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Thomas Dengler
Humboldt University of Berlin

Britta Gehrke
University of Rostock, IAB and IZA

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IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

Short-Time Work and Precautionary Savings*

In the Covid-19 crisis, most OECD countries use short-time work schemes (subsidized working time reductions) to preserve employment relationships. This paper studies whether short-time work can save jobs through stabilizing aggregate demand in recessions. We build a New Keynesian model with incomplete asset markets and labor market frictions, featuring an endogenous firing as well as a short-time work decision. In recessions, short-time work reduces the unemployment risk of workers, which mitigates their precautionary savings motive and aggregate demand falls by less. Using a quantitative model analysis, we show that this channel can increase the stabilization potential of short-time work over the business cycle up to 55%, even more when monetary policy is constrained by the zero lower bound. Further, an increase of the short-time work replacement rate can be more effective compared to an increase of the unemployment benefit replacement rate.

JEL Classification: E21, E24, E32, E52, E62, J63

Keywords: short-time work, fiscal policy, incomplete asset markets, unemployment risk, matching frictions

Corresponding author:
Thomas Dengler
School of Business and Economics
Humboldt University of Berlin
Spandauer Str. 1
10178 Berlin
Germany
E-mail: thomas.dengler@hu-berlin.de

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1 Introduction

Inspired by the successful implementation of short-time work (STW henceforth) in Germany and other countries during the Great Recession, almost all OECD countries use STW schemes as an instrument for securing jobs and as a fiscal stabilizer during the Covid-19 crisis. In Germany, almost every fifth employee (6 million workers) was affected by STW in spring 2020. When comparing this to the peak during the Great Recession, which was at about 1.5 million, it becomes clear that the use of STW has reached an unprecedented level, and so have public expenditures on these subsidies. This is not only true for Germany. Equally high numbers were observed in Italy, Spain, France, Belgium, Austria and the UK as illustrated in Figure 1. For example, the UK introduced the furlough scheme that covered up to almost 9 million workers in May 2020. At the European level, the EU has implemented the "Temporary Support to mitigate Unemployment Risks in an Emergency" (SURE) scheme, which provides 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.

Yet, knowledge of the dynamic effects of this labor market policy remains limited. While it has been established that STW affects firms by reducing their labor cost, dampening firing and incentivizing hiring, an effect on workers' consumption demand has not yet been analyzed. But in the political debate, one major argument for STW – next to reducing firms' labor costs in crises – is more stable demand and lower unemployment risk. This paper builds a dynamic macroeconomic model with labor market frictions and STW that has the firm channel, but adds a demand channel that features how STW may reduce unemployment fears and stabilize incomes with incomplete asset markets. We find that the demand channel is particularly relevant in economies with high labor market flows and uncertainty where it increases cyclical unemployment stabilization through STW by up to 55%. In addition, taking into account the demand channel of STW, changes the conclusions about the effectiveness of discretionary STW policy. For example, we find that an increase of the public STW compensation may reduce unemployment as it stabilizes aggregate demand. We further provide conditions under which an increase of the STW compensation is more effective compared to an increase of unemployment benefits.

Given that STW has a long tradition in Germany and is widely used, we describe the German policy in the following. Nevertheless, STW generally works similarly in other countries. To be eligible for support, 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. The firm then reduces workers' hours and pay proportionally, but workers receive between 60 and 67 percent compensation of the net wage loss, paid out of the unemployment insurance fund. To understand why STW may stabilize demand, it is important to note that workers that are affected by STW are typically better off compared to unemployment. Only in the rare case if hours are reduced to zero, the income from the STW compensation will be equal to the unemployment benefit.[1] In crisis times, more firms meet the STW eligibility criterion of a significant shortfall in demand, so that the instrument may serve as an automatic stabilizer. Additionally, in

[1]From March to May 2020, the average STW hours reduction in Germany was 41%. Figure 8 in the Appendix shows that this number was generally lower previously to the Covid-19-recession. In addition, during the Covid-19 crisis, benefits for short-time workers have been increased so that even for workers on zero hours these may have been higher than unemployment insurance.

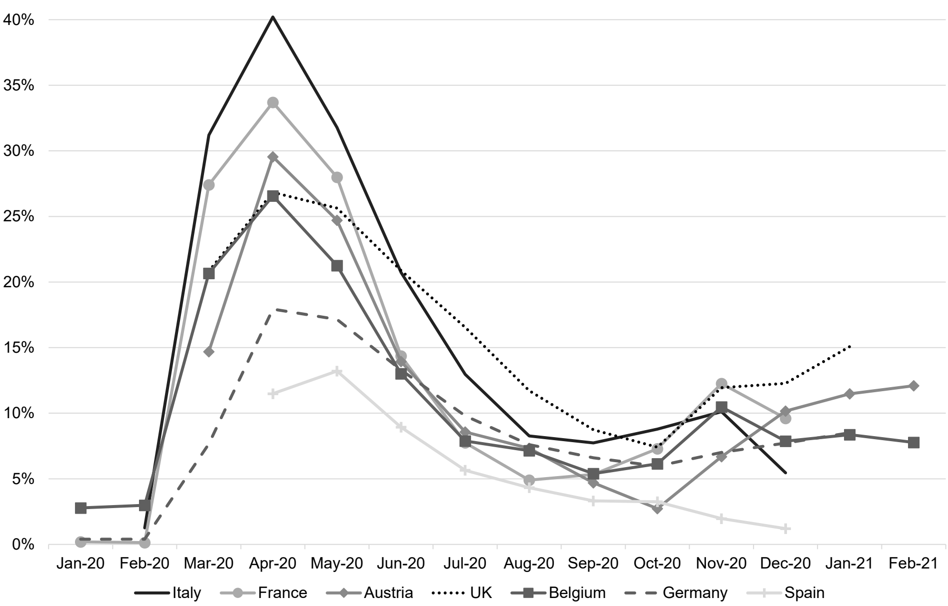

Figure 1: Share of employees affected by STW across different countries in 2020 and 2021 (as of April 2021). Source: Eurostat, except for Germany: Federal Employment Agency, and UK: ONS and CJRS.

recessions, governments often change STW rules in a discretionary way to make access to STW easier for firms and extend the duration and amount of benefits paid to workers.

