Short-Time Work and Precautionary Savings

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Abstract

In the Covid-19 crisis, most OECD countries used short-time work (subsidized working time reductions) to preserve employment relationships. This paper studies whether short-time work can save jobs by stabilizing aggregate demand in recessions. First, we show that the consumption risk of short-time work is considerably smaller than that of unemployment using household survey data from Germany. Second, we build a New Keynesian model with incomplete asset markets and labor market frictions featuring an endogenous firing and short-time work decision. In recessions, short-time work reduces the unemployment risk of workers, which mitigates their precautionary savings motive. Using a quantitative model analysis, we show that this channel increases the stabilization potential of short-time work over the business cycle. Additionally, we compute the fiscal multiplier of an increase in short-time work compensation and compare it to an increase in unemployment benefits. The marginal propensity to consume (MPC) of the short-time employed is similar to that of the employed, implying that a redistribution of funds to these agents yields a smaller multiplier than a redistribution to the unemployed.

JEL codes: E21, E24, E32, E52, E62, J63
Keywords: Short-time work, fiscal policy, incomplete asset markets, unemployment risk, matching frictions

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1 Introduction

Most OECD countries used short-time work (STW henceforth) to secure jobs and stabilize the economy during the Covid-19 crisis and the Great Recession. In Germany, Europe's largest economy, almost every fifth employee was affected by STW in spring 2020. Equally high numbers were observed in Italy, Spain, France, Belgium, Austria and the UK as illustrated in Figure 1.[1] Yet, knowledge of the dynamic effects of this labor market policy remains limited. In the public debate, one major argument for STW – next to reducing firms' labor costs – is that this instrument may stabilize demand and lower unemployment risk. In this paper, we analyze this argument formally using a quantitative macroeconomic model with search frictions, heterogeneous agents, and incomplete markets. We derive two main results. First, we show that STW is a strong automatic stabilizer. The demand channel operating through lower unemployment risk accounts for one-fifth of the total reduction in unemployment fluctuations. While this is substantial, this number nevertheless implies that the reduction of firms' labor costs is the major channel through which the policy operates. Second, we document that a discretionary increase in STW compensation – a widespread policy during the Covid-19 crisis – stabilizes demand and is expansionary in terms of aggregate output. But the effects turn out to be quantitatively negligible. These findings suggest that the demand effects of STW may be overstated in the public debate. This paper relies on German data as STW has a long tradition in Germany and excellent data availability. In the German STW system, a firm has to convince the public employment agency that it is experiencing a significant shortfall in demand which requires the reduction of labor input to be eligible for STW. The firm is then allowed to reduce workers' hours and pay proportionally. Workers receive a compensation of the net wage loss equal to the unemployment benefit replacement rate, paid out of the unemployment insurance fund. To understand why STW may stabilize demand more than unemployment benefits would, it is important to note that workers affected by STW are typically better off compared to unemployment. Only in the rare case if hours worked are reduced to zero, income from STW compensation will be equal to the unemployment benefit.[2] And even then, the employment prospects of workers on STW (who are considered as employed) are typically better compared to the unemployed.

To illustrate how STW interacts with demand and precautionary saving, we proceed in two steps. First, we provide empirical evidence from household survey data on the consumption decline that households experience during unemployment and STW spells. Using data on Germany for the Covid-19 crisis from the Bundesbank Household Online Panel, we show that the consumption drop due to unemployment was large at about 35%. This number is considerably larger compared to earlier (pre-Covid) estimates for other countries. Interestingly for our purpose, however, we find only a moderate and mainly insignificant drop in consumption during STW spells. This is direct evidence

[1] The EU implemented the "Temporary Support to mitigate Unemployment Risks in an Emergency" (SURE) scheme providing financial support of up to €100 billion in the form of loans to member states, specifically to finance the implementation or extension of schemes to preserve employment.

[2] The feature that hours worked not have to be reduced to zero differentiates STW from recalls and temporary layoffs that are common in the US labor market. From March to May 2020, the average STW hours reduction in Germany was 41%. Figure 10 in the Appendix shows that this number was generally lower before the Covid-19-recession. During the Covid-19 crisis, the compensation for short-time workers had been increased so that even for workers on zero hours income was higher compared to unemployment insurance.

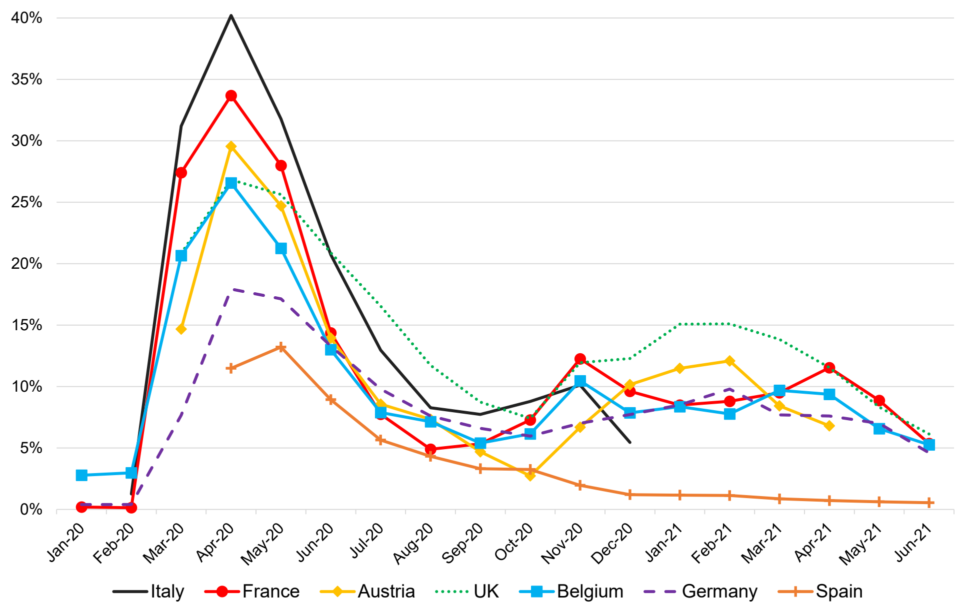

Figure 1: Share of employees affected by STW across different countries during the Covid-19-recession. Source: Eurostat, except for Germany: Federal Employment Agency and UK: ONS and CJRS.

that STW can stabilize consumption at the microeconomic level. However, assessing the impact on precautionary savings and aggregate demand requires a structural macroeconomic model. shows clearly that STW can stabilize consumption at the microeconomic level. However, a structural macroeconomic model is needed to investigate the impact of this labor market policy on precautionary savings and aggregate demand. To this end, in a second step, we construct a New Keynesian DSGE model with search and matching frictions, endogenous separations and rigidities in prices and real wages. We add a STW decision and incomplete asset markets that imply that unemployment (and STW) risk is not fully insurable, and workers save for precautionary reasons. Workers facing borrowing constraints may reduce their consumption already in anticipation of unemployment (and STW) risk without necessarily suffering job loss. The combination of nominal rigidities and endogenous labor market risk then yields an amplification channel. On top of that, our model allows for savings in a liquid asset (government debt), leading to a non-degenerate wealth distribution of households. This heterogeneity implies that workers have different marginal propensities to consume depending on their asset holdings, such that redistribution policies can raise or lower aggregate demand. We model STW in line with Balleer et al. (2016): Worker-firm matches are subject to idiosyncratic profitability shocks. When the match becomes so unprofitable that the firm would otherwise fire the worker, the government allows the firm to reduce hours and wage payments and, therefore the losses that this match generates. This reduces firing directly and affects hiring indirectly because it increases the value of the job from the firm's perspective. Importantly, because of the search and matching frictions, firms retain temporarily unprofitable matches in the firm (labor hoarding). We call this the firm channel of STW. Quantitatively, we discipline the model with our estimates from the household data. Our first main finding is that STW has additional potential to stabilize the business cycle when labor market risk is taken into account. As firings increase in recessions, full-time employed workers want to self-insure against rising unemployment risk. Lower consumption demand, given nominal rigidities, reduces production and triggers even more firings, resulting in a contractionary deflationary spiral. This amplification channel due to precautionary savings is dampened with STW. Workers know that they might be placed on STW instead of being fired. The short-time employment state is preferable because unemployment represents a reduction in both current and expected income. Current income is reduced because unemployment benefits are smaller than short-time employment wages. Expected income is reduced because an unemployed worker is less likely to become full-time employed again due to search frictions. For this reason, the presence of STW reduces unemployment and income risk and, therefore, precautionary savings. Counterfactual model analysis shows that STW is a strong automatic stabilizer. In an economy calibrated to the German labor market, unemployment fluctuations are reduced by 24% compared to a counterfactual economy without STW. Without unemployment risk, the reduction in unemployment fluctuations is around 19%. This implies that a shock that would generate an increase in the unemployment rate by 4 percentage points without STW would increase unemployment by only 3 percentage points with STW. Out of the total stabilization of 1 percentage point, one-fifth, i.e., 0.2 percentage points is due to the reduction of precautionary savings. Nonetheless, most of the stabilization is provided by the direct effect of STW on firms' separations (the firm channel). Interestingly, STW stabilization interacts with monetary policy. If monetary policy is less aggressive or constrained, the stabilization due to STW increases. Our second main contribution is an analysis of a discretionary increase in STW compensation. Such a policy has been implemented during the Covid-19 recession in different countries, including Austria and Germany. We show that this policy can be expansionary as it reduces STW risk and, hence, precautionary savings. However, we find that the effects are quantitatively small. This exercise allows to investigate whether the previously described STW stabilization is due to precautionary savings from full-time workers or due to a reallocation of funds from tax payers to short-time workers with potentially heterogeneous marginal propensities to consume. In the data and in the model, we observe that short-time workers behave rather similarly to full-time workers. For that reason, the effects from redistributing to short-time workers tend to be small in the model. Instead, our model predicts that a similar-sized increase of unemployment benefits has larger expansionary effects on output and employment as unemployed workers consume a larger share of additional transfers that they receive compared to short-time workers.

Related literature This paper contributes, first, to the literature on New Keynesian models with labor market frictions. Examples are Blanchard and Galí (2010), Krause and Lubik (2007) and Trigari (2009). These papers study normative or positive implications of monetary policy when labor market frictions, partly with endogenous separations, are present, but in complete asset markets. Second, this paper is related to the growing literature on heterogeneous agent New Keynesian models with search and matching (Gornemann et al., 2016, Challe, 2020, Ravn and Sterk, 2017, 2021, Albertini et al., 2021). These studies feature a similar precautionary savings mechanism as in our model, among them Gornemann et al. (2016) and Albertini et al. (2021), also feature a non-degenerate wealth distribution. However, our labor market features endogenous separations as well as a STW decision, whereas the existing literature studies only exogenous separations. One recent exception that also looks at endogenous separations in this context is Broer et al. (2021). Third, our paper is related to the literature that assesses the impact of fiscal policy with incomplete markets (e.g., Brinca et al., 2016; Hagedorn et al., 2019). Quantitative studies with STW and complete markets include Krause and Uhlig (2012), Faia et al. (2013), Balleer et al. (2016) and Cooper et al. (2017). We follow Balleer et al. (2016) in how we model STW and endogenous separations and in line with their findings document the business cycle stabilization due STW from the reduction of firms' labor cost. Cooper et al. (2017) study STW with heterogeneous firms and focus on reallocation effects. Lastly, there is a growing empirical literature on the effects of STW. Recent studies include Giupponi and Landais (2022), Cahuc et al. (2018), Kopp and Siegenthaler (2021) and Gehrke and Hochmuth (2021). All of these papers suggest stabilizing effects of STW for unemployment, but none of these papers discuss the role of the demand channel of STW for fiscal stabilization. One recent exception are Dao and Aiyar (2022) who find that STW indeed stabilized demand in Germany during the Covid-19 crisis.

Outline The rest of the paper is structured as follows. Section 2 presents empirical evidence on consumption risk due to unemployment and STW spells. Section 3 develops the model and characterizes the equilibrium. Section 4 discusses the calibration and the steady state properties. Section 5 uses the model for counterfactual analyses and simulation. Section 6 concludes.

2 The consumption risk of short-time work and unemployment

To quantify the risk channel of short-time work (STW) in a credible way, it is crucial to have information on the decline in household consumption during unemployment and STW spells. For this purpose, we use the Bundesbank Online Panel-Households (BOP-HH) that surveys German households, in particular during the Covid-19 crisis.[3] The survey is conducted in monthly frequency in waves covering May to July 2019 and runs continuously since April 2020, our current data vintage covers the period until September 2021. The number of participants varies between 2,000 to 7,500 in each wave. The survey is representative of the German online population, which implies that older female respondents and respondents with lower educational attainment are underrepresented, and has a panel component. Participants are asked about their labor status (including STW) since May 2020. We further have information about expenditures, wealth and several sociodemographic variables.

In Figure 2, we show the distributions of household income and net wealth across German households in three different labor market states: (1) regular employment, (2) STW, and (3) unemployment. Interestingly, the distribution of short-time workers is in between that of the employed and the unemployed, but clearly closer to that of the employed. This suggests that short-time workers behave more like employed workers rather than unemployed workers.

To quantify the consumption risk, we follow Chodorow-Reich and Karabarbounis (2016) and Graves (2020) and regress log consumption expenditure on a dummy of the

[3] See Beckmann and Schmidt (2020). Data access is provided by the Research Data and Service Centre of the Deutsche Bundesbank.

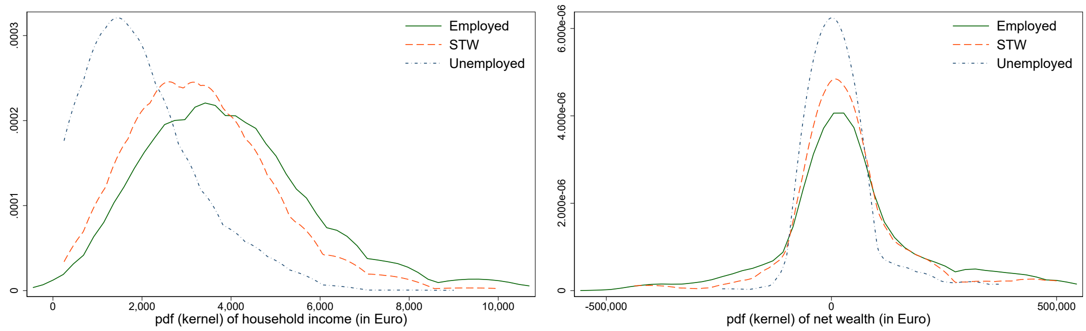

Figure 2: Empirical distributions of household income and net wealth by labor market state in Germany. Source: Bundesbank Household Online Panel, 2021 waves. Weighted according to sampling weights.

labor market status.[4]

$$\log C_{i,t} = \gamma^e + \gamma_u D^u_{i,t} + \gamma_{stw} D^{stw}_{i,t} + \beta \mathbf{X}_{i,t} + \epsilon_{i,t} \tag{1}$$

The coefficients γ_u and γ_{stw} measure the decline in log consumption for households that are unemployed or affected by STW. In line with Chodorow-Reich and Karabarbounis (2016) and Graves (2020), consumption is measured as the spending of the household on non-durables and services by excluding spending on durables such as cars and furniture and housing (rent, mortgages, etc). Consumption refers to the preceding month, the employment status is the current status.[5] To estimate Equation (1), we restrict the sample to individuals between ages 25 to 55.

