock μ_t have high persistences of 0.977 and 0.995 respectively, and low standard deviations of 0.017 and 0.042 respectively. The third shock, the shock on unemployment benefit b_t, is more peculiar as it is very transient with persistence of 0.173, but with a considerably high standard deviation of 0.834. In other words, it seems that the workers have occasionally experienced relatively strong, but very short lived shifts in their outside option. These types of temporary changes in unemployment benefits may be the result of policies which have been implemented during the large recessions, such as the Great Recession or the Covid-19 recession.

4.5 Simulation

The purpose of the simulation exercise, is to compare the economy with STW with a counterfactual economy without the policy. The strategy is the following. The previous section described the estimation process. As one of the outcomes, the estimation yields the time-series of the shocks which are accountable for the fluctuations in macro-variables over the sample period. Next, these shock series are imposed on a counterfactual model which does not have STW but is otherwise equivalent with the estimated model. Finally, the responses of the counterfactual model on the estimated shocks are compared with the baseline model that has the STW policy.

The counterfactual model is constructed by removing the STW policy from the estimated model. This has an impact on the steady state of the counterfactual model. Since, the firms no longer have access to STW, job destruction increases i.e., the separation rate shifts from 2.9% to 3.7%. However, simultaneously also job creation is higher, i.e. the vacancy rate increases from 4.1% to 4.8%. Jointly, these two effects change the steady-state unemployment rate from 8.5% in the estimated model to 11.0% in the counterfactual model. The removal of STW has the largest steady-state impact on these three variables. On the contrary, output, the job value, labor market tightness and the vacancy filling rate remain close between the two models, with less than 10% difference in relative magnitudes.

For the simulation procedure, the shock processes are estimated independently from the baseline model with STW. More specifically, the structural parameters which are part of the estimation in previous section, are mostly calibrated to their prior means. The reason for this is that the parameter estimates are induced by the existence of STW. Hence, it is probable that the calibration with posterior means is more accurate for the model with STW but would be less accurate for the counterfactual model. As such, the calibration would be unfavorable to a model without STW, and could overemphasize the role of the policy in stabilizing labor market fluctuations.

Furthermore, as the main period of interest in this paper is the Covid-19 pandemic, the calibration of STW criterion becomes essential. In this regard, the German government was strongly incentivizing firms to participate in STW during Covid-19. Consequently, it can be assumed that the STW criterion was less stringent at the time. Hence, for the shock estimation, I set the STW criterion parameter $\bar{J}$ to a value of -1.4, which is a higher value than the prior mean of -2.4, but lower than the posterior mean of -0.9. The chosen value is a trade-off between two opposite effects. First, the low values, such as the prior of -2.4, would result in unfeasibly large shocks during the recessions in the sample, most importantly the Covid-19 recession. Second, the high values, for instance the posterior of -0.9, would distort the steady-state values far from the long-term averages of observed variables. The chosen level of the parameter $\bar{J}$ results in correlation 0.28 between the wage and output, and 0.24 between productivity and output in the estimated model. These values are more feasible for the Covid-19 period, since the drop in GDP was 4.2% in 2020, while the gross-wages droped 1.3% in 2021. Over the longer period, the wage and output growth are closely correlated.[2]

The final part of the simulation is a choice of the initial-state from which the simulation begins. In general, a Bayesian estimation rarely results in an initial-state of the

[2]Source: https://www.wsi.de/de/loehne-und-gehaelter-14576-entwicklung-der-bruttostundenloehne-in-deutschland-ab-1970-26336.htm

model which equals the calibrated steady-state. Hence, the initial-state of counterfactual simulation is set to have the same relative deviation from the steady-state as the estimated initial-state of the STW model. In addition, in order to obtain simulated shock decompositions, the simulation process is repeated with one shock series at a time. These simulations are set to begin from the steady-state instead of the initial-state, in order to make them comparable.

5 Results and analysis

This section discusses the results of the estimation outcomes and the simulation exercises described in the previous section. The main results of this paper are related to the simulation results, so those are analyzed first. However, the structural parameter estimates have interesting policy implications in their own right, which are considered at the end of the section.

5.1 Stabilization of labor markets

Figure 3 shows an illustration of the unemployment rate increase during Covid-19. In order to compare more easily the two economies, the counterfactual unemployment rate has been scaled to 5% in January 2020. From this starting point, the unemployment rate would have increased to over 10% without STW during the spring 2020. The right panel of Figure 3 shows the sharp increase in the STW level, which emphasizes the difference between the two economies. In the counterfactual economy, adjustment happens through job destruction, while in the estimated model the working hours are adjusted with STW.