We construct a New Keynesian DSGE model with search and matching frictions, endogenous separations and rigidities in prices and real wages. To this model, we add a STW decision as in Balleer et al. (2016) and incomplete asset markets as in Ravn and Sterk (2017). 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 perspective of the firm. 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. This channel stabilizes employment over the business cycles as shown by Balleer et al. (2016). The firm channel is stronger the more rigid the labor market and the higher the firing costs in an economy. Our contribution is to provide complementary evidence on the *risk channel* of STW that affects workers' consumption demand and their precautionary savings decision. Given that unemployment risk cannot be perfectly insured as in Ravn and Sterk (2017), workers that face borrowing constraints may reduce their consumption already in anticipation of unemployment risk without necessarily suffering job loss.

The main finding of this paper is that STW has additional potential to stabilize the business cycle when this risk channel 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, which leaves them with a higher income. This reduces unemployment as well as income risk and dampens precautionary savings. In an economy calibrated to the German labor market, we document an increase of unemployment stabilization from 21 to 26 percent (i.e., 22%) due to the risk channel. This implies that a shock that would generate an increase of the unemployment rate by 3 percentage points with STW would increase unemployment by 4 percentage points without STW. Out of the total stabilization of 1 percentage point, 0.2 percentage points is due to the reduction of precautionary savings. This paper further shows that the motive for precautionary savings due to labor market risk depends strongly on the labor market characteristics. We document that the precautionary savings motive is generally smaller in an economy with smaller labor market flows and less uncertainty. Interestingly, this implies that stabilization from STW in an economy with large labor market flows, as in the United States for example, can be substantial as well. In such a high-flows calibration, cyclical unemployment stabilization through STW increases from 14 to 22 percent (i.e., by roughly 55%). This finding contrasts with previous studies that focused solely on the firm channel due to search frictions which is less relevant in more flexible labor markets (Balleer et al., 2016). Nonetheless, as STW policy mainly stabilizes by reducing firms' labor costs, the firm channel remains the dominant one, for the German calibration as well as the calibration with higher labor market flows.

We further investigate discretionary changes to STW policy. In light of the precautionary savings channel, easing the eligibility criterion becomes less effective in terms of decreasing unemployment because aggregate demand is negatively affected. When workers are placed on STW who would otherwise have stayed full-time employed, this increases the labor market risk of full-time workers and their precautionary savings motive, because expected wages for STW are lower than for full-time work. In contrast, an increase of the subsidy to short-time workers as implemented by the Austrian and the German government in 2020, reduces labor market risk of full-time workers because expected wages for STW approach those in full-time. Our model therefore implies that these extensions are expansionary, with sizable fiscal multipliers. An increase of STW compensation by 1% of GDP, reduces unemployment by almost 2 percentage points in the long run. The multiplier is even larger if monetary policy is constrained by the zero lower bound (ZLB). Interestingly, unemployment benefit extensions are expansionary as well as they also reduce labor market risk. However, given that higher unemployment benefits generate direct upward pressure on wages, whereas the STW compensation does not, we find that extensions to short-time benefits can be more effective in particular if wages adjust rather flexibly. Our results are complementary to McKay and Reis (2020) and Kekre (2021), who in line with our results show that extensions to unemployment benefits can have expansionary effects when the precautionary savings channel is taken into account. Our finding contrasts with the results by Balleer et al. (2016) who argue that discretionary STW policy is largely ineffective. We show that this is only true for the firm channel of STW. Interestingly, our theoretical finding is in line with the empirical results of Gehrke and Hochmuth (2021) who document that the effects of discretionary STW policy are time-varying over the business cycle. Our model explains this with the findings on the risk channel at the ZLB.

Our model features a no-borrowing constraint that renders the cross-sectional wealth distribution degenerate (Krusell et al., 2011; Challe, 2020). In equilibrium, all households consume their current income and there are no aggregate savings. Nevertheless, as full-time employed workers face the risk of becoming unemployed they have an incentive to save such that their Euler equation holds with equality and determines the equilibrium real interest rate. The no-borrowing constraint keeps the model tractable, while preserving a time-varying precautionary savings motive from fluctuations in unemployment and STW risk. This assumption has been widely used in the literature, but this paper is the first to investigate its implications in a model with endogenous separations as well as STW. Next to the risk channel, one may argue that additional demand stabilization emerges from the fact that a policy redistributes income from wealthy to poor households with a higher marginal propensity to consume as e.g., in Kaplan et al. (2018). However, in the context of STW, we believe that the risk channel is of first-order importance, given that the share of workers affected by STW is generally small and not all affected workers are necessarily poor.[2] In contrast, unemployment and STW risk and the precautionary savings motive affect all workers. Nevertheless, in deep recessions when a large share of workers is affected by STW as it is the case in the current situation, the redistribution channel may generate additional stabilization. We leave this question for future research.

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 (Challe, 2020, Gornemann et al., 2016, Ravn and Sterk, 2017, 2020). These studies feature a similar precautionary savings mechanism as in our model. However, our labor market features endogenous separations as well as a STW decision, whereas the existing literature studies only exogenous separations. Third, this 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). Cooper et al. (2017) study STW with heterogeneous firms and focus on reallocation effects. Our paper is most closely related to Balleer et al. (2016) as we model the labor market and STW decision of firms in a similar way. Our contribution is to show that the risk channel of STW may change the conclusions when markets are incomplete, and when the economy is at the ZLB. Both questions have not been addressed in the existing literature so far. Lastly, there is a growing empirical literature on the effects of STW. Recent microeconometric studies include Giupponi and Landais (2018), Cahuc et al. (2018) and Kopp and Siegenthaler (2021). Macroeconometric studies are provided by Boeri and Bruecker (2011) and Gehrke and Hochmuth (2021). All of these papers suggest stabilizing effects of STW for unemployment, but none of these papers discusses the different economic mechanisms how STW affects the labor market.

The rest of the paper is structured as follows. Section 2 develops the model and characterizes the equilibrium. Section 3 discusses the calibration. Section 4 uses the model for counterfactual analyses and simulation. Section 5 concludes.

[2] In fact, to be eligible for STW in the German system workers have to have been employed subject to social security previously. Further, STW is traditionally used more in industries that pay higher wages such as manufacturing (Boeri and Bruecker, 2011). Also internationally, STW applies often only to permanent, not temporary workers (Cahuc, 2019).