We use cross-sectional and in-household variation to identify the consumption decline. When using cross-sectional variation, we rely on the assumption that we can control for all relevant variables to avoid omitted variable bias. Our set of controls in $\mathbf{X}_{i,t}$ is large and includes age and age squared, gender, an indicator for eight categories of education, household size and household size squared, an indicator for city size, home-ownership interacted with city size and wealth of the household. To control for, among other things, (regional) lockdowns during the Covid-19 pandemic, we add time-region fixed effects. We further estimate the same regression as in Equation (1), but adding a household fixed-effect that controls for time-invariant individual characteristics. However, because of too few panel observations, we cannot control for wealth in these regressions.

The results are in Table 1 and Table 2. Average consumption as estimated from the cross-sectional variation is around 40% lower during unemployment (γ_u), 35% in our tightest specification. Using within households variation, this number increases to

[4]Chodorow-Reich and Karabarbounis (2016) and Graves (2020) have annual data and use the time spent unemployed in a given year. We have monthly data and can thus directly investigate contemporaneous consumption across different labor market states. In doing so, we estimate the average response across different durations of unemployment or STW (we do not have information about the duration of each state). Chodorow-Reich and Karabarbounis (2016) find that the estimated consumption drop is independent of duration.

[5]In a robustness check, we estimate the same regression but using the lagged employment status. The results are very similar, but the number of observations drops a lot.

	(1)	(2)	(3)	(4)	(5)
γ_u	-0.47^{***}	-0.44^{***}	-0.42^{***}	-0.42^{***}	-0.35^{***}
	(-8.53)	(-7.99)	(-7.75)	(-7.68)	(-4.68)
γ_{stw}	-0.08^{**}	-0.05	-0.04	-0.04	-0.07
	(-2.57)	(-1.62)	(-1.43)	(-1.49)	(-1.43)
Skill		$\times$	$\times$	$\times$	$\times$
Homeown			$\times$	$\times$	$\times$
Homeown $\times$ city size				$\times$	$\times$
Wealth/debt					$\times$
Observations	9,476	9,468	9,464	9,464	4,924

Table 1: Consumption expenditure across labor market states. The parameter γ_u (γ_{stw}) gives the log difference of the consumption of an unemployed (short-time) worker compared to an employed worker. The estimation uses the Bundesbank Household Online Panel that covers monthly data for 2020/2021, waves 5-21. $t-$statistics are in parentheses, standard errors are clustered at household level, $^{*}p < 0.05,^{**} p < 0.01,^{***} p < 0.001$. Dependent variable is log consumption of non-durables and services for individuals between ages 25-55. The set of control variables in all regressions includes time-fixed effects interacted with region, age and age squared, gender, household size and household size squared and an indicator for city size. Skill is measured using an indicator of eight categories of education, wealth of the household is measured using indicators across 10 categories each for gross assets, secured debt, and unsecured debt.

65%. Interestingly, these numbers are considerably larger compared to existing studies for the US and Sweden. For the US, Chodorow-Reich and Karabarbounis (2016) find a drop of 21%, while Graves (2020) estimates numbers between 20-25% using similar data. Using Swedish data, Kolsrud et al. (2018) find an average drop of 4.4% for short-term unemployed workers, that increases to 9.1% for longer unemployment spells. While the larger consumption drop may seem surprising at first sight given a higher unemployment replacement rate in Germany compared to the US, this may be explained by the fact that the usage of short-term credit, e.g., via credit cards is less widespread in Germany. Further, our estimates are the first for the Covid-19 crisis. While we control for time-fixed effects that should capture the direct impact of lockdowns on consumption, it seems likely that the unemployed have reduced their consumption by more due to the uncertainty of the pandemic and because of fewer alternative income sources during unemployment (e.g., informal work).[6]

Our estimates in Table 1 and Table 2 further allow to quantify the consumption drop during STW (γ_{stw}). These estimates are considerably smaller, between 5-10%, and mostly insignificant, in particular in the tighter specifications. This suggests that the consumption risk from STW is considerably lower compared to that from unemployment and validates our argument that STW may stabilize demand over the business cycle by

[6]To check this argument, we have repeated our estimation for a pre-Covid sample using the three survey waves from May to July 2019. This data does not have information about STW, but it allows us to estimate the consumption drop due to unemployment in a similar way to the above. In our tightest specification with fixed effects, we then find an average consumption drop of 28%. This number is well in line with the estimate by Graves (2020) for the US, who reports 26%. Table 9 in the Appendix reports our estimation results.

	(1)	(2)	(3)	(4)	(5)
γ_u	-0.65^{**}	-0.66^{**}	-0.65^{**}	-0.65^{**}	-0.66^{**}
	(-2.48)	(-2.55)	(-2.54)	(-2.55)	(-2.55)
γ_{stw}	-0.10	-0.10	-0.09	-0.08	-0.07
	(-1.17)	(-1.16)	(-0.99)	(-0.96)	(-0.90)
Household size, region, city size		$\times$	$\times$	$\times$	$\times$
Skill			$\times$	$\times$	$\times$
Homeown				$\times$	$\times$
Homeown $\times$ city size					$\times$
Individual-fixed effect	$\times$	$\times$	$\times$	$\times$	$\times$
Observations	9,495	9,476	9,468	9,464	9,464

Table 2: Consumption expenditure across labor market states using household fixed-effects. The parameter γ_u (γ_{stw}) gives the log difference of the consumption of an unemployed (short-time) worker compared to an employed worker. The estimation uses the Bundesbank Household Online Panel that covers monthly data for 2020/2021, waves 5-21. $t-$statistics are in parentheses, standard errors are clustered at household level, $^{*}p < 0.05, ^{**}p < 0.01, ^{***}p < 0.001$. Dependent variable is log consumption of non-durables and services for individuals between ages 25-55. The set of control variables in all regressions includes time-fixed effects interacted with region. Skill is measured using an indicator of eight categories of education.

reducing risk.

We find similar qualitative results on income risk in a different data set, namely the IAB HOPP as provided by the Research Data Center of the Institute for Employment Research (IAB). The IAB HOPP is an online survey of individuals during the Covid-19-crisis. In spring 2020 at the first peak of the Covid-19-crisis in Germany, more than half of those that lost their job in that crisis reported a considerable income loss, see Table 3. In contrast, only 37% of those affected by STW reported a considerable income loss. Instead, workers on STW reported, to a larger extent, a more moderate income loss.

One may worry about the fact that our measure of STW is incomplete as it does not control for the extent to which a worker is affected by STW. There are two dimensions in this regard: the hours reduction and the STW compensation. We are able to shed light

Share of respondents	Total	No STW	STW	Unemployed
Income considerably lower	13.3	4.93	36.9	54.4
Income somewhat lower	17.9	13.28	42.5	10.8
Income unchanged	56.6	71.1	12.3	13.9

Table 3: Household's net income change from February 2020 to May 2020 by worker type in Germany. Unemployed workers are those that report that they lost their job in the Covid-19-crisis. Source: IAB HOPP as provided by the Research Data Center of the Institute for Employment Research (IAB), own calculations based on wave one (weighted).

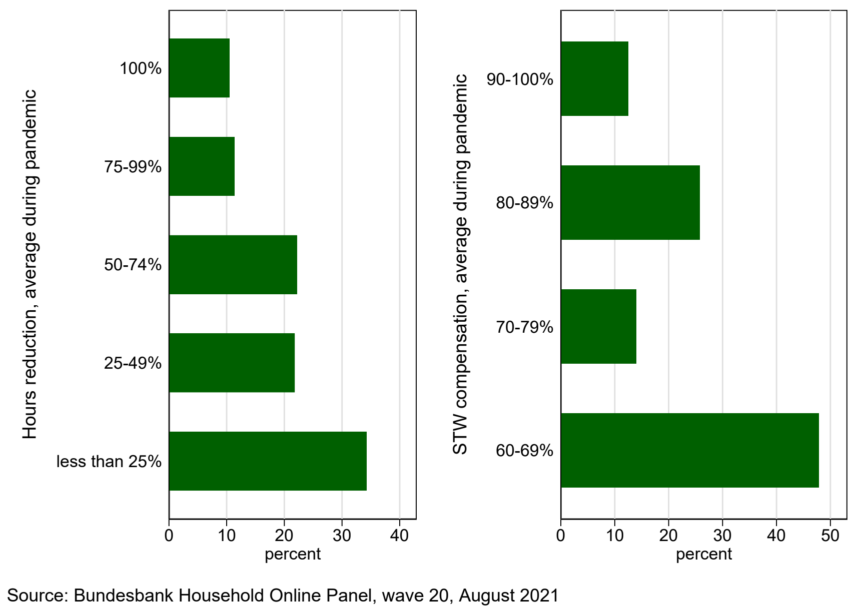

Figure 3: Average hours reduction and STW compensation during the pandemic (weighted summary statistics). Source: Bundesbank Household Online Panel, wave 20, August 2021.

on this issue, as we were able to add specific survey questions to the BOP-HH in wave 20. The results show that the hours reduction and STW compensation vary widely across workers that were affected by STW during the Covid-19-crisis. As shown in Figure 3, more than 50% of workers experienced an hours reduction of less than 50%, more than 30% of less than 25%. Only around 10% reduced their working hours to zero, i.e., by 100%. Almost half of all workers received a STW compensation between 60-69% of their net wage, whereas the other half received a higher STW compensation. This can be due to the fact that the German government introduced a higher compensation (80-89%) for workers affected by STW for a long period during the Covid-19-crisis or because many (in particular large firms) pay top-ups on the STW compensation (as agreed on in wage agreements).

Based on these observations, we define a measure of 'STW affectedness' that combines these two variables. For example, we define a worker as strongly affected by STW if she faces a large hours reduction and only a moderate STW compensation.[7] Unfortunately, the data has this information only in wave 20 (August 2021). We run the cross-sectional regression as described above for this month while controlling for the extent of STW affectedness. As documented in Table 4, these regressions reveal that workers that are strongly affected by STW reduce their consumption by more, compared to workers that are only more moderately affected. In particular, we see a consumption drop of 29%, which is borderline significant. This consumption drop is nevertheless still around a third smaller, compared to the consumption drop of an unemployed worker. This implies that

[7]Strong STW affectedness summarizes workers that experience a 100% hours reduction and either a 60-69% or 70-79% STW compensation, workers that experience a 75-99% hours reduction and either a 60-69% or 70-79% STW compensation, and workers that experience a 50-74% hours reduction and only a 60-69% STW compensation.

	(1)	(2)	(3)	(4)	(5)
γ_u	-0.55^{***}	-0.52^{***}	-0.49^{***}	-0.48^{***}	-0.43^{***}
	(-3.80)	(-4.03)	(-3.85)	(-3.68)	(-2.94)
$\gamma_{stw,strong}$	-0.26^{*}	-0.26^{*}	-0.27^{*}	-0.27^{*}	-0.29^{*}
	(-1.67)	(-1.68)	(-1.80)	(-1.70)	(-1.76)
$\gamma_{stw,median}$	0.03	0.10	0.09	0.10	0.10
	(0.15)	(0.54)	(0.48)	(0.52)	(0.46)
$\gamma_{stw,low}$	-0.05	0.02	0.01	-0.02	-0.12
	(-0.20)	(0.10)	(0.03)	(-0.09)	(-0.48)
Skill		×	×	×	×
Homeown			×	×	×
Homeown × city size				×	×
Wealth/debt					×
Observations	1,337	1,335	1,334	1,334	1,127

Table 4: Consumption expenditure across labor market states including STW affectedness. The parameter γ_u (γ_{stw}) gives the log difference of the consumption of an unemployed (short-time) worker compared to an employed worker. The estimation uses the Bundesbank Household Online Panel that covers monthly data for 2020/2021, wave 20. $t-$statistics are in parentheses, standard errors are clustered at household level, $^{*}p < 0.05, ^{**}p < 0.01, ^{***}p < 0.001$. Dependent variable is log consumption of non-durables and services for individuals between ages 25-55. The set of control variables in all regressions includes age and age squared, gender, household size and household size squared, an indicator for region and city size. Skill is measured using an indicator of eight categories of education, wealth of the household is measured using indicators across 10 categories each for gross assets, secured debt, and unsecured debt.

the consumption risk is still smaller even if we focus on workers that are strongly affected by STW.

3 The model

The model economy is a New Keynesian economy with search and matching frictions, an endogenous separation and STW decision, and incomplete markets. The labor market creates endogenous fluctuations in job risk, and hence income risk that workers want to self-insure against. The only asset available to do so is a one-period nominal government bond. The economy features pricing decisions subject to nominal rigidities, and real wages are rigid. The government pays out social insurance through unemployment benefits and STW compensation and finances this by levying taxes and issuing government debt. The monetary authority sets nominal interest rates. There is ex-ante heterogeneity, i.e., next to workers, there are wealthy risk-neutral firm owners who receive and consume all profits each period.

3.1 Households

There is a continuum of measure 1 of workers. Workers can be in four labor market states in total. (1) Workers employed in full-time earn wage w_t, (2) workers on STW earn wage $w_{s,t}$, (3) unemployed workers receive unemployment benefits δ_t, which can be time-varying, and long-term unemployed workers receive less generous benefits $\delta_{l,t} < \delta_t$. All sources of income are taxed with rate τ_t. Denoting by $x_t^i = \{f, s, u, l\}$ the set of possible employment statuses of household i, the optimization problem of household i is given by:

$$\max_{\{c_t^i, b_t^i\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_t u(c_t^i)$$

$$\text{s.t. } b_t^i + c_t^i = (1+r_t)b_{t-1}^i + (1-\tau_t)(\mathbb{1}_f^i w_t + \mathbb{1}_s^i w_{s,t} + \mathbb{1}_u^i \delta_t + (1 - \mathbb{1}_f^i - \mathbb{1}_s^i - \mathbb{1}_u^i)\delta_{l,t}),$$

$$b_t^i \geq 0,$$

$$\mathbb{E}_t Pr(x_{t+1}^i \mid x_t^i) = \begin{bmatrix} \rho_{t+1}^{ff} & \rho_{t+1}^{fs} & \rho_{t+1}^{fu} & \rho_{t+1}^{fl} \\ \rho_{t+1}^{sf} & \rho_{t+1}^{ss} & \rho_{t+1}^{su} & \rho_{t+1}^{sl} \\ \rho_{t+1}^{uf} & \rho_{t+1}^{us} & \rho_{t+1}^{uu} & \rho_{t+1}^{ul} \\ \rho_{t+1}^{lf} & \rho_{t+1}^{ls} & \rho_{t+1}^{lu} & \rho_{t+1}^{ll} \end{bmatrix},$$

where $\beta_t \in (0,1)$ is the discount factor (that may be subject to shocks) and c_t^i denotes consumption. The utility function $u(c_t^i) = \frac{(c_t^i)^{1-\sigma}}{1-\sigma}$ exhibits constant relative risk aversion (CRRA) with risk aversion parameter σ. The indicator $\mathbb{1}_j^i$ is equal to 1 if the worker i is in a particular state j and equal to 0 if not. Workers invest in domestic government bonds b_t and they cannot borrow. As explained in detail later, workers want to save in a precautionary manner and this savings motive is time-varying, since the transition probabilities ρ_{t+1}^{jj}, which determine income risk, are fluctuating in response to aggregate shocks. In the model, the transition probabilities are determined by hiring, firing and STW decisions of intermediate goods firms. Their problem is discussed in the following section. Next to the workers, there are risk-neutral entrepreneurs who earn and consume all profits as well as home production each period.