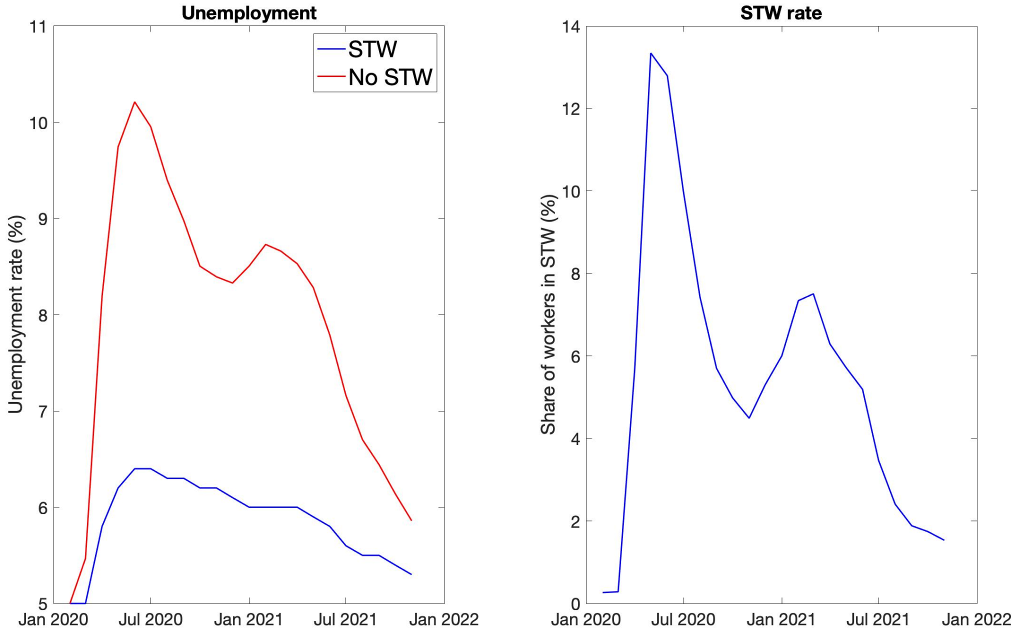

Figure 3: An illustration of unemployment increase during the Covid-19 is presented in the left panel. The blue line (below) is the observed unemployment rate, and the red line (above) the simulated counterfactual rate. For the comparison, the counterfactual unemployment rate has been scaled to 5% in January 2020. The right panel depicts the observed increase in STW level.

Figure 4 shows the comparison of the observed variables in the estimation with the counterfactual simulation outcomes of the same variables, over the whole sample period. In brief, the maximum increase in unemployment rate during the Covid-19 recession is 5.6 percentage points without STW, instead of 1.4 percentage points with the STW policy. Likewise, the stabilization can be detected during the Great Recession when the increase in unemployment rate is 2.3 percentage points without STW, instead of 1 percentage points in the data.

Considering the whole sample period, the contribution of STW in stabilizing labor markets is investigated by comparing the variances of the observed and simulated series. In this comparison, the variance of unemployment is 2.3 times higher in the economy without

STW, and the variance of separation rate is 2.1 times higher. These results confirm that the STW policy effectively participates in preventing job losses, and mitigation of unemployment fluctuations.

In addition, the volatility of the separation rate is asymmetrically lower in the economy with STW, i.e., the increases during recessions are lower. This has important welfare implications. Hairault, Langot, and Osotimehin (2010) show that the separation rate is asymmetric over business cycles in the US economy. More specifically, the separation rate decreases more during expansions than it increases during recessions. Consequently, the higher volatility of separations leads to lower average unemployment and lower business cycle costs. Here, the lower volatility due to STW increases this asymmetry by lowering the increases in recessions, which has an analogical effect in lowering business cycle costs and improving welfare.

Figure 4: A comparison of the observed variables in estimation, and their simulated counterparts in the counterfactual model without STW. The graphs show the absolute deviations from the steady states of the corresponding models.

An interesting feature shown in Figure 4 is that it reveals a known challenge related to vacancy creation in the search and matching models with endogenous separations. The counterfactual model, i.e. the red line in the graph, first has a drop in vacancy rate at the beginning of recessions, which is followed by a significant jump almost immediately after the initial drop. The reason is that the increase in separations, for instance in Figure 5, sharply increases unemployment and decreases labor market tightness, which in turn incentivizes vacancy postings. This effect is visible in the simulated series even when the shocks are estimated from the data with a smooth decline in the vacancy rate during recessions.

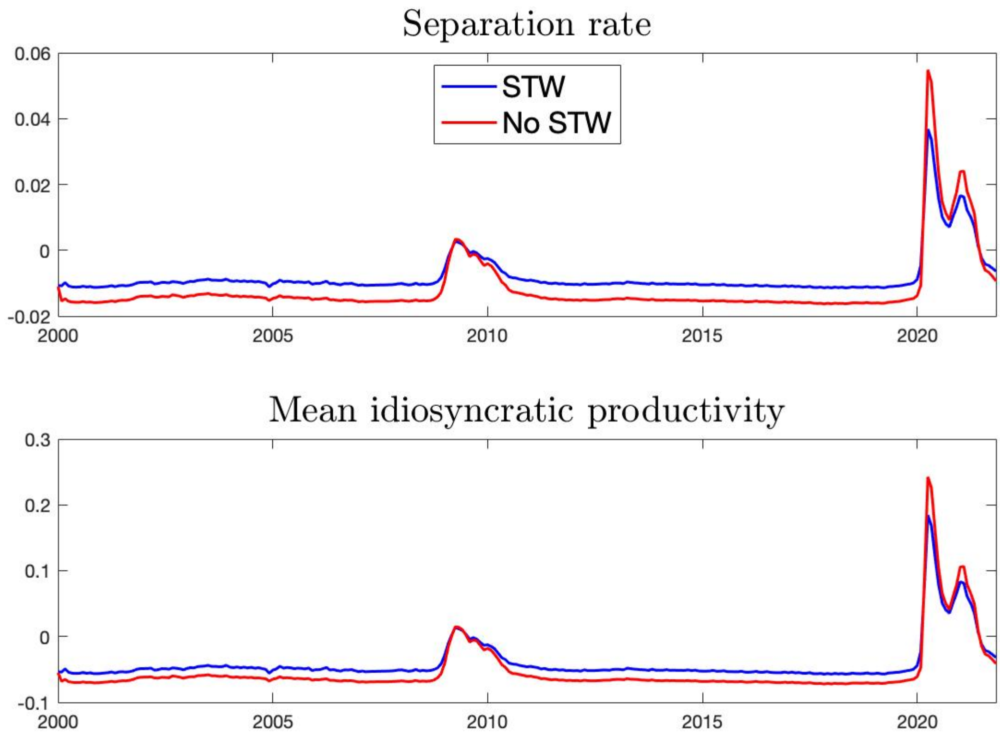

Figure 5: A comparison of separation rate and the firm level productivity between the models with and without STW. The graphs show the absolute deviations from the steady-states.