2 The model

The economy consists of households who work and consume and firms which hire labor in a frictional market to produce intermediate goods. Worker-firm matches are heterogeneous in their profitability. Below a certain profitability threshold, intermediate goods firms can decide to use short-time work (STW) to reduce hours worked of employees while keeping them in the firm. Workers then receive a partial compensation for the wage cut by the government. Workers with the lowest profitability are separated from firms and become unemployed. Wholesale goods firms buy the intermediate good and sell it to households. Their pricing decision is subject to nominal rigidities. The government runs a balanced budget and the monetary authority sets nominal interest rates. There is ex-ante heterogeneity, i.e., next to workers, there are wealthy entrepreneurs who collect all the profits from monopolistic competition.

Households cannot fully insure the unemployment risk. To add imperfect insurance to the model, we follow Krusell et al. (2011) and Ravn and Sterk (2017, 2020) and assume that there are no savings in equilibrium. Then, employed workers choose not to save voluntarily and their Euler equation for savings holds with equality. In other words, this determines the equilibrium real interest rate and prices the bond. This assumption keeps the model tractable in the presence of aggregate shocks while preserving a time-varying precautionary savings motive.

2.1 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.

2.1.1 Employment dynamics, matching technology and vacancy posting

The labor market with STW follows Balleer et al. (2016) and Gehrke et al. (2019). There is a continuum of measure 1 of workers. Workers can be in three states. (1) Workers employed in full-time earn wage w_t^f, (2) workers on STW earn wage w_t^s and (3) unemployed workers receive unemployment benefits δ_t. 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. 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. For the sake of clarity, the sequence of events in a typical period t is shown in Figure 2.

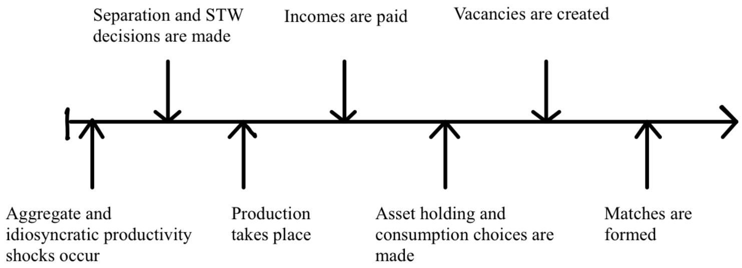

Figure 2: Sequence of events at date t

Matches m_t are formed according to a Cobb-Douglas matching technology

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

where $\alpha \in (0,1)$ is the elasticity of matches with respect to unemployment and the parameter $\mu > 1$ is the matching efficiency. It follows that unemployed workers find jobs with probability $\eta_t = \mu\theta_t^{-\alpha}$, where $\theta_t \equiv v_t/u_t$ represents labor market tightness. Unmatched firms v_t find workers at rate $q_t = \mu\theta_t^{1-\alpha}$. 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 evolution of employment is given by

$$n_t = (1-\phi_t)(n_{t-1} + m_{t-1}) = (1-\phi_t)(n_{t-1} + \eta_{t-1}(1-n_{t-1})) \tag{2}$$

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:

$$V_t = -\kappa + \mathbb{E}_t\Lambda_{t,t+1} q_t J_{t+1} + \mathbb{E}_t\Lambda_{t,t+1}(1-q_t)V_{t+1}, \tag{3}$$

where J_t is the present value of a job and κ represents vacancy posting costs. The stochastic discount factor is $\Lambda_{t,t+1} = \beta\frac{u'(C_{t+1}^E)}{u'(C_t^E)} = \beta(\frac{C_t^E}{C_{t+1}^E})^{\sigma}$ as applied by firm owners (their problem follows in Section 2.3). Assuming free entry to vacancy posting ($V_t = 0 \ \forall \ t$) results in the job creation condition:

$$\frac{\kappa}{q_t} = \mathbb{E}_t\Lambda_{t,t+1}J_{t+1}. \tag{4}$$

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

2.1.2 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

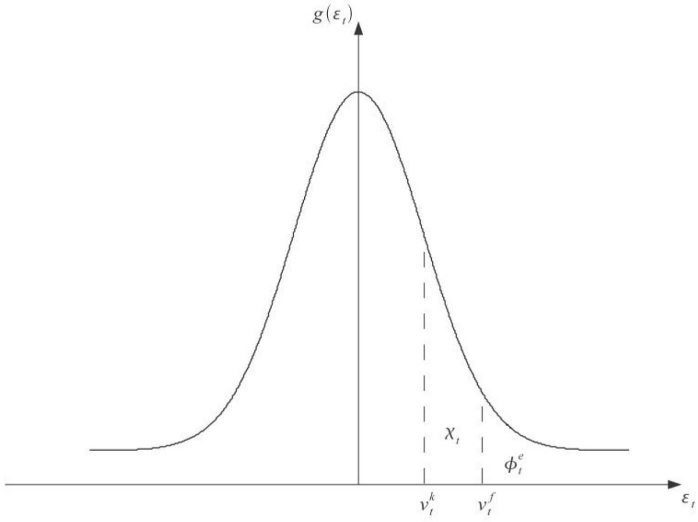

Figure 3: Illustration of the distribution of the idiosyncratic profitability shocks with STW threshold v_t^k and v_t^f following Balleer et al. (2016).

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 3.