3.2 Intermediate good producers and the labor market

Intermediate good firms employ a single worker and sell their product on a competitive market to wholesale good producers. They produce their good using a linear production technology in hours. We assume that firms are owned by risk-neutral entrepreneurs who consume all profits each period.

3.2.1 Employment dynamics, matching technology and vacancy posting

The labor market with STW builds on Balleer et al. (2016) and Gehrke et al. (2019). The labor market is subject to matching frictions, i.e., it is costly to post a vacancy and takes time to fill a vacancy. Firms post vacancies v_t to be matched with unemployed workers u_t. Matches are subject to aggregate and idiosyncratic shocks and separate both endogenously and exogenously. We assume that firms cannot adjust hours per worker along the intensive margin. This represents the fact that the hours adjustment occurs mainly along the extensive margin in Germany (Balleer et al., 2016). In recessions, the adjustment along the intensive margin increases predominantly due to STW (Burda and Hunt, 2011) as in our model.[8] For the sake of clarity, the sequence of events in a typical period t is shown in Figure 4.

[8] Cooper et al. (2017) and Giupponi and Landais (2022) develop models with STW that also feature hours adjustment. STW is then rationalized by introducing a lower bound on hours as justified by

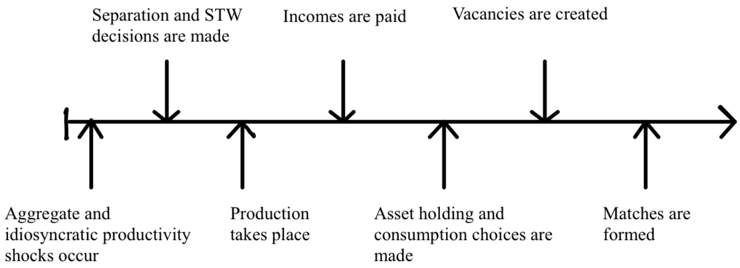

Figure 4: Sequence of events at date t

As in Moyen and Stähler (2014), there are two types of unemployed workers, short-term unemployed $u_{u,t}$ and long-term unemployed $u_{l,t}$. Short-term unemployed workers enter long-term unemployment with probably ω_l. Further, and similar to Ravn and Sterk (2017), we allow for duration dependence, i.e., long-term unemployed worker may have a lower job-finding rate than short-term unemployed workers due to lower search efficiency. The matching technology is given as: $m_t = \mu u_{e,t}^{\alpha} v_t^{1-\alpha}$, where $u_{e,t}$ is a measure of effective unemployment

$$u_{e,t} = u_{u,t} + k u_{l,t}, \tag{2}$$

taking into account that long-term unemployed only search with probability $k \in (0, 1]$. $\alpha \in (0, 1)$ is the elasticity of matches with respect to unemployment and the parameter $\mu > 1$ is the matching efficiency. Job-finding rates of short-term unemployed are therefore: $\eta_{u,t} = \mu\theta_t^{1-\alpha}$, of long-term unemployed: $\eta_{l,t} = \mu k \theta_t^{1-\alpha}$, where $\theta_t \equiv v_t/u_{e,t}$ represents labor market tightness. Conversely, the probability of a firm to fill a vacancy is given by $q_t = \mu\theta_t^{-\alpha}$. At the beginning of a given period t, separation and STW decisions are made. The separation rate is given by $\phi_t = \phi^x + (1 - \phi^x)\phi_t^e$, where ϕ^x represents exogenous job-destruction and ϕ_t^e represents endogenous job- destruction (details follow in the next section). The laws of motion for employment and unemployment are:

$$n_t = (1 - \phi_t)(n_{t-1} + m_{t-1}) \tag{3}$$

$$u_{u,t} = (1 - \omega_l)(1 - \eta_{u,t-1})u_{u,t-1} + \eta_{u,t-1}\phi_t u_{u,t-1} + \eta_{l,t-1}\phi_t u_{l,t-1} + \phi_t n_{t-1} \tag{4}$$

$$u_{l,t} = \omega_l(1 - \eta_{u,t-1})u_{u,t-1} + (1 - \eta_{l,t-1})u_{l,t-1} \tag{5}$$

where $n_t = 1 - u_t$, and $u_t = u_{u,t} + u_{l,t}$.

Employment in period t depends on employment and matches in the previous period, conditional on not being fired at the beginning of period t. Note that workers on STW are treated as employed, thus they are part of n_t, although they do not work full-time.

The present value of a vacancy to a firm is defined as:

$$V_t = -\kappa + \beta\mathbb{E}_t q_t J_{t+1} + \mathbb{E}_t\beta(1 - q_t)V_{t+1}, \tag{6}$$

where J_t is the present value of a job and κ represents vacancy posting costs. Assuming free entry to vacancy posting ($V_t = 0 \ \forall \ t$) results in the job creation condition:

$$\frac{\kappa}{q_t} = \beta\mathbb{E}_t J_{t+1}. \tag{7}$$

rigidities in the labor market or by workers not accepting hours below a certain threshold due to risk aversion or a convex disutility of work. STW then relaxes this lower bound.

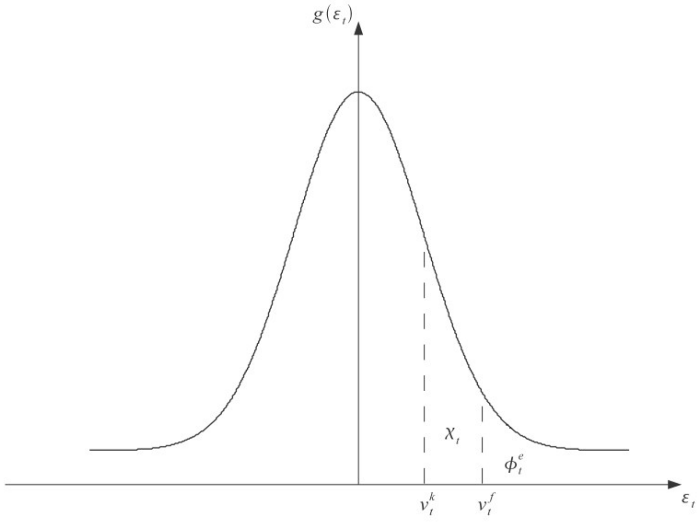

Figure 5: Illustration of the distribution of the idiosyncratic profitability shocks with STW threshold v_t^k and v_t^f following Balleer et al. (2016).

The average costs of finding a worker are recouped in expectation after a match occurs through the discounted expected value of a job.

3.2.2 Separation and short-time work decisions

The separation and STW decisions follow Balleer et al. (2016). Separations are endogenous in the spirit of Mortensen and Pissarides (1994). Let ϵ_t be the realization of an *i.i.d.* idiosyncratic cost shock drawn from the distribution $g(\epsilon_t)$ that is subtracted from period profits. If the shock is above a certain threshold v_t^f such that the firm surplus of a filled job turns negative, the worker is fired. STW introduces a second threshold v_t^k, above which workers are not profitable enough to be full-time employed, but they are not fired because their expected future value is positive. Consequently, the rate of workers on STW is denoted by $\chi_t = \int_{v_t^k}^{v_t^f} g(\epsilon_t)d\epsilon_t$, and the endogenous separation rate is $\phi_t^e = \int_{v_t^f}^{\infty} g(\epsilon_t)d\epsilon_t$. This is illustrated in Figure 5. For the separation and STW decision, we focus on the firm surplus. This implies that separations or STW decisions may occur because of a negative firm surplus, even though the joint surplus of worker and firm may still be positive, rendering these decisions inefficient. This inefficiency can be explained by institutional constraints and bargaining frictions such as wage floors. Using data for Austria and Italy, Jäger et al. (2022) and Giupponi and Landais (2022) show empirically that such rigidities in wages and hours matter and indeed create inefficient separations.

The value of a worker from the firm's perspective with a specific realization of the idiosyncratic shock ϵ_t such that the worker is not on STW is given by:

$$J_t(\epsilon_t|\epsilon_t < v_t^k) = a_t p_{z,t} - w_t - \epsilon_t + \beta \mathbb{E}_t J_{t+1}, \tag{8}$$

where a_t is aggregate productivity and $p_{z,t} = P_{z,t}/P_t$ is the relative price of the intermediate good in terms of the final good price and w_t is the wage of the worker.

The government defines an eligibility criterion ζ_t for STW such that only those firms with a value below that threshold are allowed to use STW:

$$a_t p_{z,t} - w_t - \epsilon_t + \beta \mathbb{E}_t J_{t+1} < \zeta_t. \tag{9}$$

The value of the idiosyncratic shock ϵ_t where Equation 9 holds with equality is given by v_t^k. It defines the threshold value for STW v_t^k as

$$v_t^k = a_t p_{z,t} - w_t + \beta \mathbb{E}_t J_{t+1} - \zeta_t. \tag{10}$$

The variable ζ_t is a policy instrument and may be changed unexpectedly in a discretionary manner. In steady state, it is assumed that $\zeta_t = -f$, where f is the cost of firing a worker, implying that only those firms are allowed to use STW that would otherwise fire. A higher value of ζ_t than the steady state value would imply that workers can be sent on STW even before they would be fired, i.e., the eligibility criterion becomes less stringent. This directly shifts the threshold in Figure 5 to the left implying a higher STW rate χ_t.

Given that a worker is eligible for STW, the firm can freely choose the optimal working time reduction K subject to convex adjustment costs $C(K(\epsilon_t))$ with $\frac{\partial C(K(\epsilon_t))}{\partial K(\epsilon_t)} > 0$ and $\frac{\partial^2 C(K(\epsilon_t))}{\partial K(\epsilon_t)^2} > 0$ to ensure interior solutions.[9] The choice of convex adjustment costs reflects the fact that the reduction in labor costs for firms is typically not proportional to the hours reduction. This can be due to (i) the fact that the employer has to pay social security contributions for the full-time equivalent, (ii) the existence of bureaucratic barriers (iii) or possible resistance by workers to high hours reductions.[10] The firm chooses the optimal level of hours reduction K by maximizing the contemporaneous profit of a worker on STW:

$$\max_{K(\epsilon_t)} \pi_t = (a_t p_{z,t} - w_t - \epsilon_t)\big(1 - K(\epsilon_t)\big) - C\big(K(\epsilon_t)\big) \tag{11}$$

The reduction in working time reduces output of the worker, but also wage payments and the idiosyncratic cost. Assuming a quadratic functional form for the costs of STW:

$$C(K(\epsilon_t)) = c_k \frac{1}{2} K(\epsilon_t)^2 \tag{12}$$

yields an optimal STW hours reduction for a given ϵ_t

$$K^*(\epsilon_t) = -\frac{a_t p_{z,t} - w_t - \epsilon_t}{c_k}. \tag{13}$$

Then, the firing decision of the firm is described by:

$$(a_t p_{z,t} - w_t - \epsilon_t)\big(1 - K^*(\epsilon_t)\big) - C\big(K^*(\epsilon_t)\big) + \beta \mathbb{E}_t J_{t+1} < -f. \tag{14}$$

Solving for the firing threshold v_t^f at which the firm is indifferent between firing and retaining a worker on STW yields:

$$v_t^f = p_{z,t} a_t - w_t + \frac{f + \beta \mathbb{E}_t J_{t+1}}{1 - K^*(v_t^f)} - \frac{C(K^*(v_t^f))}{1 - K^*(v_t^f)}. \tag{15}$$

[9] Linear costs would imply corner solutions where workers either work full-time or hours are reduced by 100%. This would not be in line with the data, see also Figure 10 in the Appendix.

[10] For example in the German context, the workers representation has to agree to using STW.

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 (see also Figure 5). STW exists in this economy only if $v_t^f > v_t^k$, which is ensured under plausible values of the STW cost c_k. Equation (13) highlights that if c_k approaches infinity, the optimal hours reduction approaches zero, and firms do not use STW ($K^* = 0$, $v_t^f = v_t^k$).

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

$$
\begin{aligned}
J_{t+1} &= (1-\phi^x)\int_{-\infty}^{v_{t+1}^k}(a_{t+1}p_{z,t+1} - w_{t+1} - \epsilon_{t+1})g(\epsilon_{t+1})d\epsilon_{t+1} \\
&+ (1-\phi^x)\int_{v_{t+1}^k}^{v_{t+1}^f}\big[(a_{t+1}p_{z,t+1} - w_{t+1} - \epsilon_{t+1})(1-K^*(\epsilon_{t+1})) - C(K^*(\epsilon_{t+1}))\big]g(\epsilon_{t+1})d\epsilon_{t+1} \\
&- (1-\phi^x)\phi_{t+1}^e f + \beta\mathbb{E}_{t+1}(1-\phi_{t+1})J_{t+2}.
\end{aligned} \tag{16}
$$

Finally, aggregating over all intermediate firms and taking into account the cost for vacancy posting yields total period-by-period dividends paid out to firm owners:

$$
\begin{aligned}
d_t^I = n_t^B(1-\phi^x)&\int_{-\infty}^{v_t^k}(a_t p_{z,t} - w_t - \epsilon_t)g(\epsilon_t)d\epsilon_t \\
+ n_t^B(1-\phi^x)&\int_{v_t^k}^{v_t^f}\left[(a_t p_{z,t} - w_t - \epsilon_t)(1-K^*(\epsilon_t)))\right]g(\epsilon_t)d\epsilon_t \\
- n_t^B(1-\phi^x)&\phi_t^e f - \kappa v_t,
\end{aligned} \tag{17}
$$

where $n_t^B = \frac{n_t}{(1-\phi_t)}$ is employment before separations.

Now that the relevant equations for hiring, separation and STW decisions have been discussed, we can show the transition matrix of workers in more detail, with current states in rows and future states in columns:

$$
\mathbb{E}_t Pr(x_{t+1}^i \mid x_t^i) \tag{18}
$$

$$
= \begin{bmatrix}
(1-\phi^x)\mathbb{E}_t(1-\phi_{t+1}^e - \chi_{t+1}) & (1-\phi^x)\mathbb{E}_t\chi_{t+1} & \mathbb{E}_t\phi_{t+1} & 0 \\
(1-\phi^x)\mathbb{E}_t(1-\phi_{t+1}^e - \chi_{t+1}) & (1-\phi^x)\mathbb{E}_t\chi_{t+1} & \mathbb{E}_t\phi_{t+1} & 0 \\
\eta_{u,t}(1-\phi^x)\mathbb{E}_t(1-\phi_{t+1}^e - \chi_{t+1}) & \eta_{u,t}(1-\phi^x)\mathbb{E}_t\chi_{t+1} & (1-\omega_l)(1-\eta_{u,t}(1-\mathbb{E}_t\phi_{t+1})) & \omega_l(1-\eta_{u,t}(1-\mathbb{E}_t\phi_{t+1})) \\
\eta_{l,t}(1-\phi^x)\mathbb{E}_t(1-\phi_{t+1}^e - \chi_{t+1}) & \eta_{l,t}(1-\phi^x)\mathbb{E}_t\chi_{t+1} & 0 & 1-\eta_{l,t}(1-\mathbb{E}_t\phi_{t+1})
\end{bmatrix} \tag{19}
$$

Note that the transition probabilities for employed workers and workers on STW (row 1 and row 2) are identical but differ from those of unemployed workers. Due to the *i.i.d.* assumption on the profitability shock ϵ_t, the firing and STW probability in $t+1$ is independent of whether a worker is employed or on STW in t. This assumption keeps the model tractable as the STW decision of firms is not intertemporal. The zeros in column 4 reflect the fact that there is no direct transition from employment to the long-term unemployment state. Row 3 shows the transition probabilities for the short-term unemployment state, which also depend on the job-finding rate $\eta_{u,t}$ in addition to the variables that matter in row 1 and 2. It is easy to see then, that as long as $\eta_{u,t} < 1$, the prospective employment probability for unemployed workers is smaller than that of short-time workers. This is how STW reduces employment risk. This is also true in the data. In survey data from the Covid-19 crisis for Germany[11], only 4% of employees

[11] Source: IAB HOPP, May to September 2020.

on STW state that it is very likely that they will be unemployed in the next 3 three months, 27% state that it is very likely that they will stay employed. In contrast, for the unemployed 21% consider it highly likely that they will stay unemployed in the next 3 months, only 8% consider it very likely that they will find a new job. Further, the exogenous probability ω_l determines transitions from short-term unemployment (row 3) to long-term unemployment (row 4). Lastly, row 4, showing the transition probabilities out of long-term unemployment, includes a zero, because transitions back to short-term unemployment are not possible.