Figure 5 shows the comparison of separation rate and firm level productivity in the economies with STW and without the STW policy. It presents one of the trade-offs of STW. Job destruction is increasing more when the STW policy does not exist. Correspondingly, the firms are increasing the firm specific productivity more, as a response to negative shocks, when the labor hoarding is not subsidized with STW. The productivity increase is a result of firms destroying a larger number of low productive jobs, and simultaneously creating a larger number of jobs with higher productivity. To be exact on the size of this effect, the mean idiosyncratic productivity increases up to 30% more during the Covid-19 recession in the economy without STW.

5.2 Shock decompositions

The second simulation exercise imposes the three shock series on the counterfactual model one shock at a time. The outcome of these simulations is compared with the corresponding historical shock decompositions from the estimated model. Figure 6 shows the shock decompositions of the unemployment rate and the separation rate from the two models. Out of the three shocks, the TFP and matching efficiency accounts for the largest share of the volatility in unemployment. In turn, the matching efficiency shock does not contribute to the fluctuations in the separation rate. In addition, the contribution of each shock on both models follows the same patterns. However, the magnitudes are systematically larger in the model without STW.

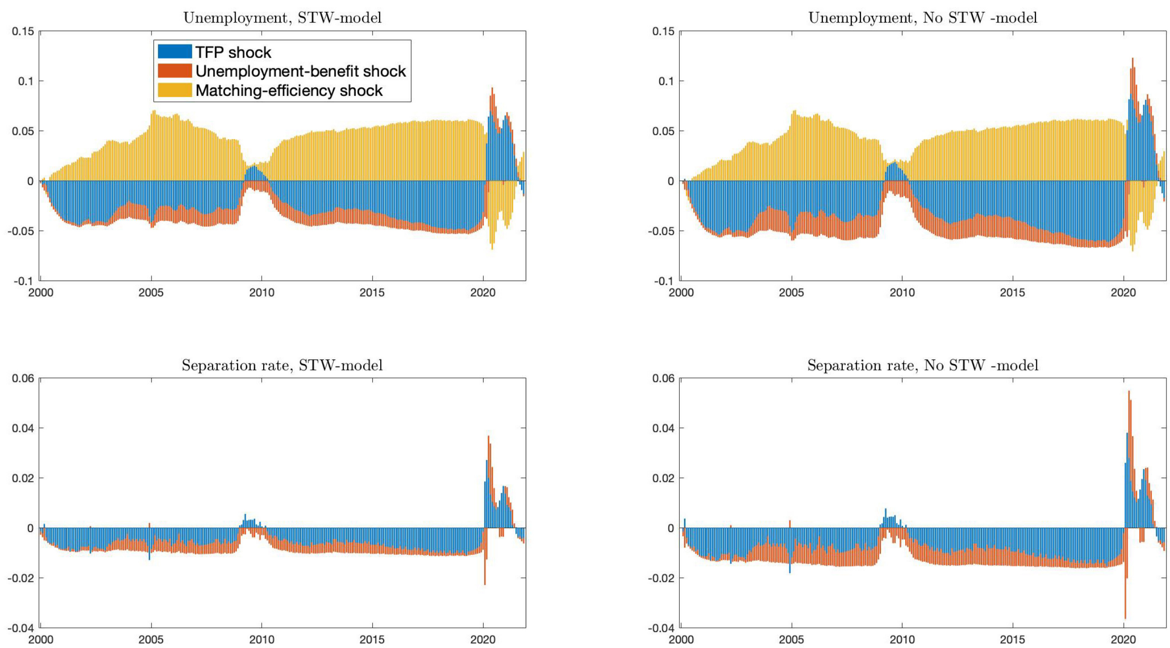

Figure 6: The shock decompositions of unemployment rate and separation rate in the two models, with and without STW. The scales are the absolute deviations from the steady states.

In order to observe more specifically the difference in magnitudes of each shock in the two models, Figure 7 presents the contributions of the three shocks on unemployment. As discussed in the previous section the total differences in unemployment rates between the model with and without STW are significant, especially during the Covid-19 crisis, but also over the whole sample period. The shock decomposition shows that the difference between the two models arises from the productivity and the workers' outside option shocks. In turn, the impact of the matching efficiency shock on unemployment is identical in both models. In other words, the STW policy does not increase the propagation of the changes in the labor market matching on unemployment. The matching efficiency either increases or decreases the job finding probability for unemployed workers, and hence the relative effect is equivalent if the labor market tightness is the same in both economies. This is the case if the number of vacancies and the rate of unemployment are systematically higher in the economy without STW, compared with the economy with the policy.