The present value of a match with a specific realization of the idiosyncratic shock ϵ_t such that the worker is not on STW is given by:

$$J_t(\epsilon_t | \epsilon_t < v_t^k) = a_t p_t^z - w_t - \epsilon_t + \mathbb{E}_t \Lambda_{t,t+1} J_{t+1}, \tag{5}$$

where a_t is aggregate productivity and $p_t^z = P_t^z / P_t$ 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:

$$a_t p_t^z - w_t - \epsilon_t + \mathbb{E}_t \Lambda_{t,t+1} J_{t+1} < \zeta_t. \tag{6}$$

The value of the idiosyncratic shock ϵ_t where Equation 6 holds with equality is given by v_t^k. It defines the threshold value for STW v_t^k as

$$v_t^k = a_t p_t^z - w_t + \mathbb{E}_t \Lambda_{t,t+1} J_{t+1} - \zeta_t. \tag{7}$$

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 3 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.[3] 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.[4] The firm chooses the optimal level of hours reduction K by maximizing the contemporaneous profit of a worker on STW:

$$\max_{K(\epsilon_t)} \pi_t = K(\epsilon_t)(a_t p_t^z - w_t - \epsilon_t)\big(1 - K(\epsilon_t)\big) - C\big(K(\epsilon_t)\big) \tag{8}$$

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:

$$C(K(\epsilon_t)) = c_k \frac{1}{2} K(\epsilon_t)^2 \tag{9}$$

yields an optimal STW hours reduction for a given ϵ_t

$$K^*(\epsilon_t) = -\frac{a_t p_t^z - w_t - \epsilon_t}{c_k}. \tag{10}$$

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

$$(a_t p_t^z - w_t - \epsilon_t)\big(1 - K^*(\epsilon_t)\big) - C\big(K^*(\epsilon_t)\big) + \mathbb{E}_t \Lambda_{t,t+1} J_{t+1} < -f. \tag{11}$$

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

$$v_t^f = p_{z,t} a_t - w_t + \frac{f + \mathbb{E}_t \Lambda_{t,t+1} J_{t+1}}{1 - K^*(v_t^f)} - \frac{C(K^*(v_t^f))}{1 - K^*(v_t^f)}. \tag{12}$$

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 3). 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 (10) 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

$$\begin{aligned} J_{t+1} = {} & (1-\phi^x) \int_{-\infty}^{v_{t+1}^k} (a_{t+1} p_{zt+1} - w_{t+1} - \epsilon_{t+1}) g(\epsilon_{t+1}) d\epsilon_{t+1} \\ & + (1-\phi^x) \int_{v_{t+1}^k}^{v_{t+1}^f} \big[(a_{t+1} p_{zt+1} - w_{t+1} - \epsilon_{t+1})(1 - K^*(\epsilon_{t+1})) - C(K^*(\epsilon_{t+1}))\big] g(\epsilon_{t+1}) d\epsilon_{t+1} \\ & - (1-\phi^x)\phi_{t+1}^e f + \mathbb{E}_{t+1}(1-\phi_{t+1})\Lambda_{t+1,t+2} J_{t+2}. \end{aligned} \tag{13}$$

[3] 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 8 in the Appendix.

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

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:

$$
\begin{aligned}
d_t^I &= n_t^B(1-\phi^x)\int_{-\infty}^{v_t^k}(a_t p_{zt} - w_t - \epsilon_t)g(\epsilon_t)d\epsilon_t \\
&+ n_t^B(1-\phi^x)\int_{v_t^k}^{v_t^f}\left[(a_t p_{zt} - w_t - \epsilon_t)(1-K^*(\epsilon_t)))\right]g(\epsilon_t)d\epsilon_t \\
&- n_t^B(1-\phi^x)\phi_t^e f - \kappa v_t,
\end{aligned}
\tag{14}
$$

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

2.1.3 Wage determination

For wages, we assume collective bargaining in line with 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.[5] The value of the median worker to the firm is therefore

$$F_t = a_t p_t^z - w_t + \mathbb{E}_t \Lambda_{t,t+1} J_{t+1}. \tag{15}$$

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

$$\tilde{F}_t = \mathbb{E}_t \Lambda_{t,t+1} J_{t+1}. \tag{16}$$

The median worker's surplus W_t from a match is

$$W_t = w_t + \mathbb{E}_t \Lambda_{t,t+1}(1-\phi_{t+1})W_{t+1} + \mathbb{E}_t \Lambda_{t,t+1}\phi_{t+1}, \tag{17}$$

where U_t is the value of unemployment defined as $U_t = \delta_t + \eta_t(1-\phi_{t+1})W_{t+1} + (1 - \eta_t(1-\phi_{t+1})U_{t+1})$. Lastly, the worker's fall-back option under disagreement is

$$\tilde{W}_t = \delta_t + \mathbb{E}_t \Lambda_{t,t+1}(1-\phi_{t+1})W_{t+1} + \mathbb{E}_t \Lambda_{t,t+1}\phi_{t+1}U_{t+1}. \tag{18}$$

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

$$w_t^N = \arg\max\ (W_t - \tilde{W}_t)^{1-\gamma}(F_t - \tilde{F}_t)^{\gamma}, \tag{19}$$

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 4.1.

$$w_t = (w_t^N)^{1-\gamma_w}(w_{ss})^{\gamma_w}. \tag{20}$$

[5] 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. Instead, STW is only allowed in case of a temporary lack of demand and financial difficulties.

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, the average wage for short-time workers is given by

$$w_t^s = \int_{v_t^k}^{v_t^f} \frac{(1-K(\epsilon_t))w_t + \delta_t K(\epsilon_t)}{\chi_t} g(\epsilon_t) d\epsilon_t. \tag{21}$$

Here, the worker is on STW for a share $K(\epsilon_t)$ of her working time. For that fraction she only receives STW compensation that is (in the baseline model) equal to the unemployment benefit. 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.[6]

2.2 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:

$$y_{jt} = \left(\frac{P_t^j}{P_t}\right)^{-\epsilon} y_t, \tag{22}$$

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.They set prices to maximize the present discounted value of profits:

$$\mathbb{E}_t \sum_{s=0}^{\infty} \left[\left(\frac{P_{j,t+s}}{P_{t+s}} - p_{t+s}^z\right) y_{j,t+s} - \frac{\Psi}{2}\left(\frac{P_{j,t+s} - P_{j,t+s-1}}{P_{j,t+s-1}}\right)^2 y_t \right], \tag{23}$$

subject to the demand constraint (22). The first order condition using that all firms set the same prize becomes:

$$0 = (1-\epsilon) + \epsilon p_t^z - \Psi(\Pi_t - 1)\Pi_t + \mathbb{E}_t \left\{ \Lambda_{t,t+1} \Psi(\Pi_{t+1} - 1) \frac{y_{t+1}}{y_t} \Pi_{t+1} \right\}, \tag{24}$$

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

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

$$d_t^W = (1 - p_t^z)\, y_t - \frac{\Psi}{2}(\Pi_t - 1)^2 y_t, \tag{25}$$

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

$$d_t = d_t^W + d_t^I. \tag{26}$$

[6] 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.