Generally, note that the job-finding rates ($\eta_{u,t}$, $\eta_{l,t}$), the short-time rate χ_{t+1} and the endogenous separation rate ϕ^e_{t+1} are all fluctuating in response to aggregate shocks, thereby making employment and consequently income risk endogenous. The latter aspect is a feature of the search and matching labor market. However, the complexity of the labor market sets this model apart from simpler search models where only fluctuations in the job-finding rate drive precautionary savings (e.g. Ravn and Sterk (2021); Challe (2020)).

3.2.3 Wage determination

For wages, we assume collective bargaining to capture labor market institutions in continental Europe. The wage is bargained in a Nash bargaining game between the representative firm and the median incumbent worker with a realization of the profitability shock ϵ_t equal to zero. Every worker who is working full-time earns this wage. Workers on STW also receive a collective wage, according to the average working time of short-time workers, plus a reimbursement for the lost wage income. This type of bargaining makes the model easier to solve but implies inefficient separations.[12] The value of the median worker to the firm is therefore

$$F_t = a_t p_{z,t} - w_t + \beta \mathbb{E}_t J_{t+1}. \tag{20}$$

In case of disagreement, there is no production, but bargaining is resumed in the next period such that the match of the median worker continues. This type of bargaining setup is described in more detail in Hall and Milgrom (2008) and is also used in Lechthaler et al. (2010). The assumption on the disagreement value differentiates collective from individual wage bargaining, reflecting that with collective bargaining it is typically not the case that all workers will become unemployed in case of disagreement. The fall-back option is thus

$$\tilde{F}_t = \beta \mathbb{E}_t J_{t+1}. \tag{21}$$

The median worker's surplus W_t from a match is

$$W_t = w_t + \beta(1-\phi^x)\mathbb{E}_t(1-\phi^e_{t+1}-\chi_{t+1})W_{t+1} + \beta\mathbb{E}_t(1-\phi^x)\chi_{t+1}W^{stw}_{t+1} + \beta\mathbb{E}_t\phi_{t+1}U_{t+1}, \tag{22}$$

where U_t is the value of short-term unemployment. The worker knows that the wage will also be collectively bargained in the next period, hence W_{t+1} does not depend on the idiosyncratic shock either. Lastly, the worker's fall-back option under disagreement is

$$\tilde{W}_t = \delta_t + \beta(1-\phi^x)\mathbb{E}_t(1-\phi^e_{t+1}-\chi_{t+1})W_{t+1} + \beta\mathbb{E}_t(1-\phi^x)\chi_{t+1}W^{stw}_{t+1} + \beta\mathbb{E}_t\phi_{t+1}U_{t+1}. \tag{23}$$

[12] The median worker is not affected by STW. Further, STW does not affect the outside option in the bargaining game as it is not a relevant outside option in case of wage disagreement. In practice, STW is only allowed in case of a temporary lack of demand and financial difficulties.

In case of disagreement, the worker receives unemployment benefits $\delta_t < w_t$. The wage follows from

$$w_t^N = \arg\max\ (W_t - \tilde{W}_t)^{1-\gamma}(F_t - \tilde{F}_t)^{\gamma}, \tag{24}$$

where $\gamma \in (0,1)$ represents the bargaining power of the worker. Following Shimer (2005) and Hall (2005), we add real wage rigidity to the model. There are two reasons for this. First, this generates realistic volatility of labor market variables over the business cycle. Second, the degree of wage rigidity has important implications for the behavior of the real interest rate and precautionary savings, as will be discussed in Section 5.1.

$$w_t = (w_t^N)^{1-\gamma_w}(w_{ss})^{\gamma_w}. \tag{25}$$

The real wage is a weighted average between the bargained wage and the wage at the steady state, where a higher value of $\gamma_w \in (0,1)$ implies more rigid real wages. Finally, a short-time worker is paid the wage for the remaining working time $1-K(\epsilon_t)$, but receives STW compensation that is (in the baseline model) equal to the unemployment benefit for the share $K(\epsilon_t)$. Since being on STW is a convex combination of full employment and unemployment, workers generally prefer STW to being laid off. In the limit where $K(\epsilon_t) = 1$, workers would be indifferent.[13] For tractability of the model, we introduce an average STW wage that all workers on STW receive irrespective of the idiosyncratic ϵ_t realization. This STW wage is given by

$$w_t^s = \int_{v_t^k}^{v_t^f} \frac{(1-K(\epsilon_t))w_t + \delta_t K(\epsilon_t)}{\chi_t} g(\epsilon_t) d\epsilon_t.^{14} \tag{26}$$

3.3 Wholesale and final goods firms

Wholesale firms use intermediate goods as their only input in production, turn it into a specialized good and monopolistically resell it to the final goods sector. Final good firms produce homogeneous consumption goods with a Dixit-Stiglitz aggregator and sell in a perfectly competitive market to households. Profit maximization by final goods firms implies that wholesale firms face the following downward sloping demand function:

$$y_{jt} = \left(\frac{P_{j,t}}{P_t}\right)^{-\epsilon} y_t, \tag{27}$$

where ϵ is the elasticity of substitution among goods varieties and the price index is given by $P_t = \left(\int_j P_{j,t}^{1-\epsilon} dj\right)^{\frac{1}{1-\epsilon}}$.

We introduce nominal rigidities so that fluctuations in aggregate demand affect aggregate employment. Following Rotemberg (1982), wholesale goods firms face quadratic costs of price adjustment, governed by parameter Ψ. They are also owned by the risk-neutral entrepreneurs. They set prices to maximize the present discounted value of profits:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_t \left[\left(\frac{P_{j,t}}{P_t} - p_{z,t}\right) y_{j,t} - \frac{\Psi}{2}\left(\frac{P_{j,t} - P_{j,t-1}}{P_{j,t-1}}\right)^2 y_t\right], \tag{28}$$

[13]In Germany, the average hours reduction due to STW was 41% in March to May 2020 at the peak of the Covid-19-crisis, the long-run average is lower with 29% from January 2007 to May 2020.

[14]Similarly to the full-time wage, ensuring that the short-time wage does not depend on idiosyncratic productivity eases the computational burden, in the sense that one does not need to keep track of a nondegenerate wage distribution.

subject to the demand constraint (27). The first order condition using that all firms set the same price becomes:

$$0 = (1 - \epsilon) + \epsilon p_{z,t} - \Psi(\Pi_t - 1)\Pi_t + \beta \mathbb{E}_t \left\{ \Psi(\Pi_{t+1} - 1) \frac{y_{t+1}}{y_t} \Pi_{t+1} \right\}, \tag{29}$$

where $\Pi_t = \frac{P_{j,t}}{P_{j,t-1}}$ is the gross inflation rate.

Lastly, the period by period dividends paid out to firm owners are

$$d_t^W = (1 - p_{z,t})\, y_t - \frac{\Psi}{2} (\Pi_t - 1)^2 y_t, \tag{30}$$

and total dividends paid out to firm owners by wholesale and intermediate firms are thus given by:

$$d_t = d_t^W + d_t^I. \tag{31}$$

3.4 Government and market clearing

The monetary authority adheres to a simple Taylor rule that targets the inflation rate:

$$\frac{1 + i_t}{1 + r} = (1 + \pi_t)^{\psi_\pi}, \tag{32}$$

where $\psi_\pi > 1$ is the elasticity of the policy rate to inflation. Real and nominal interest rates are connected via the Fisher equation $1 + i_t = (1 + r_t)(1 + \mathbb{E}_t \pi_{t+1})$. The government finances expenditures on unemployment insurance and STW benefits by issuing one-period bonds B_t, and collecting taxes T_t. The government's budget constraint is therefore:

$$T_t + B_t = (1 + r_t)B_{t-1} + \delta n_t^B (1 - \phi^x) \int_{v_t^k}^{v_t^f} K^*(\epsilon_t) g(\epsilon) d\epsilon_t + \delta_t u_{u,t} + \delta_{l,t} u_{l,t}, \tag{33}$$

where tax income T_t is obtained by taxing all agents' income with tax rate τ_t. In the baseline specification, government debt is determined exogenously by a deficit rule:

$$\frac{B_t}{B} = \left(\frac{B_{t-1}}{B}\right)^{\rho_B} \left(\frac{n_t}{n}\right)^{(1-\rho_B)\gamma_B}, \tag{34}$$

so that government debt expands in a countercyclical manner when the labor market is slack, governed by the elasticity parameter $\gamma_B < 0$, with some inertia, controlled by parameter ρ_B. Taxes then adjust such that the government's budget constraint holds.

The bond market clears when bonds supplied by the government are equal to the aggregate savings of the respective agents

$$B_t = \mathbb{E}_t \left[n_{f,t} b_{f,t}^* + n_{s,t} b_{s,t}^* + u_{u,t} b_{u,t}^* + u_{l,t} b_{l,t}^* \right], \tag{35}$$

where the expectation on the right-hand side is taken with respect to the distribution over assets, and $b_{i,t}^*$ denote optimal savings decisions of agents in employment state i.

Market clearing in the intermediate goods market implies

$$y_t = n_t^B (1 - \phi^x) \left[\int_{-\infty}^{v_t^k} a_t g(\epsilon_t) d\epsilon_t + \int_{v_t^k}^{v_t^f} a_t (1 - K^*(\epsilon_t)) g(\epsilon_t) d\epsilon_t \right]. \tag{36}$$

Finally, adding up the budget constraints of all households, one arrives at at the aggregate resource constraint. Aggregate consumption equals production minus frictional costs:

$$\begin{aligned}
&\mathbb{E}_t\left[n_{f,t}c^*_{f,t} + n_{s,t}c^*_{s,t} + u_{u,t}c^*_{u,t} + u_{l,t}c^*_{l,t}\right] + c_{e,t} = \\
&n_t^B(1-\phi^x)\int_{-\infty}^{v_t^k}(a_t-\epsilon_t)g(\epsilon_t)d\epsilon_t + n_t^B(1-\phi^x)\int_{v_t^k}^{v_t^f}(a_t\epsilon_t)(1-K^*(\epsilon_t))g(\epsilon_t)d\epsilon_t \quad - \\
&(1-\phi^x)n_t^B\phi_t^e f - \kappa v_t - \frac{\Psi}{2}\left(\Pi_t - 1\right)^2 y_t + \xi,
\end{aligned} \tag{37}$$

where $c^*_{i,t}$ denote optimal consumption decisions of agents in employment state i, and ξ denotes home production of entrepreneurs.

3.5 Equilibrium and solution method

An equilibrium is a sequence of value and policy functions, tightness, employment, short-time rate, prices, wages, such that workers solve their optimization problem given prices and employment probabilities, which are implied by equations (3), (4), (5), (7), together with equations for the short-time rate 10) and firing rate (15). Optimal hours reduction is given by (13), and wages are determined by Nash-bargaining (24). Retailers maximize (28), the government budget constraint holds (3.4) and the markets for assets (35) and goods clears (36).

To solve the model, we rely on perturbation methods, i.e., we compute a first-order Taylor expansion around the steady state following the method discussed in Reiter (2009), which allows solving heterogeneous agents models with aggregate uncertainty.

3.6 Inspecting the unemployment risk stabilization of short-time work

To illustrate how STW stabilizes unemployment risk, we analyze a simplified model first. In particular, we assume that bonds are in zero net supply such that the wealth distribution is degenerate in equilibrium, and all agents consume their current income, as in Challe (2020) or Ravn and Sterk (2021). Then, the Euler equation of full-time workers determines the real interest rate in equilibrium. Further, we abstract from long-term unemployment here. In a counterfactual model without STW, the Euler equation is:

$$\beta\mathbb{E}_t\left\{R_t^{nostw}\left[(1-\phi_{t+1}^{nostw})\left(\frac{w_{t+1}}{w_t}\right)^{-\sigma} + \phi_{t+1}^{nostw}\left(\frac{\delta}{w_t}\right)^{-\sigma}\right]\right\} = 1 \tag{38}$$

For the consumption-saving decision, the household weighs the probabilities and outcomes of the different labor market states in the next period. In particular, the household compares the full-time workers wage to the income loss that is associated with unemployment, δ.

With STW, the full-time workers' Euler Equation is:

$$\beta\mathbb{E}_t\left\{R_t\left[(1-\phi_{t+1}-\chi_{t+1})\left(\frac{w_{t+1}}{w_t}\right)^{-\sigma} + \chi_{t+1}\left(\frac{w_{s,t+1}}{w_t}\right)^{-\sigma} + \phi_{t+1}\left(\frac{\delta}{w_t}\right)^{-\sigma}\right]\right\} = 1. \tag{39}$$

First, STW introduces additional risk as captures by the term $\chi_{t+1}\left(\frac{w_{s,t+1}}{w_t}\right)^{-\sigma}$ that represents the additional STW state that occurs with probability χ. But second, STW reduces the firing risk $\phi < \phi^{nostw}$, because the existence of STW prevents firings. This is the probability of the bad outcome, where workers receive unemployment benefits δ. A higher probability on the bad outcome in the model without STW implies more risk and more precautionary savings, and a *lower* equilibrium interest rate.

Thus, as long as $\delta < w_s \leq w$, i.e., being on STW is preferred to being unemployed, we obtain $R^{nostw} < R$, implying less precautionary savings in the model with STW as full-time workers face lower risk. The condition $\delta < w_s \leq w$ holds as we showed in Section 2. Thus, the existence of STW helps to stabilize demand in recessions. Next, we quantify the extent of this stabilization in our full quantitative model.

4 Quantitative analysis of short-time work and precautionary savings

4.1 Benchmark economies

To illustrate the transmission mechanism when there is uninsurable unemployment risk in a model with STW, we compare several scenarios.

Short-time work with unemployment risk Our benchmark is an economy where firms face a STW decision and households are imperfectly insured against unemployment risk.

No short-time work with unemployment risk The benchmark model economy nests a smaller model with endogenous separations but without a short-time margin. This acts as a benchmark to illustrate the effects of STW in interaction with precautionary savings.

Short-time work without unemployment risk In this economy, there is a STW decision but households pool their income risk perfectly, so that there is no precautionary savings mechanism.