The shock decompositions also indirectly confirm that the economies in estimation and simulation are identical, notwithstanding the STW policy. The above discussed matching efficiency shock has the same effect on unemployment, but the other decompositions also point out that it does not have an impact on the STW rate, and more surprisingly on the vacancy filling rate. The reason is that the matching efficiency shock makes vacancies and unemployment move with the same proportions, perfectly compensating each other. Moreover, as the shock has no impact on the STW rate, or working hours in STW, it seems clear that it makes no difference between the two economies, in which the only difference is the STW policy. (See Appendix C.1 for more details.)

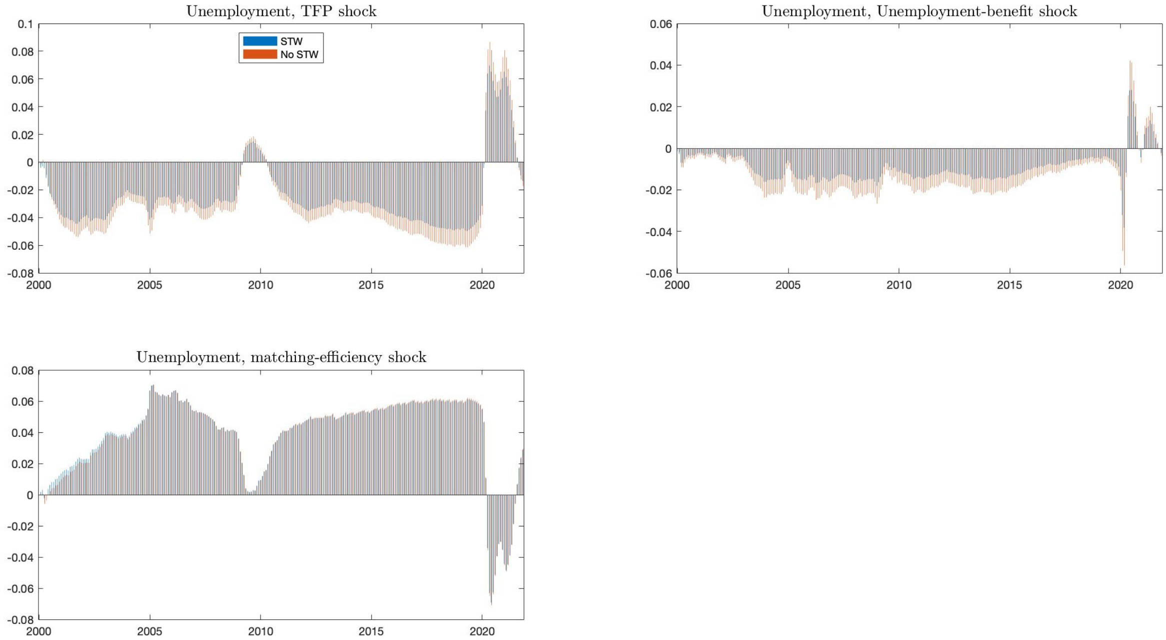

Figure 7: The impact of different shocks on the unemployment rate in the two models, with and without STW. Monthly impact on each model is depicted side by side, in order to compare the magnitudes. The scales are the absolute deviations from the steady-states.

5.3 Parameter estimates

This sections discusses two key parameter estimates namely the STW criterion $\bar{J}$ and the separation cost f. The priors and posteriors are presented in Table 2. The estimates of these two parameters are particularly interesting, since they capture if the STW criterion allows a larger number of workers in STW than the number of jobs which are saved from separations. This indeed seems to be the case.

As argued in the model section, if the parameter values are set such that $\bar{J} = -f$, the choice of STW is a true alternative to separation. However, the posterior mean estimates are approximately $\bar{J} = -0.9$ and $f = 2.7$, i.e. the STW criterion is higher than the cost of separation. This allows the situation in which the value of the job is low enough for STW, but too high for separation. More specifically, let us consider a job with value J_t

such that $-f < J_t < \bar{J}$, which is possible given the estimated parameter values. Now, this job meets the STW condition in equation (2), meaning that the firm sends this worker to STW. Simultaneously, the same job generates less profit losses than the cost of separation, i.e., it does not meet the separation condition in equation (6) even with the full working hours. Hence, the firm has no incentive to separate with the worker, but is still reducing the working hours of this job in STW, because the policy criterion allows this.

The estimated values of the STW criterion and separation costs suggest that the policy is too slack. Hence, the policy does not prevent job losses, but allows firms to participate opportunistically in the STW program, in order to increase profits. However, this result is heavily influenced by the two large recession periods in the sample, especially the Covid-19 recession, when the German government deliberately incentivized higher participation in the program. Consequently, these results propose that if the STW policy is expanded during the economic downturns, the duration of this expansion should be carefully limited to avoid the fiscal deadweight costs.

6 Conclusion

The short-time work policy (STW) stabilized unemployment and prevented excess job destruction in Germany during the Covid-19 recession. This paper investigates the effectiveness of STW during Covid-19 by estimation of a general equilibrium labor market model with STW using Bayesian techniques, in order to obtain a series of shocks accountable for the labor market fluctuations. These shock series are then imposed on a counterfactual model without STW to detect that the unemployment rate in Germany would have been 4.2 percentage points higher during the Covid-19 in the absence of the STW policy.

This paper confirms results reported earlier in the economic literature about the contribution of STW programs in stabilizing unemployment. In addition, I find some trade-offs of the policy. For instance, the firms may not increase their performance sufficiently by creating jobs with high productivity if the government is subsidizing the working time reductions of current workers with STW. Furthermore, if the STW policy is overly generous, the firms may increase their profits by participating in the program, and as such cutting the labor costs with subsidized working time reductions, even when the jobs in STW are profitable and not in danger of layoffs. Hence, the results in this paper indicate the need for a further investigation into the optimal level of the policy. I leave these considerations for future research.