2.3 Households and entrepreneurs

Households There is a continuum of measure 1 of households. Households are heterogeneous in that they can be employed in full time and earn wage w_t^f, can be on STW and earn wage w_t^s or can be unemployed and receive unemployment benefits δ_t. For an hours reduction $0 < K^* < 1$, it holds that $w_t^f > w_t^s > \delta_t$.

The transition probabilities across the three states $x = \{f, s, u\}$ can be summarized in the following matrix:

$$T_{t+1} = \begin{bmatrix} \rho_{t+1}^{ff} & \rho_{t+1}^{fs} & \rho_{t+1}^{fu} \\ \rho_{t+1}^{sf} & \rho_{t+1}^{ss} & \rho_{t+1}^{su} \\ \rho_{t+1}^{uf} & \rho_{t+1}^{us} & \rho_{t+1}^{uu} \end{bmatrix}, \tag{27}$$

or using the previously established notation for the flow rates:

$$T_{t+1} = \begin{bmatrix} (1-\phi^x)\mathbb{E}_t(1-\phi_{t+1}^e-\chi_{t+1}) & (1-\phi^x)\mathbb{E}_t\chi_{t+1} & \mathbb{E}_t\phi_{t+1} \\ (1-\phi^x)\mathbb{E}_t(1-\phi_{t+1}^e-\chi_{t+1}) & (1-\phi^x)\mathbb{E}_t\chi_{t+1} & \mathbb{E}_t\phi_{t+1} \\ \eta_t(1-\phi^x)\mathbb{E}_t(1-\phi_{t+1}^e-\chi_{t+1}) & \eta_t(1-\phi^x)\mathbb{E}_t\chi_{t+1} & (1-\eta_t)+\eta_t\mathbb{E}_t\phi_{t+1} \end{bmatrix}. \tag{28}$$

Note that the transition probabilities for employed workers and workers on STW (first and second row) are identical, but differ from those of unemployed workers. This reflects the fact that all of these workers are counted as employed and comes from the $i.i.d$ assumption on the profitability shock ϵ_t. In other words, 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. Additionally, the relevant job finding rate for the next period η_t depends on vacancies and unemployment at date t, and is thus known. Not known in the current period are the job separation rate, ϕ, and the short-time rate, χ. As a result, it will be the risk of job separation and STW that drives the precautionary savings motive.[7] Further, as long as $\eta_t < 1$, the prospective employment probability for unemployed workers is smaller than that of short-time workers. This is also true in the data. In survey data from the Covid-19 crisis for Germany[8], only 4% of employees 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.

Households indexed by i maximize intertemporal utility by choosing consumption $c_{i,t}$ and savings $b_{i,t}$ subject to their respective budget constraints, and a no-borrowing constraint. Specifically, the Bellman equation for an employed worker in full-time is

$$\begin{aligned} V(n_{it}^f, b_{it-1}) = \max_{\{c_{i,t}, b_{i,t}\}} \frac{c_{i,t}^{1-\sigma}-1}{1-\sigma} &+ \beta\mathbb{E}_t[(1-\phi^x)(1-\phi_{t+1}^e-\chi_{t+1})V(n_{it+1}^f, b_{it}) \\ &+ (1-\phi^x)\chi_{t+1}V(n_{it+1}^s, b_{it}) + \phi_{t+1}V(n_{it+1}^u, b_{it})] \end{aligned} \tag{29}$$

[7] This assumption sets this model apart from work by Challe (2020) and Ravn and Sterk (2020), where the separation rate is exogenous and fixed, but the job finding rate is uncertain at date t.

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

s.t.

$$
\begin{aligned}
c_{it} + b_{it} &= w_{it}^{f} + \frac{1 + i_{t-1}}{1 + \pi_t} b_{it-1} \\
b_{it} &\geq 0.
\end{aligned}
$$

The worker in full-time earns the current wage w_{it}^{f}. The problem of short-time workers is identical except that they are paid current wage w_{it}^{s}

$$
\begin{aligned}
V(n_{it}^{s}, b_{it-1}) = \max_{\{c_{i,t}, b_{i,t}\}} \frac{c_{i,t}^{1-\sigma} - 1}{1-\sigma} &+ \beta \mathbb{E}_t[(1-\phi^{x})(1-\phi_{t+1}^{e} - \chi_{t+1}) V(n_{it+1}^{f}, b_{it}) \\
&+ (1-\phi^{x})\chi_{t+1} V(n_{it+1}^{s}, b_{it}) + \phi_{t+1} V(n_{it+1}^{u}, b_{it})]
\end{aligned} \tag{30}
$$

s.t.

$$
\begin{aligned}
c_{it} + b_{it} &= w_{it}^{s} + \frac{1 + i_{t-1}}{1 + \pi_t} b_{it-1} \\
b_{it} &\geq 0.
\end{aligned}
$$

Lastly, the Bellman equation for an unemployed worker with income δ_{it} in the current period is:

$$
\begin{aligned}
V(n_{it}^{u}, b_{it-1}) = \max_{\{c_{i,t}, b_{i,t}\}} \frac{c_{i,t}^{1-\sigma} - 1}{1-\sigma} &+ \beta \mathbb{E}_t[\eta_t(1-\phi^{x})(1-\phi_{t+1}^{e} - \chi_{t+1}) V(n_{it+1}^{f}, b_{it}) \\
&+ \eta_t(1-\phi^{x})\chi_{t+1} V(n_{it+1}^{s}, b_{it}) + (1 - \eta_t + \eta_t \phi_{t+1}) V(n_{it+1}^{u}, b_{it})]
\end{aligned} \tag{31}
$$

s.t.

$$
\begin{aligned}
c_{it} + b_{it} &= \delta_{it} + \frac{1 + i_{t-1}}{1 + \pi_t} b_{it-1} \\
b_{it} &\geq 0.
\end{aligned}
$$

Entrepreneurs Entrepreneurs have positive mass ν and do not participate in the labor market, but own firms. Given that, they face no unemployment risk. The Bellman equation of the representative entrepreneur is

$$
V(b_{E,t-1}) = \max_{\{c_{E,t}, b_{E,t}\}} \frac{c_{E,t}^{1-\sigma} - 1}{1-\sigma} + \beta_t \mathbb{E}_t V(b_{E,t}) \tag{32}
$$

s.t.