No short-time work without unemployment risk The final comparison will be a model without unemployment risk and without STW.

4.2 Calibration

Our baseline model is calibrated to the German economy at quarterly frequency. Table 5 summarizes our calibration strategy. For the New Keynesian block of the model, we impose standard values. The discount factor β is 0.98, which, given fixed bond supply in steady state, delivers an annual real interest rate of 2.02%. We follow McKay et al. (2016) and set the elasticity of substitution ϵ to 6. For the value of the price adjustment costs Ψ we choose a value consistent with a Calvo (1983) probability of maintaining a fixed price equal to 0.86. In comparison, Thomas and Zanetti (2009) estimate a value of 0.88 in a model with labor market frictions for Europe. This estimate is on the high side of the values used in the business cycle literature but it ensures a plausible slope of the Phillips curve.[15] The Taylor weight on inflation ψ_π and the value for relative risk aversion σ are both set to 1.5.

Regarding the labor market, we set steady state targets in line with Christoffel et al. (2009) and Balleer et al. (2016). Specifically, the targets for the worker finding rate and separation rate are 0.7 and 0.03 respectively. Out of all separations, we assume that one-third are endogenous, while two-thirds are exogenous. Further, the targeted unemployment rate of 9% implies a quarterly job-finding rate of 31%. The STW rate is 0.7%. The elasticity of matching with respect to unemployment α is set to 0.6. It is well known that, in search models, smaller accounting profits imply a higher volatility of labor market variables (Shimer, 2005; Hagedorn and Manovskii, 2008). Setting the operating profits for a job with mean profitability of zero equal to 0.05 implies a contemporaneous elasticity of the extensive margin of STW with respect to output changes of -4.5 in the case without unemployment risk. This number is in the range of the estimated elasticities by Balleer et al. (2016).

The labor market targets determine several of our parameters. Assuming that the idiosyncratic profitability shock follows a logistic distribution with an unconditional mean of zero, the implied value for the scale parameter s is 1.02, the matching efficiency μ is 0.43, and the costs of posting a vacancy κ are 1.18. The firing costs f are set to 60% of annual productivity, following Balleer et al. (2016). The target for the STW rate implies a value for the costs of STW usage c_k of 19.75.

We set the duration in short-term unemployment to on average 5 quarters implying a transition probability to long-term unemployment ω_l of 0.2..[16] For the relative search efficiency of the long-term unemployed k, we set a value of 1. This implies that they are equally efficient searchers as the short-term unemployed, which we regard as an upper bound.[17]

Regarding the precautionary savings mechanism, first, key parameters are the replacement rates of short-term unemployed δ/w and long-term unemployed δ_l/w workers. We set the former to 0.6, equal to the typical replacement rate in Germany upon unemployment, and adjust the latter to obtain an average consumption drop upon unemployment in line with the empirical results from Section 2 (a discussion follows in the next section). Second, the degree of wage rigidity is important as a driver of the cyclicality of labor income. The wage rigidity parameter γ_w is calibrated to match an elasticity of real wages with respect to labor productivity of 0.2. In the benchmark case of imperfect insurance and STW, this implies a value of $\gamma_w = 0.82$. We show how our main results change with different values of this elasticity in Section 5.4.[18] Third, the

[15] Harding et al. (2022) show that a relatively minor modification of a New Keynesian model with a Kimball aggregator and a non-linear solution is able to produce a flat Phillips curve, while being consistent with more realistic price adjustment at the micro level. However, the latter is not the focus of our paper.

[16] In Germany, entitlement to the highest level of unemployment benefits (Arbeitslosengeld I, ALG 1) is based on age and duration of employment, and can be between 6 to 24 months long. 5 quarters is close to the duration of the average worker.

[17] In Section 5.4, we show what happens if we relax this assumption.

[18] Note that income risk is countercyclical in this economy by assumption, meaning that precautionary savings motives increase in recessions, because the unemployment probability increases. This is an ongoing empirical issue. Storesletten et al. (2004) study PSID household income data and find that individual income processes exhibit countercyclical variance. Guvenen et al. (2014) find that countercyclical fluctuations in earnings risk may derive from countercyclical left-skewness of shocks, i.e., an increasing likelihood of large income losses rather than large income gains in recessions. This concept is distinct from a countercyclical variance but similar predictions arise, namely that precautionary savings rise in

	Description	Value	Explanation/Target
Parameters			
β	Discount factor	0.98	Standard value
r	Real interest rate (annual.)	2.02%	Target bond supply
Ψ	Price adjustment costs	207	Slope of New Keynesian Phillips curve
ϵ	Elasticity of subst. between varieties	6	McKay et al. (2016)
ψ_π	Taylor weight on inflation	1.5	Kaplan et al. (2018)
σ	Relative risk aversion	1.5	Standard value
α	Matching elasticity w.r.t. unemployment	0.6	Balleer et al. (2016)
δ/w	Replacement rate	0.6	German replacement rate in ALG I
δ_l/w	Replacement rate for long-term unemployed	0.17	Consumption drop upon unemployment
μ	Matching efficiency	0.43	Target labor market flows
f	Firing costs	2.4	60% Annual productivity
k	Relative search efficiency long-term unemployed	1	Most conservative value
ω_l	Transition probability long-term unemployment	0.2	Average duration of ALG I
$p_z a - w$	Operating profits	0.05	Contemporaneous elasticty of STW w.r.t. output
s	Scale parameter of profitability distribution	1.02	Target labor market flows
κ	Costs of posting a vacancy	1.18	Target labor market flows
c_k	Costs of STW usage	19.75	STW rate in steady state
γ_w	Wage rigidity parameter	0.82	Elasticity of wages w.r.t productivity
γ	Worker bargaining power	0.86	Implied by operating profits
ξ	Home production	0.97	Entrepreneur income share
γ_B	reaction of debt to employment	-0.2	Countercyclical fiscal policy
ρ_B	inertia of debt	0.9	Standard value
η	Job-finding rate	0.31	Target unemployment rate
Steady state targets			
q	Worker-finding rate	0.7	Christoffel et al. (2009)
ϕ	Overall job-destruction rate	0.03	Christoffel et al. (2009)
u	Unemployment rate	0.09	Christoffel et al. (2009)
χ	STW rate	0.007	Balleer et al. (2016)
Π	Inflation	1	Standard value
B	Bond supply	1	Liquid assets to output ratio

Table 5: Calibration

bond supply by the government is set to 1, implying a debt-to-GDP ratio of roughly 0.3. This is considerably lower than the actual German debt-to-GDP ratio, but this relatively low amount of liquidity is needed to generate realistic average MPCs in the model.[19] The reaction of public debt to employment γ_B is equal to -0.2, and the autoregressive parameter ρ_B is equal to 0.9. Given that government debt plays a role for the ability of agents to self insure in the model, and therefore affects precautionary savings and our results, we discuss different specifications of these fiscal policy rules for robustness in Section 5.4. Entrepreneurial consumption is interpreted as the consumption of the top 20% in the income distribution. To target an income share of entrepreneurs of roughly 60% (Kuhn and Ríos-Rull, 2016), we set the value of home production equal to $\xi = 0.97$. When comparing economies with and without STW, we keep all parameters the same between these scenarios, ensuring that our stabilization results are not driven by parameter changes. This then impliees that the steady states may differ.[20] For this reason, we only interpret percentage deviations from steady state in the following.

4.3 Policy functions and model validation

Before we show impulse responses, we discuss model intuition and model fit. Towards that end, Figure 6 displays distributions in steady state and policy rules over the asset grid. Panel 1 shows the stationary asset distributions for the different employment states. A significant fraction (around 3 percent) of all long-term unemployed workers hold zero assets. The asset distributions of full-time employed and short-time employed look similar. The lower left panel plots net savings $b' - b$ for workers across assets and states. The plot supports the intuition from Panel 1. The policy rules of full-time workers and short-time workers are similar except for a level effect arising from lower incomes of short-time workers. This observation is in line with the empirical evidence from the German household data as presented in Figure 2 (Section 2). The policy rules of unemployed workers are steeper compared to those of employed workers in general, and net savings are negative almost over the whole grid. An exception arises for very low assets: savings of short-term unemployed workers are positive and higher than those of short-time workers because they fear that they might become long-term unemployed. The precautionary savings motive at low assets for all states except long-term unemployment explains why only a significant fraction of that group holds zero assets, as visible in Panel 1. The upper right panel plots the consumption rules. They imply that on average, workers on STW have similar consumption to full-time workers, whereas consumption of short-time unemployed workers is lower by 31% percent and those of long-term unemployed workers is lower on average by 44%. Overall, this implies that consumption is 35% lower in unemployment than in employment, in line with the empirical results of Section 2. The lower average consumption and the different shape of the policy rules are due to the lower current income in unemployment, as well as the different transition probabilities conditional on the employment state. Lastly, the

recessions. Ravn and Sterk (2021) provide a detailed discussion on the countercyclicality of income risk.

[19]With a more realistic debt-to-GDP ratio, and therefore higher average wealth in steady state, we would need to introduce additional heterogeneity, for example discount factor heterogeneity as in Carroll et al. (2017), so that workers either cannot or do not want to save themselves out of being constrained. This would complicate the model further without additional insights for the analysis of STW.

[20]For instance, targeting the same level of unemployment in models with STW and without STW would imply a difference in matching efficiency. The real interest rate in steady state of the model without STW is lower with the same discount factor and the same bond supply.

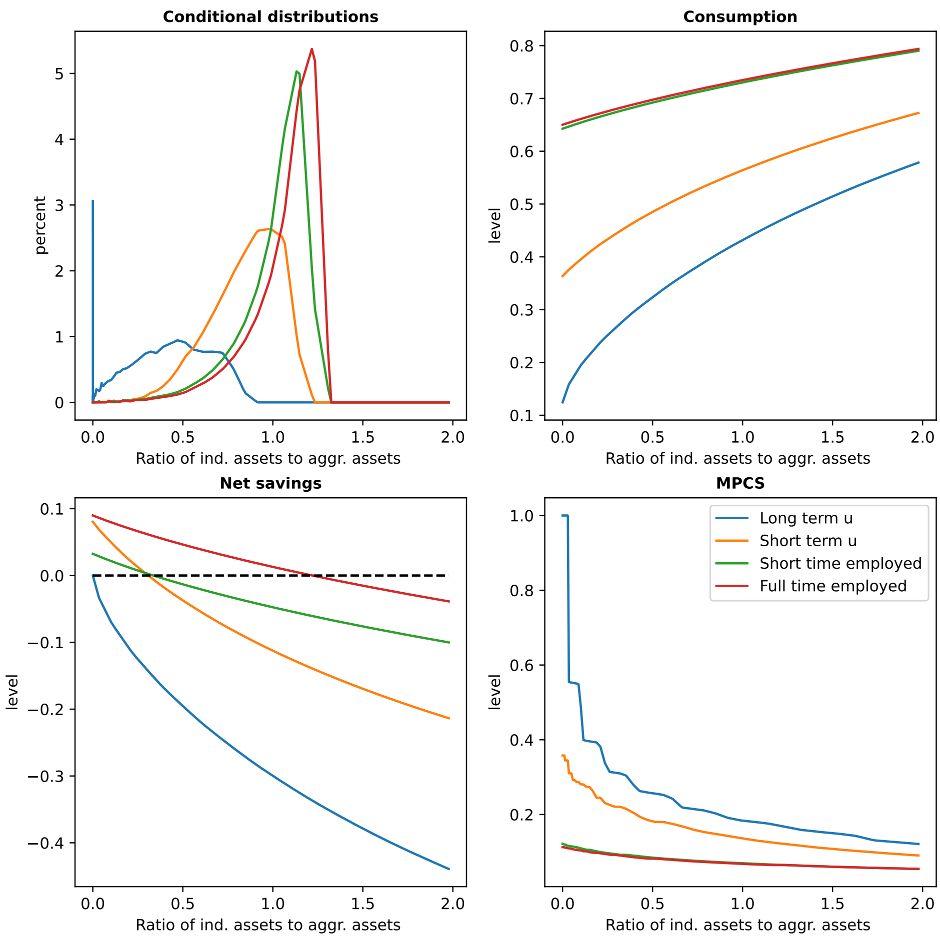

Figure 6: Model properties in steady state.

lower right panel plots the MPCs, which are obtained as a numerical derivative of the consumption rules. In line with the consumption rules, MPCs are very high for low assets in the unemployment states, especially in long-term unemployment. By looking at this panel, a prediction can be made that transfers to unemployed workers will yield the highest fiscal multiplier.

5 Short-time work and precautionary savings over the business cycle

The goal of the paper is to study whether the presence of STW mitigates the precautionary savings motive of households and thereby potentially stabilizes demand in recessions. Further, we want to evaluate how discretionary changes to STW may boost demand in recessions. First, for illustration, we show the impact of a productivity shock in the model without STW to highlight the effects of the precautionary savings motive. Second, we examine the stabilizing effects of STW over the business cycle. Third, we evaluate discretionary changes to STW.

5.1 No-STW model

Figure 7 shows the responses of several key variables to a one percent contractionary productivity shock with autocorrelation 0.95 in the model without STW for the calibration with unemployment risk (row 1) and without unemployment risk (row 2), respectively.

In both cases, a fall in productivity reduces the value of a job J, which induces firms to reduce hiring and to increase separations, as can be seen from the fall in the job-finding rate η as well as the increase in the separation rate ϕ in column 3. As a consequence, unemployment increases (column 2) and output decreases (column 1). The clearest difference between the two models lies in the behavior of the real interest rate (column 4) and inflation (column 5). When workers are insured against unemployment risk (row 2), lower productivity raises the marginal cost of production and inflation, putting upward pressure on the real interest rate (as $\psi_\pi > 1$). The opposite is true with unemployment risk. In that case, there is persistent downward pressure on the real interest rate and inflation. Facing increasing unemployment risk, workers save for precautionary reasons, i.e., they raise their demand for government bonds and postpone consumption. This generates a fall in aggregate demand and deflationary pressure, consistent with a decline in nominal and real interest rates. However, the cut in the nominal interest rate by the monetary authority is not enough to prevent a deflationary feedback loop between unemployment risk and demand. Households cut back demand in fear of unemployment, which induces firms to increase separations. This raises unemployment fears by more and results in an even larger contraction of demand. Because the drop in the intermediate goods price on impact is stronger in the case with unemployment risk, unemployment rises by more immediately. The feedback loop then results in larger peak responses and more persistent responses of the job-finding rate, separation rate and unemployment to the shock. The peak response of unemployment is 0.36 percentage points in the no unemployment risk case, compared to 0.50 percentage points in the unemployment risk case. The drop in output is 1.25 percent compared to 1.39 percent.