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A Appendix, Model

This appendix presents the details of the model derivation. The model is from Balleer et al. (2016), and detailed information about the model is available in the original article and its Appendix.

A.1 Firms and labor markets

Value of a job or worker with idiosyncratic realization ε_t is J_t as

$$J_t = a_t - w_t - \varepsilon_t - c_f + \beta E_t J_{t+1} \tag{A.1}$$

in which a_t is TFP, w_t a wage, c_f fixed cost of production and β a subjective discount factor of households. ε_t is drawn each period to each job surviving exogenous separations from a time-invariant distribution with CDF $G(\varepsilon)$ and PDF $g(\varepsilon)$.

The government imposes a criteria of eligibility for workers in STW. These criteria is presented by an exogenously given parameter $\bar{J}$. Workers with value less than $\bar{J}$ can be sent to STW, yielding a following condition

$$a_t - w_t - \varepsilon_t - c_f + \beta E_t J_{t+1} < \bar{J} \tag{A.2}$$

A threshold value v_t^k for the idiosyncratic shock ε_t is solved as

$$v_t^k = a_t - w_t - c_f + \beta E_t J_{t+1} - \bar{J} \tag{A.3}$$

The firm chooses between STW and full-time work such that, if $\varepsilon_t > v_t^k \Leftrightarrow J_t < \bar{J}$, the worker is sent to STW , and if $\varepsilon_t < v_t^k \Rightarrow J_t > \bar{J}$ the worker is regular full time worker.

A firm chooses the optimal level of working-time reduction by maximizing the contemporaneous profit of a worker in STW. Maximization problem is given by

$$\max_{K(\varepsilon_t)} \quad \Pi_t = (a_t - w_t - \varepsilon_t)(1 - K(\varepsilon_t)) - c_f - C(K(\varepsilon_t)), \tag{A.4}$$

in which $K(\varepsilon_t)$ is the share of working hours reduced from full working time and $C(K(\varepsilon_t))$ is the cost of reducing $K(\varepsilon_t)$ units of working time.

Defining a quadratic cost function as

$$C(K(\varepsilon_t)) = c_k \frac{1}{2} K(\varepsilon_t)^2, \tag{A.5}$$

in which c_k is a fixed unit cost of work time reduction, the optimal hour reduction choice is given by

$$K^*(\varepsilon_t) = -\frac{a_t - w_t - \varepsilon_t}{c_k}. \tag{A.6}$$

The least profitable workers are in STW, which reduces the losses they generate. If these losses, albeit the hour cuts, are larger than the cost of layoff, the worker and the firm separate, and the job is destroyed. Assuming a separation cost f, the condition of layoff becomes

$$(a_t - w_t - \varepsilon_t)(1 - K^*(\varepsilon_t)) - C(K^*(\varepsilon_t)) - c_f + \beta E_t J_{t+1} < -f, \tag{A.7}$$

from which a separation threshold of idiosyncratic component named v_t^f can be solved as

$$v_t^f = a_t - w_t - c_f + \frac{1}{(1 - K^*(v_t^f))}(f + \beta E_t J_{t+1} - C(K^*(v_t^f))). \tag{A.8}$$

If $\varepsilon_t > v_t^f \Leftrightarrow J_t < -f$, the worker and the firm separate.

The clarify the choices between STW and firing, let us assume $\bar{J} = -f > J_t$, the firm first chooses an optimal hour cut K_t^*. The value of the job after hour reduction K_t^* is named J_t'. If $J_t' > -f$ the worker is sent to STW with $(1 - K_t^*)$ working hours. In turn, if $J_t' < -f$ the worker and the firm separate.

The idiosyncratic shock follows a distribution with PDF $g(\varepsilon)$. Hence, the share of workers in STW is given by

$$\chi_t = \int_{v_t^k}^{v_t^f} g(\varepsilon) d\varepsilon. \tag{A.9}$$

Analogically, the rate of endogenous separation is

$$\phi_t^e = \int_{v_t^f}^{\infty} g(\varepsilon) d\varepsilon, \tag{A.10}$$

Total separation rate is defined as a combination of exogenous rate ϕ^X, and the endogenous rate. Total separation rate is named ϕ_t, and defined as

$$\phi_t = \phi^X + \left(1 - \phi^X\right) \phi_t^e. \tag{A.11}$$

Finally, we can define the expected value of a job before the idiosyncratic shock is realized, which is J_t as

$$\begin{aligned} J_t = (1-\phi^X) & \underbrace{\int_{-\infty}^{v_t^k} (a_t - w_t - \varepsilon_t) g(\varepsilon_t) d\varepsilon_t}_{\text{Full time work}} \\ +(1-\phi^X) & \underbrace{\int_{v_t^k}^{v_t^f} [(a_t - w_t - \varepsilon_t)(1 - K^*(\varepsilon_t)) - C(K^*(\varepsilon_t))] g(\varepsilon_t) d\varepsilon_t}_{\text{STW work}} \\ & \underbrace{-(1-\phi_t)c_f - (1-\phi^X)\phi_t^e f}_{\text{Fixed cost of production and separatoin costs}} \quad +(1-\phi_t)\beta E_t J_{t+1}, \end{aligned} \tag{A.12}$$

On the labor markets, the employment evolution follows the canonical search and matching models, and is defined as

$$n_t = (1 - \phi_t)(n_{t-1} + m_{t-1}) \tag{A.13}$$

in which n_t is employment and m_t is a number of new matches. The new matches are resulted by a matching function, defined in Cobb-Douglass form, and given by

$$m_t = \mu_t u_t^{\alpha} v_t^{1-\alpha}, \tag{A.14}$$

in which v is vacancies, μ_t is an exogenous matching efficiency and α is an elasticity of matches with respect to unemployment.