$$
\begin{aligned}
c_{E,t} + b_{E,t} &= (d_t + \xi - T_t)/\nu + \frac{1 + i_{t-1}}{1 + \pi_t} b_{E,t-1} \\
b_{it} &\geq 0,
\end{aligned}
$$

where d_t are real dividends paid out to firms, of which all entrepreneurs receive an equal share. Further, ξ is home production and T_t is a lump-sum tax paid to the fiscal authority. The assumption of two types of households is consistent with the fact that equity holdings are very concentrated (Kuhn and Ríos-Rull, 2016). In addition, Bilbiie (2020) and Acharya and Dogra (2020), among others, have shown that the distribution and cyclicality of dividends may affect the time-varying income risk that households face and their implied precautionary savings decisions in equilibrium models in controversial ways. In our model, this is not the case. As shown below, in equilibrium, only workers have a precautionary savings motive, while entrepreneurs collect all dividends and pay taxes. This is consistent with our focus on the importance of time-varying unemployment risk for precautionary savings.

2.4 Government, market clearing and equilibrium implications

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

$$\frac{1+i_t}{1+\bar{r}} = (1+\pi_t)^{\psi_\pi}, \tag{33}$$

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 fiscal authority follows a balanced budget rule and finances STW expenses and unemployment benefits through lump-sum taxes that are paid by firm owners:

$$T_t = \delta_t n_t^B (1-\phi^x) \int_{v_t^k}^{v_t^f} K^*(\epsilon_t) g(\epsilon) d\epsilon_t + \delta_t u_t. \tag{34}$$

There is no government debt, therefore bonds are in zero net supply, i.e., $\int b_{i,t} di = 0$. Market clearing in the intermediate goods market implies

$$y_t = n_t^B (1-\phi^x) \left[\int_{-\infty}^{v_t^k} a_t g(\epsilon_t) d\epsilon_t + \int_{v_t^k}^{v_t^f} a_t (1 - K^*(\epsilon_t)) g(\epsilon_t) d\epsilon_t \right]. \tag{35}$$

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

$$\begin{aligned} c_t =& n_t^B (1-\phi^x) \int_{-\infty}^{v_t^k} (a_t - \epsilon_t) g(\epsilon_t) d\epsilon_t + n_t^B (1-\phi^x) \int_{v_t^k}^{v_t^f} (a_t - \epsilon_t)(1 - K^*(\epsilon_t)) g(\epsilon_t) d\epsilon_t \\ & - (1-\phi^x) n_t^B \phi_t^e f - \kappa v_t - \frac{\Psi}{2} (\Pi_t - 1)^2 y_t + \xi. \end{aligned} \tag{36}$$

The assumption of a no-borrowing constraint together with the assumption that bonds are in zero net supply implies that the wealth distribution is degenerate in equilibrium, and all agents consume their current income, as in Challe (2020) or Ravn and Sterk (2020). To make this point clearer, we discuss the Euler equations of all the agents in the economy in turn. We suppress the individual subscript i from now on, because there is no heterogeneity in savings and consumption within groups of agents. The maximization problem yields the following Euler equation for the full-time employed worker:

$$c_{f,t}^{-\sigma} = \beta \mathbb{E}_t \frac{1+i_t}{1+\pi_{t+1}} \Big[(1-\phi^x)(1-\phi_{t+1}^e - \chi_{t+1}) c_{f,t+1}^{-\sigma} + (1-\phi^x)\chi_{t+1} c_{s,t+1}^{-\sigma} + \phi_{t+1} c_{u,t+1}^{-\sigma} \Big] + \lambda_{f,t}, \tag{37}$$

where λ_f is the Kuhn-Tucker multiplier on the no-borrowing constraint (29). Rearranging and assuming $\lambda_f \geq 0$ gives:

$$1 \geq \beta \mathbb{E}_t(1+r_t)\left[(1-\phi^x)(1-\phi^e_{t+1}-\chi_{t+1})(\frac{c_{f,t+1}}{c_{f,t}})^{-\sigma}+(1-\phi^x)\chi_{t+1}(\frac{c_{s,t+1}}{c_{f,t}})^{-\sigma}+\phi_{t+1}(\frac{c_{u,t+1}}{c_{f,t}})^{-\sigma}\right]. \tag{38}$$

Similarly, the Euler equation for employed workers on STW is:

$$1 \geq \beta \mathbb{E}_t(1+r_t)\left[(1-\phi^x)(1-\phi^e_{t+1}-\chi_{t+1})(\frac{c_{f,t+1}}{c_{s,t}})^{-\sigma}+(1-\phi^x)\chi_{t+1}(\frac{c_{s,t+1}}{c_{s,t}})^{-\sigma}+\phi_{t+1}(\frac{c_{u,t+1}}{c_{s,t}})^{-\sigma}\right], \tag{39}$$

and that for unemployed workers is:

$$1 \geq \beta \mathbb{E}_t(1+r_t)\Big[\eta_t(1-\phi^x)(1-\phi^e_{t+1}-\chi_{t+1})(\frac{c_{f,t+1}}{c_{u,t}})^{-\sigma}+\eta_t(1-\phi^x)\chi_{t+1}(\frac{c_{s,t+1}}{c_{u,t}})^{-\sigma} \\ +(1-\eta_t+\eta_t\phi_{t+1})(\frac{c_{u,t+1}}{c_{u,t}})^{-\sigma}\Big]. \tag{40}$$

Lastly, the Euler equation of the representative entrepreneur is:

$$1 \geq \beta \mathbb{E}_t(1+r_t)\left(\frac{c_{E,t+1}}{c_{E,t}}\right)^{-\sigma} \tag{41}$$

Each of the Euler equations holds with strict inequality if the no-borrowing constraint of the agent is binding and with equality if the constraint is slack.