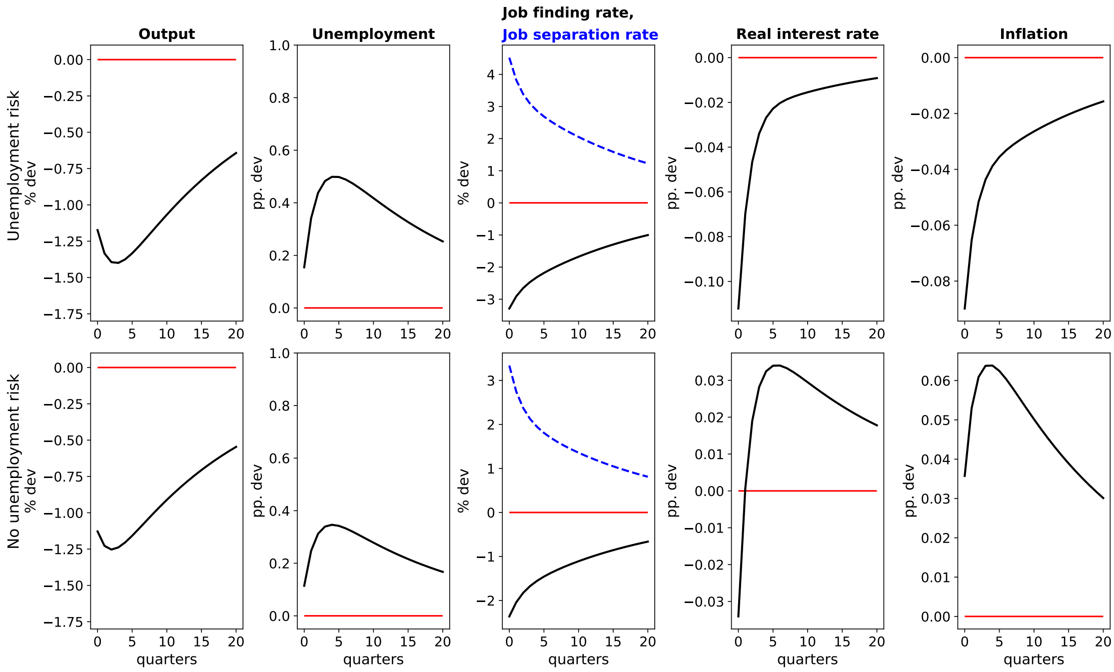

Figure 7: Impulse responses to a negative one percent shock to productivity with autocorrelation 0.95, models without STW. First and second row show IRFs with unemployment risk and without unemployment risk, respectively.

5.2 Adding the STW margin

To assess the role of STW as a stabilizer of the labor market and the aggregate economy, and specifically its effect on stabilizing demand, we compare in Figure 8 an economy with and without STW. As before, we compare a scenario where unemployment risk matters to a scenario where labor income is pooled. First, we discuss the latter as displayed in row 2 to clarify the stabilizing role of STW through its effect on a firm's firing decision (the firm channel). Both with and without STW, the negative productivity shock reduces the value of the job from the perspective of the firm, firings increase and hiring decrease, which results in an increase in the unemployment rate and a fall in output. However, with the STW option available to firms (dashed lines), some firms choose to place workers on STW (consider the increase in the STW-rate as shown in the third column of Figure 8), thereby keeping workers employed at reduced hours instead of firing them to avoid having to search for a new worker once the recession is over.[21] In addition, because firms anticipate that they have the STW option also in the future, they also reduce hiring by less. Naturally, this leads to a smaller increase in unemployment and a smaller drop in output with STW. Table 6 displays the stabilization of unemployment and output fluctuations due to STW. Unemployment fluctuations are reduced by 19 percent. Output fluctuations are reduced by less, because firms use the option of STW to reduce the hours worked of workers with lower match quality. When it comes to the behavior of inflation and the real interest rate, the shock is inflationary, as expected for a supply shock, consistent with an increase in the real interest. In the case without unemployment

[21] Adding match-specific human capital to the model would even increase the motive for labor hoarding. In this regard, our stabilization results are a lower bound.

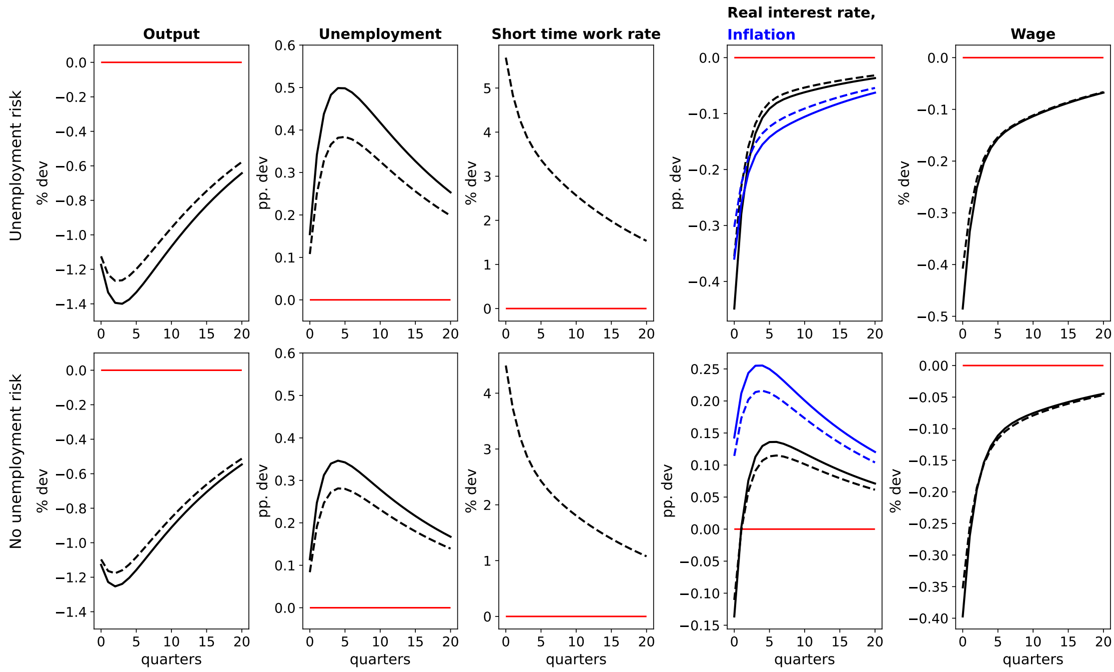

Figure 8: Impulse responses to a negative one percent shock to productivity with autocorrelation 0.95. First and second row show IRFs under unemployment risk and without unemployment risk. Dashed lines indicate IRFs when firms can use STW, solid lines indicate IRFs when firms have no such option.

risk, households' consumption is equal to all labor income plus unemployment benefits as well as interest income on savings in government bonds. This moves proportional to employment, therefore the behavior of the two variables resembles the behavior of unemployment. As STW allows firms to save costs, inflation and the real interest rate rise somewhat less with the STW option available.

In contrast to that, consider the response of inflation and the real interest rate between the model with and without STW in the economy with unemployment risk (row 1). Because households fear unemployment, goods demand is depressed due to the precautionary savings motive, and the productivity shock is deflationary. However, in the model with STW, households internalize that they may be placed on STW instead of being fired. Since the wage in STW is expected to be higher than income when unemployed (as long as working time is not reduced by 100%[22]), this is preferred, and the precautionary savings motive is weaker. Consequently, there is a smaller contraction in demand and therefore a smaller deflation. The central bank responds by cutting the nominal interest rate, more so in the economy without STW. The robustness analysis in Section 5.4 discusses what happens when monetary policy responds less aggressively. For the model without as well as the model with STW, the deflationary spiral that feeds back into output and unemployment is active, but less so in the latter case.

In summary, the precautionary savings channel that is active only in the unemployment risk case (row 1) leads to additional unemployment and output stabilization of STW on top of the mere firm channel that is active with income pooling (row 2). In

[22] This holds in the model and in reality. The average working time reduction under STW in Germany was 29% between 2007 and 2020. See also Figure 10 in the Appendix.

Difference of standard dev. in %	Productivity shocks		Demand shocks	
	STW vs no STW Unemployment risk	STW vs no STW No unemployment risk	STW vs no STW Unemployment risk	STW vs no STW No unemployment risk
	(1)	(2)	(3)	(4)
Output	-8.397	-5.402	-25.047	-20.420
Unemployment	-23.739	-19.351	-24.028	-19.361

Table 6: Difference of standard deviation conditional on productivity shock across different models in percent. We use HP filtered deviations from steady state (smoothing parameter $1,600$). For output, we use log-deviations, for unemployment level deviations, since this variable is already denoted in percentage points.

fact, this implies two things at the same time: First, precautionary savings amplify the negative productivity shock and imply a larger contraction of output and employment. This increases the firms' STW response compared to the perfect insurance case because STW becomes more attractive for firms if profits decline more due to lower demand. Thus, the firm channel is boosted when accounting for precautionary savings. In other words, the firm channel and the risk channel are complementary. Second, STW stabilizes aggregate demand and in turn the labor market as discussed above. The difference in stabilization can be seen in the gaps between the dashed and solid lines for unemployment and output across the two cases. The numbers are summarized in Table 6. The table displays the change of business cycle volatility of output and unemployment across the different models, both for productivity as well as demand shocks. To simulate demand shocks, we shock the discount factor β in the worker's Euler equation. First, in response to productivity shocks, STW reduces unemployment fluctuations by roughly 23.8% in a model with unemployment risk (compared to 19.4% in the case without unemployment risk). This is an increase of 23% or roughly one fifth and implies that a shock that would imply an increase of the unemployment rate by 4 percentage points without STW stabilization would only increase unemployment by 3 percentage points with STW. Out of the total stabilization of 1 percentage point, one fifth (i.e., 0.2 percentage points) would be due to the reduction of precautionary savings. The picture looks qualitatively similar for demand shocks, unemployment and output are stabilized more when there is unemployment risk in the economy. The numbers for output are now much more similar to those of unemployment than they are for productivity shocks, because with constant productivity, employment and output move one to one. Figure 11 in the appendix shows the stabilization in response to demand shock. In order to illustrate the different transmission mechanism, the discount factor shock is scaled so that the peak response of unemployment is the same.

5.3 STW fiscal multipliers

Where does the stabilization of the STW policy come from? Next to its effect on full-time workers precautionary savings, it is also plausible that this policy stabilizes consumption demand by redistributing funds from households with a low marginal propensity to consume (full-time workers) to households with a higher marginal propensity to consume (short-time workers). Since our model features MPC heterogeneity, in contrast to

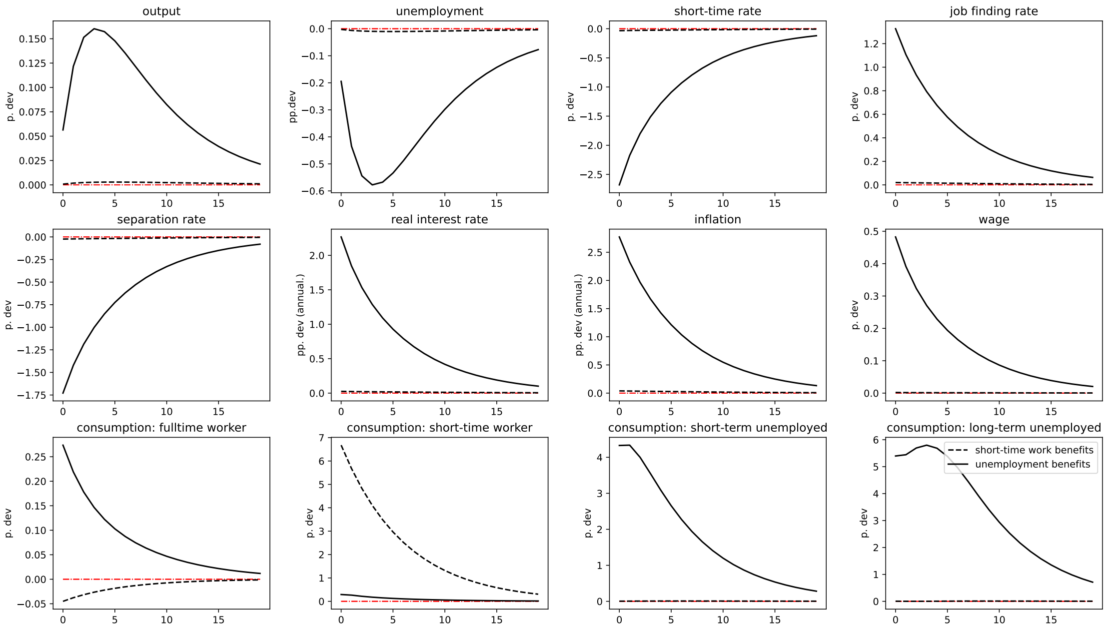

Figure 9: Impulse responses to an increase in STW compensation and an increase in unemployment benefits, normalized to 0.5% of GDP on impact.

traditional representative agent models, we can investigate this. To do so, we assume that the short-time wage, given by Equation 26, is now increased exogenously. The increase in STW benefits follows an autoregressive process with autocorrelation 0.85. Furthermore, we assume that the additional benefits are financed with a tax on full-time workers so that the policy experiment represents a redistribution from full-time workers to short-time employed workers.

Figure 9 compares the effects of this exercise to a similar-sized increase in unemployment benefits, financed again by an increase in taxes to full-time employed workers. The first thing that becomes apparent is the severe quantitative difference between the two policies. An increase in short-time work benefits (dashed line) is barely expansionary, whereas an increase in unemployment benefits has noticeable effects. Qualitatively, however, the transmission mechanism of both policies is quite similar. Consider first the increase in unemployment benefits. Average consumption of unemployed workers (short-term and long-term) increases, more so for long-term unemployed workers, since their average marginal propensity to consume (MPC) is higher (see also the discussion in Section 4.3). Since the increase in benefits is financed by agents with lower MPCs (full-time employed workers), this redistribution raises aggregate demand, and therefore demand for intermediate goods. Note that in a model without unemployment risk and MPC heterogeneity, these effects would be completely absent. This leads to a persistent increase in the price of intermediate goods $p_{z,t}$, and therefore a persistent increase in the expected value of a filled position $\mathbb{E}_t J_{t+1}$ (see Equation (7)). This increase is more pronounced if real wages and therefore labor costs are expected to be rigid, which is the case here. The job-finding rate increases and the separation rate decreases, leading to a fall in unemployment and, importantly, a decline in unemployment risk. The decline in unemployment risk plays a crucial role for employed worker's (full-time and short-time) consumption, lowering precautionary savings motives and boosting consumption demand. This channel is counteracted by a negative wealth effect resulting from the increase in taxation to full-time employed workers, but the precautionary savings channel dominates, so that even the consumption of employed workers increases overall. By contrast, when the STW compensation is increased (dashed line), full-time workers' consumption actually declines, because the wealth effect dominates. Overall, the redistribution also results in an increase in aggregate demand and therefore an increase in output, but the effects on output are negligible. Only short-time employed workers raise their consumption by a large amount on average. In fact, they increase their consumption by slightly more in percentage terms than unemployed workers do in response to an increase in unemployment benefits, but this is due to the fact that there are more than ten times as many unemployed workers as short-time workers in steady state. The fiscal cost of both measures is the same overall, therefore the transfers per person to short-time workers are much higher. Accordingly, the small fraction of short-time workers in steady state implies that the increase in aggregate demand is much lower compared to the increase in unemployment benefits. Overall, this implies that the automatic STW stabilization from the demand channel discussed in the previous section works through the precautionary savings of the full-time workers rather than the redistribution from funds to short-time workers.

Table 7 summarizes the quantitative effects of increasing STW compensation and compares these to an increase in unemployment benefits. Displayed are output and unemployment fiscal multipliers following Monacelli et al. (2010). The present value multiplier of government spending in terms of unemployment in percentage points at horizon k is defined as:

$$m_G^k = \frac{\sum_{t=0}^{k} \beta^t (u_t - u)}{\sum_{t=0}^{k} \beta^t (G_t - G)/Y}. \tag{40}$$

To compute the output multiplier, the numerator is replaced with the relative change in output.[23] The quantitative results in Table 7 support the qualitative results of Figure 9. The unemployment multiplier of an increase in STW compensation (column 1) is close to zero, whereas in increase in unemployment benefits yields a multiplier of around -0.3 after five quarters and -0.4 in the long run, and an output multiplier of 0.46.