As is typical in this type of labor market models, the labor force is normalized to one and all workers are either employed or unemployed, equation employment and unemployment as

$$u_t = 1 - n_t. \tag{A.15}$$

Labor market tightness is defined as $\theta_t = \frac{v_t}{u_t}$ and a vacancy filling rate becomes

$$q_t = \mu_t \theta^{-\alpha}. \tag{A.16}$$

For the job creation side, the present value of a vacancy is defined as

$$V_t = -\kappa + \beta E_t q_t J_{t+1} + \beta E_t (1 - q_t) V_{t+1}, \tag{A.17}$$

in which κ is a fixed vacancy posting cost. A free entry condition is assumed, and it implies that $V_t = 0, \forall\, t$ resulting in a traditional job creation condition, given by

$$\kappa = \beta E_t q_t J_{t+1}. \tag{A.18}$$

Finally, the aggregate output is given by

$$Y_t = \frac{n_t}{1-\phi_t^e}\int_{-\infty}^{v_t^k}(a_t-\varepsilon_t)g(\varepsilon_t)d\varepsilon_t$$

$$+\frac{n_t}{1-\phi_t^e}\int_{v_t^k}^{v_t^f}[(a_t-\varepsilon_t)(1-K^*(\varepsilon_t))]g(\varepsilon_t)d\varepsilon_t \tag{A.19}$$

$$-n_t c_f - \frac{n_t}{1-\phi_t^e}\phi_t^e f - v_t\kappa.$$

A.2 Wage bargaining

Wages are a result of collective bargaining, in which the labor union bargains wages for all workers jointly. If the agreement is not reached, the outside option is a strike where workers do not produce any output and the firm pays no wages. In turn, the job relationships are retained. The Nash bargaining problem is given by

$$\arg\max_{w_t}(W_t-\tilde{W}_t)^{\gamma}(F_t-\tilde{F}_t)^{1-\gamma}, \tag{A.20}$$

in which γ is the bargaining power of labor union and the value functions are

$$W_t = w_t + \beta E_t[(1-\phi_t)W_{t+1} + \phi_{t+1}U_{t+1}], \tag{A.21}$$

$$\tilde{W}_t = b_t + \beta E_t[(1-\phi_t)W_{t+1} + \phi_{t+1}U_{t+1}], \tag{A.22}$$

$$F_t = a_t - w_t - c_f + \beta E_t J_{t+1}, \tag{A.23}$$

$$\tilde{F}_t = -c_f + \beta E_t J_{t+1}, \tag{A.24}$$

and the U_t is the value of unemployment for the worker.

In case of a strike, workers are assumed to earn an outside option, which equals the unemployment benefit b_t, but the work contracts are not resigned. The solution of wage bargaining is given by

$$w_t = \gamma a_t + (1 - \gamma) b_t. \tag{A.25}$$

A.3 Households, the government and closing the model

The households in the model are stylized and maximize utility from consumption. The household's utility function is assumed to take CRRA-form as

$$U(C_t) = \left(\frac{C_t^{1-\sigma} - 1}{1 - \sigma} \right), \tag{A.26}$$

in which σ is a risk-aversion parameter. And budget constraint is given by

$$\begin{aligned} C_t + B_{t+1} = {} & \underbrace{w_t \frac{n_t}{1 - \rho_t^e} \int_{-\infty}^{v_t^k} g(\varepsilon_t) d\varepsilon_t}_{\text{Wages of full-time workers}} + \underbrace{w_t \frac{n_t}{1 - \rho_t^e} \int_{v_t^k}^{v_t^f} (1 - K^*(\varepsilon_t)) g(\varepsilon_t) d\varepsilon_t}_{\text{Wages of STW workers}} \\ & + \underbrace{b_t \frac{n_t}{1 - \rho_t^e} \int_{v_t^k}^{v_t^f} K^*(\varepsilon_t) g(\varepsilon_t) d\varepsilon_t}_{\text{Unemployment benefits of STW workers}} + b_t u_t + R_t B_t + \Pi_t - T_t, \end{aligned} \tag{A.27}$$

in which C_t is consumption, B_t a government risk-free bond, R_t a gross return of the bond, Π_t the profits from firms which the household owns, and T_t a lump sum tax.

$$\frac{1}{R_{t+1}} = \beta E_t \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma}. \tag{A.28}$$

The government pays unemployment benefits not only to unemployed workers, but also for hours not worked to workers in STW. The government runs a balanced budget, with budget constraint given by

$$b_t \frac{n_t}{1 - \rho_t^e} \int_{v_t^k}^{v_t^f} K^*(\varepsilon_t) g(\varepsilon_t) d\varepsilon_t + b_t u_t + R_t B_t = T_t + B_{t+1}. \tag{A.29}$$

All output, which is left after the frictional costs, is consumed. Hence, the aggregate budgets constraint is simply

$$Y_t = C_t. \tag{A.30}$$

B Appendix, Estimation

B.1 Data

The observables used in calibration are retrieved from the Bundesbank website (`https://www.bundesbank.de/en/statistics`). The following lists the data series.