Intuitively, the full-time workers have the strongest incentive to save for precautionary reasons. They face idiosyncratic unemployment risk and the highest income risk. This pushes the equilibrium interest rate downwards. Other workers have a weaker precautionary savings motive, as short-time workers may become full-time employed or unemployed and unemployed workers may become employed in the future, while entrepreneurs face no idiosyncratic risk. Thus, those agents would like to borrow at the equilibrium interest rate, but the no-borrowing constraint prevents them from doing so. Hence, in equilibrium, because of zero net supply of bonds, there is neither saving nor borrowing and all agents consume their current income. Effectively, the equilibrium real interest rate adjusts such that the Euler equation of the full-time worker has to hold with equality, while the other agents are off their Euler equations. Thus, the full-time workers price the bond and their consumption-saving decisions determine the real interest rate. Due to the idiosyncratic risk, the equilibrium real interest rate lies below the subjective discount factor in steady state:[9]

$$1+r < \frac{1}{\beta}. \tag{42}$$

Assuming a no-borrowing constraint and zero net supply of bonds is a tractable way to introduce a precautionary savings mechanism in this model. Recessions imply higher unemployment risk due to anticipated separations and more precautionary savings of

[9]To see this, use the fact that Equation (38) holds with equality and that the marginal rate of intertemporal substitution (the term in brackets) is greater than 1 due to the idiosyncratic risk. All other Euler equations are consistent with this provided that they hold with inequality. In particular, it is clear from Equation (41) that entrepreneurs are not willing to save at any interest rate below the time preference rate, because they face no idiosyncratic risk, hence they are off their Euler equation as well.

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 1: 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).

employed workers, depressing the real interest rate and goods demand. Depressed goods demand leads to more firings and again more precautionary savings. Note that the precautionary savings channel works entirely through fluctuations in the endogenous separation rate, unlike in Ravn and Sterk (2017) and Challe (2020), where it works through fluctuations in the job-finding rate.

To illustrate the potential benefits of STW, it is helpful to compare the Euler equations for the full-time worker with a *counterfactual* Euler equation for an employed worker in an economy without STW. First, the full-time Euler Equation (37), slightly rewritten reads as:

$$\frac{1}{1+r_{stw,t}} = \beta \mathbb{E}_t \left[(1-\phi^x)(1-\phi^e_{t+1}-\chi_{t+1}) \left(\frac{w_{f,t+1}}{w_{f,t}}\right)^{-\sigma} + (1-\phi^x)\chi_{t+1} \left(\frac{w_{s,t+1}}{w_{f,t}}\right)^{-\sigma} \right. \\ \left. + \phi_{stw,t+1} \left(\frac{\delta_t}{w_{f,t}}\right)^{-\sigma} \right], \tag{43}$$

compared to the Euler equation in a counterfactual model without STW:

$$\frac{1}{1+r_t} = \beta \mathbb{E}_t \left[(1-\phi_{t+1}) \left(\frac{w_{f,t+1}}{w_{f,t}}\right)^{-\sigma} + \phi_t \left(\frac{\delta_t}{w_{f,t}}\right)^{-\sigma} \right]. \tag{44}$$

In comparing these two scenarios, it is assumed that everything is the same except $\phi_{stw,t+1} < \phi_t$, because the existence of STW at the rate χ_{t+1} prevents firings. This is the probability of the bad outcome, where workers receive unemployment benefits δ_t next period. 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 $\delta_t < w_{s,t+1} \leq w_{t+1}$, i.e., being short-time employed is preferred to being unemployed, we obtain $r_t < r_{stw,t}$, implying less precautionary savings in the model with STW. Thus, the existence of STW may help to stabilize demand in recessions. The idea that the income risk is considerably different across labor market states is consistent with the data. For example, 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. In contrast, only 37% of those affected by STW reported a considerable income loss. Instead, workers on STW report to a larger extend a more moderate income loss (source: survey evidence from the IAB-HOPP data, see Table 1).

3 Quantitative analysis of short-time work and precautionary savings

3.1 Benchmark economies

To illustrate the transmission mechanism under incomplete markets in a model with STW, we compare several scenarios.

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

No short-time work and imperfect insurance 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 under incomplete markets.

Short-time work and perfect insurance As suggested by Challe (2020), one can eliminate the precautionary savings mechanism by setting the replacement rate close to 1, so that unemployment benefits are essentially equal to the real wage. Since the short-time wage is a weighted average of the full-time wage and unemployment benefits, this also implies that the incomes in all three idiosyncratic states are equalized. Then, the worker has no precautionary savings motive because there is no income risk from becoming unemployed or a short-time worker. This serves as a benchmark to illustrate the amplification effects of the incomplete markets assumption.

No short-time work and perfect insurance The final comparison will be a model with perfect insurance and without STW.

3.2 Calibration

Our baseline model is calibrated to the German economy. A time period represents a quarter. Table 2 summarizes our parameters and calibration targets. The first column shows the calibration with imperfect insurance, which we regard as the realistic case, and the second column shows the perfect insurance case. The aim of the calibration is to isolate the precautionary savings channel while keeping other parameters relevant for the firm channel constant.

For the New Keynesian block of the model, we impose standard values. The discount factor β is 0.98, which delivers an annual interest rate of 1%. In the perfect insurance case, the annual interest rate is around 2%. In this case, households have no desire to save in a precautionary manner against unemployment risk, accordingly the real interest rate consistent with the no borrowing constraint must be higher.[10]

We follow McKay et al. (2016) and set the elasticity of substitution to 6. For the value of the price adjustment costs we choose a value consistent with a Calvo (1983) probability

[10]Targeting the same real interest rate would imply different discount factors between the models, because of the different risk in steady state. This would change the discounted expected value ΛJ of the job from the perspective of the firm, and therefore other parameters of the labor market would change as well, which play a role for the firm channel. To avoid this, we allow for the different steady state interest rates.

	Description	Imperfect insurance	Perfect insurance
Parameters			
β	Discount factor	0.98	0.98
Ψ	Price adjustment costs	207	207
ϵ	Elasticity of subst. between varieties	6	6
ρ_π	Taylor weight on inflation	1.5	1.5
σ	Relative risk aversion	1.5	1.5
α	Matching elasticity w.r.t. unemployment	0.6	0.6
δ/w	Replacement rate (1− consumption drop upon unemployment)	0.8	0.99
μ	Matching efficiency	0.43	0.43
f	Firing costs	2.4	2.4
$p^z a - w$	Operating profits	0.025	0.025
s	Scale parameter of profitability distribution	0.85	0.85
κ	Costs of posting a vacancy	0.69	0.69
c_k	Costs of STW usage	16.49	16.49
γ_w	Wage rigidity parameter	0.73	0.43
γ	Worker bargaining power	0.87	0.25
ξ	Home production	1.07	1.11
Steady state targets			
q	Worker finding rate	0.7	0.7
ϕ	Overall job destruction rate (endogenous 1/3, exogenous 2/3)	0.03	0.03
η	Job finding rate	0.31	0.31
u	Unemployment rate	0.09	0.09
χ	STW rate	0.007	0.007
Π	Inflation	1	1
r	Real interest rate (annual.)	1%	2%

Table 2: Calibration

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. We show that our main results are robust to a lower value in Section 4.5.[11] The Taylor weight on inflation is 1.5.