As discussed previously, the expansionary effects of shocks to the short-time wage and the replacement rate are due to the incomplete markets assumption in combination with nominal rigidities, which sets this paper apart from results obtained in representative agent models with income pooling that lack a precautionary savings motive (Hagedorn et al., 2013; Christiano et al., 2016). Then, an increase in unemployment benefits increases unemployment.[24] Instead our results are in line with papers featuring search and matching frictions and incomplete markets that find that extensions to unemployment benefits may stabilize the business cycle. Examples are McKay and Reis (2021) and Kekre (2022) with models calibrated to the US labor market. We add the perspective on shocks to the short-time wage in a model calibrated to the German labor market. Here, with incomplete markets, the policy affects the risk perception of full-time workers

[23]The total amounts of STW compensation and unemployment benefits are endogenous variables as the unemployment and the STW rate may fall below the steady state level after an expansionary shock. To ensure comparability and to not overstate the results, multiplier calculations are based on the steady state values for the endogenous variables for both shocks as in Faia et al. (2013).

[24]Christiano et al. (2016) find in an estimated medium scale DSGE model with search frictions and a representative agent that an increase in unemployment benefits is contractionary in normal times and expansionary at the ZLB.

	Short-time compensation		Unemployment benefits	
	Unemployment	Output	Unemployment	Output
Horizon	(1)	(2)	(3)	(4)
5	-0.006	0.010	-0.296	0.330
10	-0.008	0.014	-0.369	0.410
Long run	-0.012	0.020	-0.416	0.462

Table 7: Fiscal multipliers in response to a discretionary shock equal to an increase of fiscal spending of 1% of GDP. Multipliers for unemployment in percentage points and multipliers for output in percent. The denominator is made up of costs holding the endogenous variables constant at the steady state level.

and, hence, boosts their consumption demand. Similar to the results by Kekre (2022) for the U.S., we find that an increase in unemployment benefits is expansionary, with output multipliers below 1 in normal times. At the ZLB, multipliers would be higher, because the increase in inflation triggered by the rise in aggregate demand in Figure 9 would go hand in hand with a decline in the real interest rate, further boosting consumption demand. The same mechanism would apply to the increase in STW compensation, but it would remain less expansionary than an increase in unemployment benefits. The initial increase in aggregate demand, triggering the rise in inflation, depends on the MPC of the agents receiving the benefits. As the bottom right panel of Figure 6 shows, the MPCs of unemployed workers are much higher. Our analysis abstracts from the fact that higher unemployment benefits discourage search effort. Given that employment prospects are worse for the unemployed compared to workers affected by STW, a reduction of search effort could be more problematic for the former and may render the extension of the STW compensation relatively more effective. Nevertheless, the effects of search effort play less of a role in recessions when unemployment is high and labor market tightness is low (see Landais et al., 2018).[25]

5.4 Sensitivity analysis of stabilization results

The previous subsection has shown that the redistribution caused by the STW benefits plays little role for the stabilization effect. Indeed, most of the effect comes from a reduction in precautionary savings caused by lower income risk. The strength of this channel may vary depending on the choice of parameters. In particular, we have argued that the unemployment insurance and the degree of wage rigidity drive the cyclicality of income risk and are therefore relevant for the precautionary savings channel. We illustrate this by changing those parameters. Column 1 in Table 8 repeats the baseline results from Table 6 for comparison.

Replacement rate The replacement rate represents the relative income drop upon unemployment. In our baseline scenario, we kept the replacement rate of short-term unemployed workers fixed at 0.6 and chose the replacement rate for long-term unemployed

[25] Empirical evidence for the Covid-19 recession that confirms this notion is provided by Marinescu et al. (2021).

workers to fit the consumption drop of roughly 35% that we estimated in Section 2. First, lowering the replacement rate will imply a larger consumption drop, and therefore a stronger precautionary savings motive in response to unemployment risk. Second, lower unemployment benefits also imply a larger relative income gain from STW compared to unemployment. To see that, consider that the short-time wage lies between the unemployment benefits and the full-time wage (equation 26), closer to the latter if the reduction in hours is less than 50%. Overall, this implies that a lower replacement rate yields more automatic stabilization, and a higher replacement rate implies less automatic stabilization, which is reflected in column 2 and 3 of Table 8.

Wage rigidity Column 4 and 5 of Table 8 show the stabilization results for different levels of real wage rigidity. Perfectly rigid wages ($d \ln w/a = 0$) imply larger fluctuations of firm profits, and consequently, a stronger decline in the job-finding and separation rate in response to productivity shocks. Hence, the stabilization of unemployment risk coming from STW is increased. By contrast, when wages are twice as flexible as in the baseline case ($d \ln w/d \ln a = 0.4$), it is reduced but remains substantial.

Monetary policy As discussed in Section 5.2 and visible in Figure 8 row 1, the monetary authority cuts the nominal interest rate in response to the deflation caused by precautionary savings in the recession, more so in the model without STW. This stabilizes demand to some extent, lowering the automatic stabilization potential coming from STW. Columns 6 of Table 8 shows that the stabilization of STW increases slightly with a monetary reaction coefficient to inflation of only 1.3 compared to the baseline value of 1.5. The opposite is true with more aggressive monetary policy. The differences in stabilization are small because the parameter values are close to our baseline. In contrast to that, we suspect that automatic stabilization would increase more substantially with a binding zero lower bound, i.e., if the interest rate would not adjust at all.

Financing In models with incomplete markets, the financing of fiscal policy can play a large role in theory (see e.g. Kaplan et al., 2018). Therefore we test how different fiscal rules affect our stabilization results. In the baseline scenario, we assume that government bonds are determined by an exogenous deficit rule which reacts in a countercyclical manner to output. The tax rate on all workers adjusts endogenously consistent with the government's budget constraint. For robustness, we show what happens when bonds are held constant, and higher unemployment or STW benefits are purely financed by a higher tax rate (column 8 of Table 8). This increases the stabilization slightly compared to the baseline. In column 9, we show the results if there is a tax rule instead of a deficit rule, so that the tax rate adjusts according to the following equation:

$$\frac{\tau_t}{\tau} = \left(\frac{B_t}{B}\right)^{\gamma_B}, \tag{41}$$

so that the tax rate reacts to bond holdings, ensuring stationarity of the model. We set $\gamma_B = 0.5$. Government bonds adjust endogenously to clear the government's budget constraint. Here, the STW stabilization declines slightly compared to baseline. Figure 12 in the appendix shows that the transmission of the productivity shock looks quite different for the unemployment risk compared to the baseline case. The reason behind this result is that government debt expands slightly more with a tax rule compared to

	Baseline	Replacement rate δ/w (0.6)		Wage rigidity $d\ln w/d\ln a$ (0.2)		Monetary policy ψ_π (1.5)		Taxation		Relative search efficiency k (1)
								Constant debt	Tax rule	
Stabilization (%)		0.5	0.7	0	0.4	1.3	1.7			0.5
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Output	-8.48	-9.83	-7.63	-12.76	-4.78	-9.27	-8.1	-8.56	-8.86	10.83
Unemployment	-23.75	-25.41	-22.60	-25.81	-21.88	-24.55	-23.3	-23.91	-23.13	24.82

Table 8: This table compares the stabilization of STW across different calibrations in response to productivity shocks.

the baseline case. In the model without STW, payments for unemployment benefits are higher because the unemployment rate rises more, compared to the model without STW (wages for short-time workers are only partially funded by the government). Accordingly, the no STW model requires more government debt to finance these payments. Ceteris paribus, more supply of government debt has a stabilizing effect on the business cycle because it provides more insurance possibilities (see e.g. Aiyagari and McGrattan, 1998), thereby increasing workers' consumption. This decreases the stabilization that STW provides. Interestingly, as Figure 12 shows, the deviations of unemployment from steady state intersect after around 18 quarters. Nevertheless, Table Table 8 shows that the qualitative difference in the impulse responses matters very little quantitatively. The no-unemployment risk case is unchanged compared to baseline, because the bond supply provides no additional insurance.

In the case of constant bonds, the aforementioned insurance effect is turned off completely, increasing the stabilization of STW. Lastly, it becomes clear that the baseline case in column 1 lies in between the two scenarios, but closer to the scenario with constant debt.

Lower relative search efficiency of the long-term unemployed In the baseline scenario, the search efficiency of the long-term unemployed was set equal to that of the short-term unemployed ($k = 1$), a conservative choice. In column 10, we show how the stabilization changes if this assumption is relaxed, we set $k = 0.5$, so that the job-finding rate of the long-term unemployed is half of that of the short-term unemployed. [26] The stabilization of STW increases slightly, due to more unemployment risk and therefore a stronger precautionary savings motive. Figure 13 in the appendix confirms also visually that the overall volatility in the labor market is increased by a lot with incomplete markets (row 1), and that the stabilization of STW is stronger. Since a lower job-finding rate of the long-term unemployed also makes the labor market more rigid in the case of no unemployment risk, the stabilization is also increased slightly in that case.

6 Conclusions

This paper is the first to investigate the effects of STW over the business cycle while allowing for aggregate demand effects through precautionary savings. We document that precautionary savings matter for assessing the effectiveness of STW. In particular, STW becomes more effective over the business cycle as STW reduces the income risk for

[26] Holding all other parameters constant, this lowers the average job-finding rate in steady state so that overall unemployment increases to 11.4%.

full-time workers and their precautionary savings motive. We back this mechanism with empirical evidence showing that households' average consumption decline during STW periods is small and mainly insignificant. In contrast, during unemployment spells, we observe a substantial consumption drop. The demand channel through labor market risk discussed in this paper matters most in crisis times when risk is high. If STW is applied for a more extended period outside of economic crises, it may trigger biases and inefficiencies that the model in this paper does not address. For example, STW may hinder the reallocation of labor to growing and productive firms or lead to excessive hours reductions. As a result, we can conclude that STW is a well-suited policy for temporary crises, but we cannot speak to more long-run phenomena. We leave an analysis of the long-run and welfare properties of the policy for future research.

References

Aiyagari, S. R. and McGrattan, E. R. (1998). The optimum quantity of debt. *Journal of Monetary Economics*, 42(3):447–469.

Albertini, J., Auray, S., Bouakez, H., and Eyquem, A. (2021). Taking off into the wind: Unemployment risk and state-dependent government spending multipliers. *Journal of Monetary Economics*, 117:990–1007.

Balleer, A., Gehrke, B., Lechthaler, W., and Merkl, C. (2016). Does short-time work save jobs? a business cycle analysis. *European Economic Review*, 84:99–122.

Beckmann, E. and Schmidt, T. (2020). Bundesbank online pilot survey on consumer expectations. *Deutsche Bundesbank Technical Paper*, 01/2020.

Blanchard, O. and Galí, J. (2010). Labor markets and monetary policy: A new keynesian model with unemployment. *American Economic Journal: Macroeconomics*, 2(2):1–30.

Brinca, P., Holter, H. A., Krusell, P., and Malafry, L. (2016). Fiscal multipliers in the 21st century. *Journal of Monetary Economics*, 77:53–69.

Broer, T., Druedahl, J., Harmenberg, K., and Öberg, E. (2021). The unemployment-risk channel in business-cycle fluctuations. *CEPR Discussion Paper*.

Burda, M. C. and Hunt, J. (2011). What explains the german labor market miracle in the great recession? *Brookings Papers on Economic Activity*, Spring:273–335.

Cahuc, P., Kramarz, F., and Nevoux, S. (2018). When short-time work works. *CEPR Discussion Paper No. 13041*.

Calvo, G. A. (1983). Staggered prices in a utility-maximizing framework. *Journal of Monetary Economics*, 12(3):383–398.

Carroll, C., Slacalek, J., Tokuoka, K., and White, M. N. (2017). The distribution of wealth and the marginal propensity to consume. *Quantitative Economics*, 8(3):977–1020.

Challe, E. (2020). Uninsured unemployment risk and optimal monetary policy in a zero-liquidity economy. *American Economic Journal: Macroeconomics*, 12(2):241–83.

Chodorow-Reich, G. and Karabarbounis, L. (2016). The cyclicality of the opportunity cost of employment. *Journal of Political Economy*, 124(6):1563–1618.

Christiano, L. J., Eichenbaum, M. S., and Trabandt, M. (2016). Unemployment and business cycles. *Econometrica*, 84(4):1523–1569.

Christoffel, K., Kuester, K., and Linzert, T. (2009). The role of labor markets for euro area monetary policy. *European Economic Review*, 53(8):908–936.

Cooper, R., Meyer, M., and Schott, I. (2017). The employment and output effects of short-time work in germany. *NBER Working Paper No. 23688*.

Dao, M. and Aiyar, S. S. (2022). The effectiveness of job-retention schemes: Covid-19 evidence from the german states. *Available at SSRN, https://ssrn.com/abstract=4197076*.

Faia, E., Lechthaler, W., and Merkl, C. (2013). Fiscal stimulus and labor market policies in europe. *Journal of Economic Dynamics and Control*, 37(3):483–499.

Gehrke, B. and Hochmuth, B. (2021). Counteracting unemployment in crises: Non-linear effects of short-time work policy. *The Scandinavian Journal of Economics*, 123(1):144–183.

Gehrke, B., Lechthaler, W., and Merkl, C. (2019). The german labor market during the great recession: Shocks and institutions. *Economic Modelling*, 78:192–208.

Giupponi, G. and Landais, C. (2022). Subsidizing labor hoarding in recessions: The employment and welfare effects of short time work. *Review of Economic Studies*, Conditionally accepted.

Gornemann, N., Kuester, K., and Nakajima, M. (2016). Doves for the rich, hawks for the poor? distributional consequences of monetary policy.

Graves, S. (2020). Does unemployment risk affect business cycle dynamics? *FRB International Finance Discussion Paper*, (1298).

Guvenen, F., Ozkan, S., and Song, J. (2014). The nature of countercyclical income risk. *Journal of Political Economy*, 122(3):621–660.

Hagedorn, M., Karahan, F., Manovskii, I., and Mitman, K. (2013). Unemployment benefits and unemployment in the great recession: the role of macro effects. Technical report, National Bureau of Economic Research.

Hagedorn, M. and Manovskii, I. (2008). The cyclical behavior of equilibrium unemployment and vacancies revisited. *American Economic Review*, 98(4):1692–1706.

Hagedorn, M., Manovskii, I., and Mitman, K. (2019). The fiscal multiplier. *NBER Working Paper*, 25571.

Hall, R. E. (2005). Employment fluctuations with equilibrium wage stickiness. *American Economic Review*, 95(1):50–65.

Hall, R. E. and Milgrom, P. R. (2008). The limited influence of unemployment on the wage bargain. *American Economic Review*, 98(4):1653–74.

Harding, M., Lindé, J., and Trabandt, M. (2022). Resolving the missing deflation puzzle. *Journal of Monetary Economics*, 126:15–34.

Jäger, S., Schoefer, B., and Zweimüller, J. (2022). Marginal jobs and job surplus: a test of the efficiency of separations. *Review of Economic Studies*, accepted article.