Unemployment rate. Unemployment registered pursuant to section 16 Social Security Code III / Germany / Social Security Code III and Social Security Code II / Rate / Calendar and seasonally adjusted

Series: BBDL1.M.DE.Y.UNE.UBA000.A0000.A01.D00.0.R00.A

Source: Seasonal adjustment based on data provided by the Federal Employment Agency.

Vacancies. Reported vacancies, total / Germany / Total / Absolute value / Calendar and seasonally adjusted

Series: BBDL1.M.DE.Y.VAC.VBA000.A0000.A00.D00.0.ABA.A

Source: Seasonal adjustment based on data provided by the Federal Employment Agency.,

Employed workers. Employed persons according to ESA 2010 / Germany / Domestic concept / Absolute value / Calendar and seasonally adjusted

Series: BBDL1.M.DE.Y.EMP.EAA000.A0000.A00.D10.0.ABA.A

Source: Seasonal adjustment based on data provided by the Federal Statistical Office.

Short-time workers. Short-time workers, basis for entitlement according to section 96 only / Germany / Social Security Code III / Absolute value / Calendar and seasonally adjusted

Series: BBDL1.M.DE.Y.LMP.LKA100.A0000.A02.D00.0.ABA.A

Source: Seasonal adjustment based on data provided by the Federal Employment Agency.

B.2 Detrending

Due to the so-called Hartz reforms there is a long declining trend in the German unemployment rate. A linear trend is removed from the beginning of the sample until the Covid-19, which is attached at the end of the sample. Figure 8 illustrates this detrending.

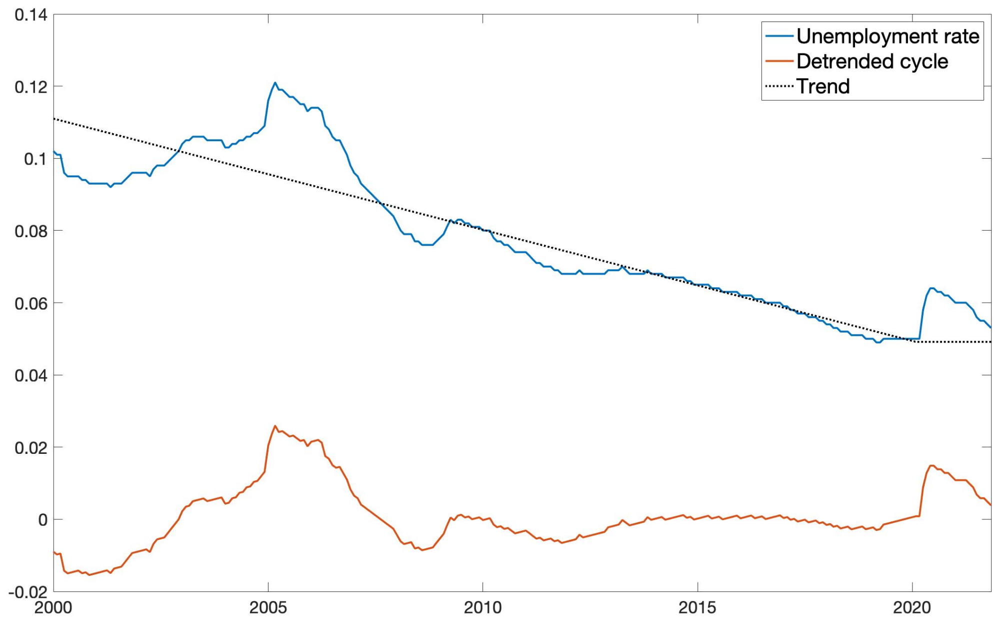

Figure 8: Unemployment rate, its trend and detrended cycle.

C Appendix, Simulation

C.1 Shock decomposition

This section contains additional shock decomposition graphs of the two models.

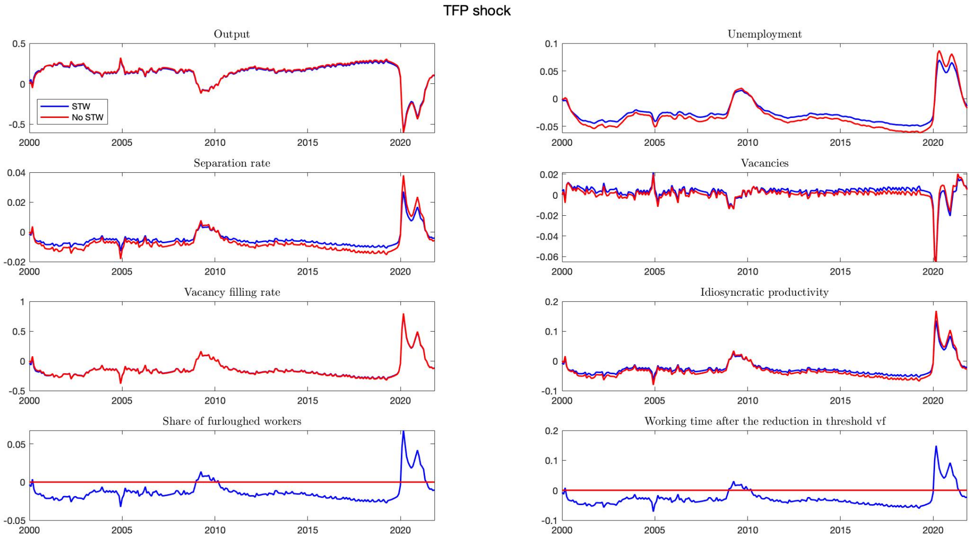

Figure 9: Productivity shock.

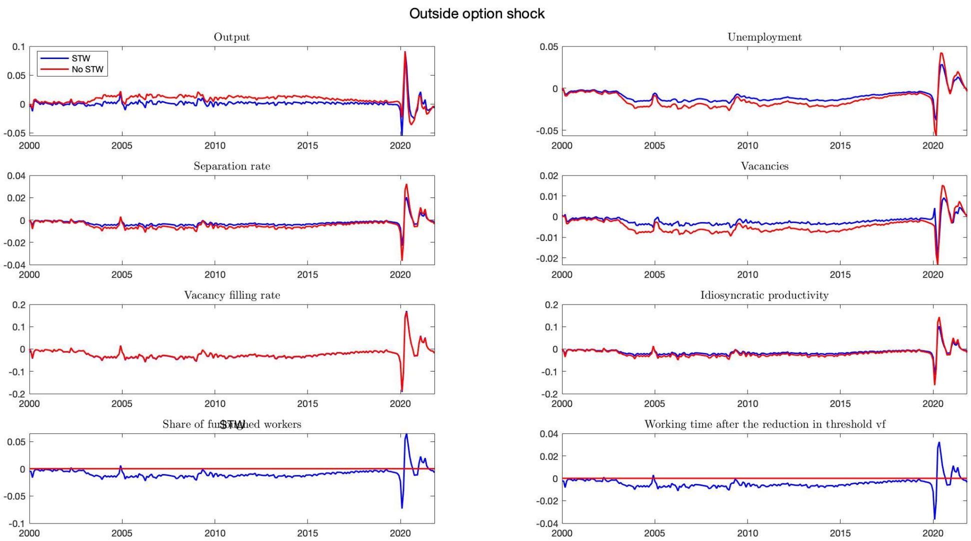

Figure 10: Workers' outside option shock.

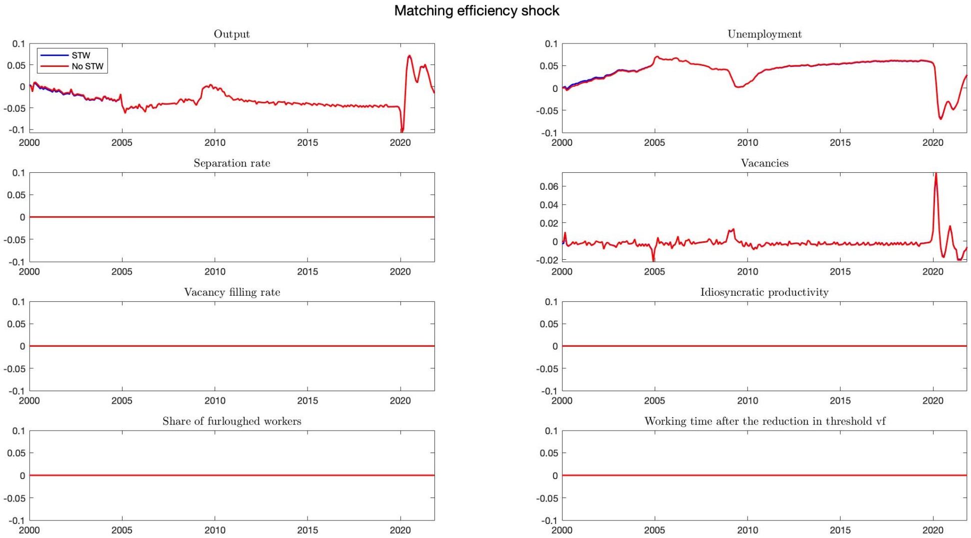

Figure 11: Matching efficiency shock.

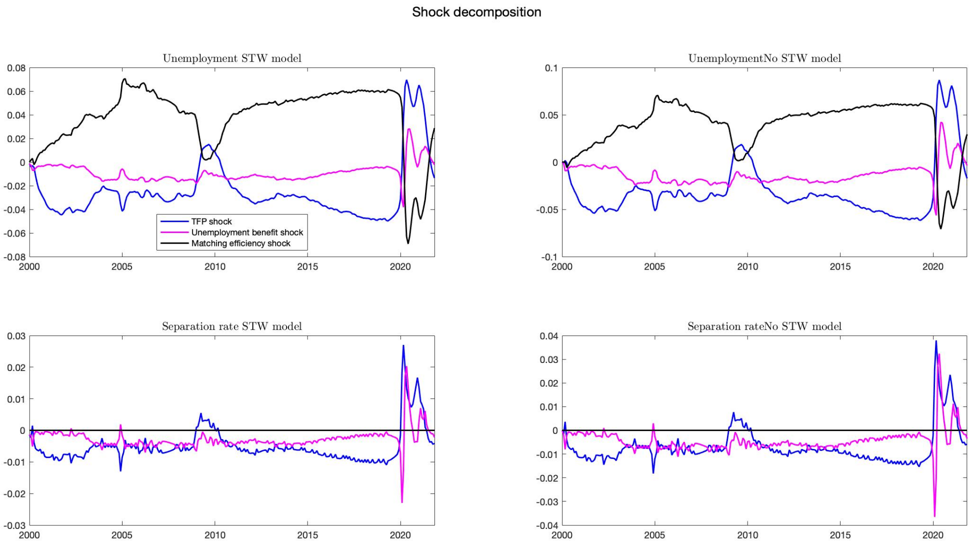

Figure 12: Decompositions of the unemployment and separation rates.