Kaplan, G., Moll, B., and Violante, G. L. (2018). Monetary policy according to hank. *American Economic Review*, 108(3):697–743.

Kekre, R. (2022). Unemployment insurance in macroeconomic stabilization. *Review of Economic Studies*, accepted article.

Kolsrud, J., Landais, C., Nilsson, P., and Spinnewijn, J. (2018). The optimal timing of unemployment benefits: Theory and evidence from sweden. *American Economic Review*, 108(4-5):985–1033.

Kopp, D. and Siegenthaler, M. (2021). Short-Time Work and Unemployment in and after the Great Recession. *Journal of the European Economic Association*, 19(4):2283–2321.

Krause, M. U. and Lubik, T. A. (2007). The (ir) relevance of real wage rigidity in the new keynesian model with search frictions. *Journal of Monetary Economics*, 54(3):706–727.

Krause, M. U. and Uhlig, H. (2012). Transitions in the german labor market: Structure and crisis. *Journal of Monetary Economics*, 59(1):64–79.

Kuhn, M. and Ríos-Rull, J.-V. (2016). 2013 update on the us earnings, income, and wealth distributional facts: A view from macroeconomic modelers. *Federal Reserve Bank of Minneapolis Quarterly Review*, 37(1):2–73.

Landais, C., Michaillat, P., and Saez, E. (2018). A macroeconomic approach to optimal unemployment insurance: Theory. *American Economic Journal: Economic Policy*, 10(2):152–81.

Lechthaler, W., Merkl, C., and Snower, D. J. (2010). Monetary persistence and the labor market: a new perspective. *Journal of Economic Dynamics and Control*, 34(5):968–983.

Marinescu, I., Skandalis, D., and Zhao, D. (2021). The impact of the federal pandemic unemployment compensation on job search and vacancy creation. *Journal of Public Economics*, 200:104471.

McKay, A., Nakamura, E., and Steinsson, J. (2016). The power of forward guidance revisited. *American Economic Review*, 106(10):3133–58.

McKay, A. and Reis, R. (2021). Optimal automatic stabilizers. *The Review of Economic Studies*, 88(5):2375–2406.

Monacelli, T., Perotti, R., and Trigari, A. (2010). Unemployment fiscal multipliers. *Journal of Monetary Economics*, 57(5):531–553.

Mortensen, D. T. and Pissarides, C. A. (1994). Job creation and job destruction in the theory of unemployment. *The Review of Economic Studies*, 61(3):397–415.

Moyen, S. and Stähler, N. (2014). Unemployment insurance and the business cycle: should benefit entitlement duration react to the cycle? *Macroeconomic Dynamics*, 18(3):497–525.

Ravn, M. O. and Sterk, V. (2017). Job uncertainty and deep recessions. *Journal of Monetary Economics*, 90:125–141.

Ravn, M. O. and Sterk, V. (2021). Macroeconomic fluctuations with hank & sam: An analytical approach. *Journal of the European Economic Association*, 19(2):1162–1202.

Reiter, M. (2009). Solving heterogeneous-agent models by projection and perturbation. *Journal of Economic Dynamics and Control*, 33(3):649–665.

Rotemberg, J. J. (1982). Sticky prices in the united states. *Journal of Political Economy*, 90(6):1187–1211.

Shimer, R. (2005). The cyclical behavior of equilibrium unemployment and vacancies. *American Economic Review*, 95(1):25–49.

Storesletten, K., Telmer, C. I., and Yaron, A. (2004). Consumption and risk sharing over the life cycle. *Journal of Monetary Economics*, 51(3):609–633.

Thomas, C. and Zanetti, F. (2009). Labor market reform and price stability: An application to the euro area. *Journal of Monetary Economics*, 56(6):885–899.

Trigari, A. (2009). Equilibrium unemployment, job flows, and inflation dynamics. *Journal of Money, Credit and Banking*, 41(1):1–33.

A Additional figures and tables

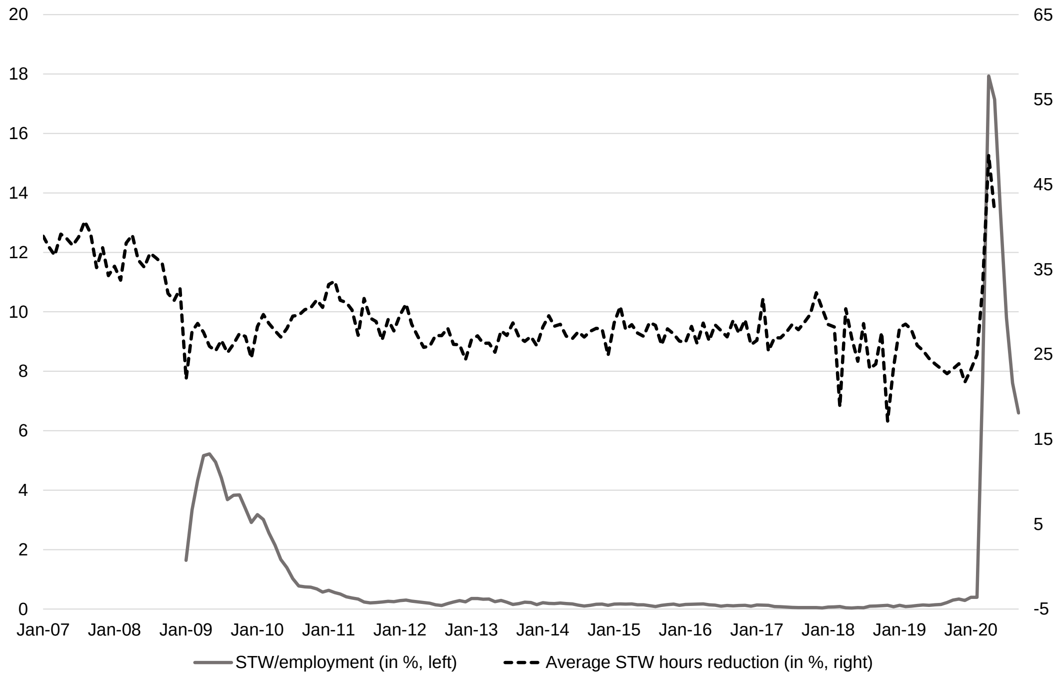

Figure 10: STW as a percentage of total employment (left axis) and average hours reduction in Germany (right axis). Source: Federal Employment Agency.

	(1)	(2)	(3)	(4)	(5)
γ_u	-0.36^{***}	-0.36^{***}	-0.29^{***}	-0.27^{***}	-0.28^{***}
	(-7.36)	(-12.19)	(-4.46)	(-4.10)	(-4.32)
Household size, region, city size		×	×	×	×
Skill			×	×	×
Homeown				×	×
Homeown × city size					×
Individual-fixed effect	×	×	×	×	×
Observations	2,587	2,582	1,793	1,793	1,793

Table 9: Consumption expenditure across labor market states using household fixed-effects, pre-Covid sample. The parameter γ_u gives the log difference of the consumption of an unemployed worker compared to an employed worker. The estimation uses the Bundesbank Household Online Panel that covers monthly data for 2019, waves 1-3. $t-$statistics are in parentheses, standard errors are clustered at household level, $^{*}p < 0.05,^{**}p < 0.01,^{***}p < 0.001$. Dependent variable is log consumption of non-durables and services for individuals between ages 25-55. The set of control variables in all regressions includes time-fixed effects. Skill is measured using an indicator of eight categories of education.

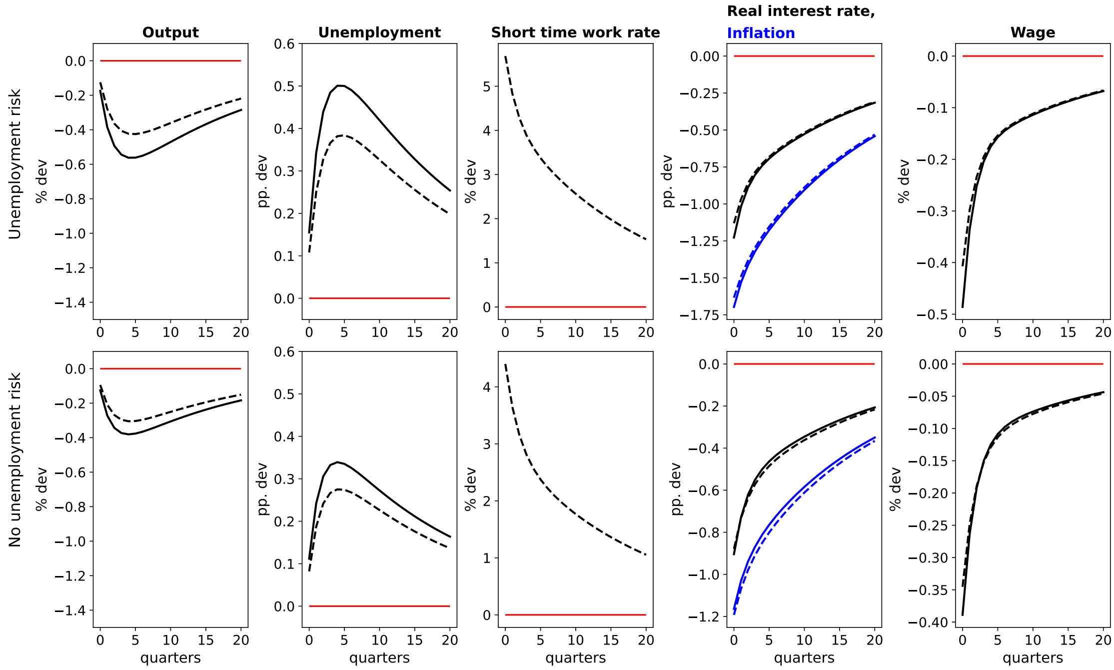

Figure 11: Impulse responses to a negative shock to the discount factor with autocorrelation 0.95. Shock is scaled to yield the same peak response of unemployment as for productivity. First and second row show IRFs under unemployment risk and without unemployment risk. Dashed lines indicate IRFs when firms can use STW, solid lines indicate IRFs when firms have no such option.

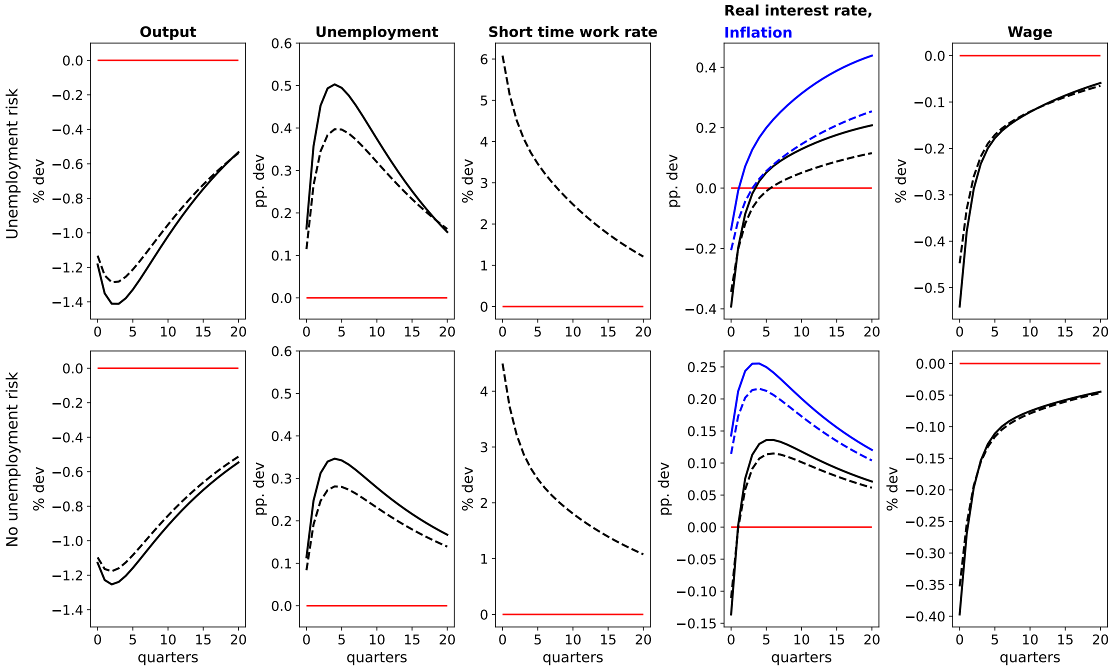

Figure 12: Impulse responses to a negative one percent shock to productivity with autocorrelation 0.95, for a bond supply that expands more flexibly. First and second row show IRFs under unemployment risk and without unemployment risk. Dashed lines indicate IRFs when firms can use STW, solid lines indicate IRFs when firms have no such option.

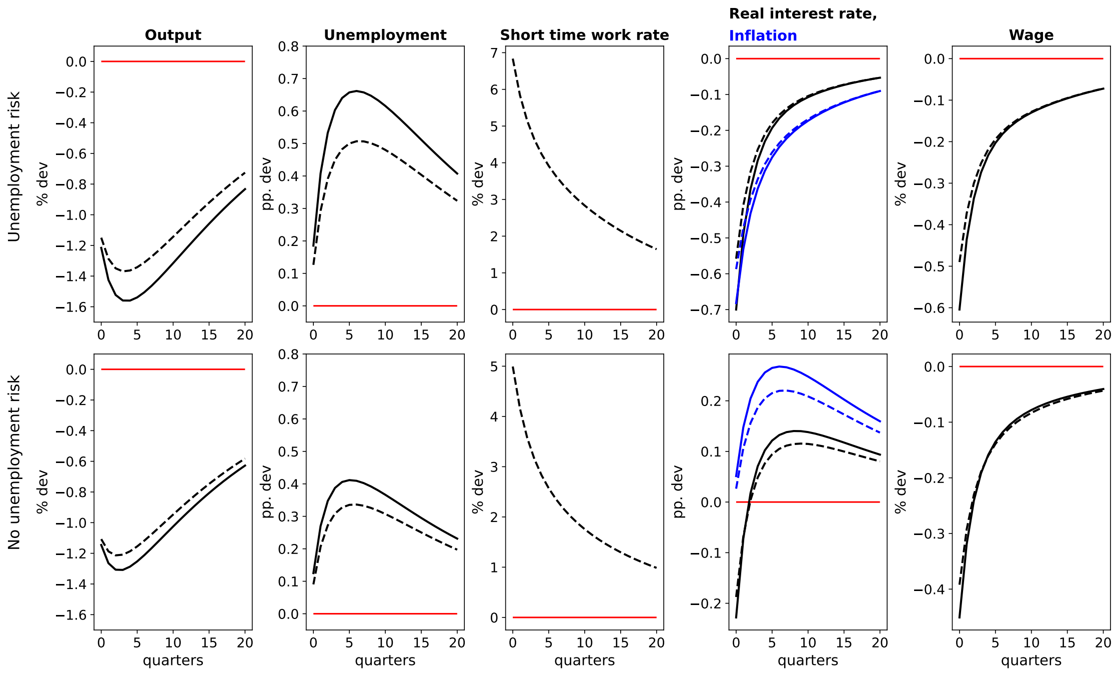

Figure 13: Impulse responses to a negative one percent shock to productivity with autocorrelation 0.95, for a lower search efficiency of the long-term unemployed First and second row show IRFs under unemployment risk and without unemployment risk. Dashed lines indicate IRFs when firms can use STW, solid lines indicate IRFs when firms have no such option.