Regarding the labor market, the steady state targets are in line with Balleer et al. (2016). Specifically, the targets for the steady state 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 elasticity of matching with respect to unemployment α is set to 0.6. The steady state targets imply values for several parameters of the model. The idiosyncratic profitability shock follows a logistic distribution, which is normalized to have an unconditional mean of zero. To achieve our targets, we set the scale parameter of the distribution s to 0.85, the matching efficiency μ to 0.43, and the costs of posting a vacancy κ to 0.69. The firing costs f are set to 60% of annual productivity. The target for the STW rate in steady state of 0.7% implies a value for the costs of STW usage c_k of 16.49.

We set the STW elasticity with respect to output in line with the data as in Balleer

[11] Lindé and Trabandt (2019) 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.

et al. (2016). 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). Hence, we use the operating profits to target the contemporaneous elasticity of the extensive margin of STW with respect to output changes of -3.6 under perfect insurance, for comparability to the results obtained by Balleer et al. (2016) in a representative agent setting. The target implies operating profits for a job with mean profitability of zero equal to 0.025. Those operating profits imply a worker bargaining power of 0.87 in the imperfect insurance case.

Regarding the precautionary savings mechanism, first, a key parameter in the model is δ/w, which represents the consumption drop upon entering unemployment in steady state, and therefore the strength of the precautionary savings mechanism. Matching the actual replacement rate to δ/w in the model would overstate the importance of the mechanism, because households may have access to other insurance so that the consumption drop is smaller than the difference between unemployment benefits and the wage. Chodorow-Reich and Karabarbounis (2016) find that the drop in consumption of nondurable goods and services upon unemployment is roughly 20% in the US. Although there is no empirical evidence on the equivalent elasticity for Germany, Bentolila and Ichino (2008) analyze data for Italy, Spain, UK, and the US and find that food consumption losses induced by unemployment are similar across countries. Therefore, we think it is reasonable to extrapolate and we set $(w - \delta)/w$ to 20%. As mentioned before, the replacement rate in the perfect insurance case is equal to 0.99 which virtually eliminates the precautionary savings mechanism.

Second, next to the steady state value of δ/w the cyclicality is important as well. More precisely, the degree of income risk associated with unemployment depends both on the risk of becoming unemployed (ϕ_t) and the size of the proportional consumption drop determined by δ_t/w_t. As in Challe (2020), we focus on the former mechanism by holding δ_t/w_t constant, i.e., unemployment benefits vary such that they are always a constant share of the wage. This assumption, together with the division of workers and entrepreneurs, guarantees that countercyclical unemployment risk is the only source of income risk that workers face.[12]

Third, the cyclicality of labor income determined by the flexibility of wages is key. The wage rigidity parameter γ_w is calibrated to match an elasticity of real wages with respect to labor productivity of 0.3, as in Challe (2020).[13] In the benchmark case of imperfect insurance and STW, this implies a value of $\gamma_w = 0.73$.

To isolate the effect of precautionary savings when comparing the different models, we set the parameters such that all models share the same wage cyclicality and steady state, with the exception of the real interest rate. Accordingly, the same operating profits combined with the higher replacement rate of 0.99 imply a lower value for the worker bargaining power (0.25) in the model with perfect insurance compared to the model with imperfect insurance. Similarly, obtaining the same wage cyclicality requires a lower value for the wage rigidity parameter (0.43).

[12] 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 fluctutations 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 recessions. Ravn and Sterk (2020) provide a detailed discussion on the countercyclicality of income risk.

[13] Merkl and Stüber (2020) find a median wage cyclicality of 0.32 when regressing wage changes on employment changes in a recent study for Germany.

Entrepreneurial consumption is interpreted as aggregate capital income. To target a labor share of 60%, we set the value of home production equal to $\xi = 1.07$ in the baseline calibration.

Lastly, to assess the role of STW as an automatic stabilizer of the macroeconomy, we compare 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, but the steady states may differ.[14]

4 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.

4.1 No-STW model

Figure 4 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 perfect insurance (row 1) and imperfect insurance (row 2), respectively.[15]

In all 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 and vacancies v, as well as the increase in the separation rate ϕ in column 3 of Figure 4. As a consequence, unemployment increases (column 2) and output decreases (column 1).

The clearest difference between the case of imperfect insurance and perfect insurance lies in the behavior of the real interest rate (column 4) and inflation (column 6). When workers are insured against unemployment risk (row 1), the real interest rate increases persistently with the contraction, and inflation increases. The opposite is the case when workers are imperfectly insured. In that case, there is persistent downward pressure on the real interest rate and inflation. This behavior reflects the consumption-saving decisions of full-time workers on their Euler equation.

To understand this, consider the log-linearized Euler equation in the basic model without STW (follows from Equation (44), with $b_t/w_{f,t} = b/w$) and assuming flexible prices) that decomposes the natural interest rate as:

$$\frac{1}{\sigma}\hat{R^n}_t = \mathbb{E}_t\hat{w}_{f,t+1} - \hat{w}_{f,t} - \frac{1}{\sigma}\Theta_u\mathbb{E}_t\hat{\phi}_{t+1}, \tag{45}$$

where R_t^n is the natural interest rate, $w_{f,t}$ is the full-time wage, ϕ_t is the separation rate, hats indicate proportional deviations from steady state and $\Theta_u = \beta R\phi\left[(\frac{\delta}{w})^{-\sigma} - 1\right] \geq$

[14]For instance, targeting the same level of unemployment in models with STW and without STW would imply a difference in matching efficiency.

[15]Figure 9 in the appendix plots the impulse responses with flexible prices.

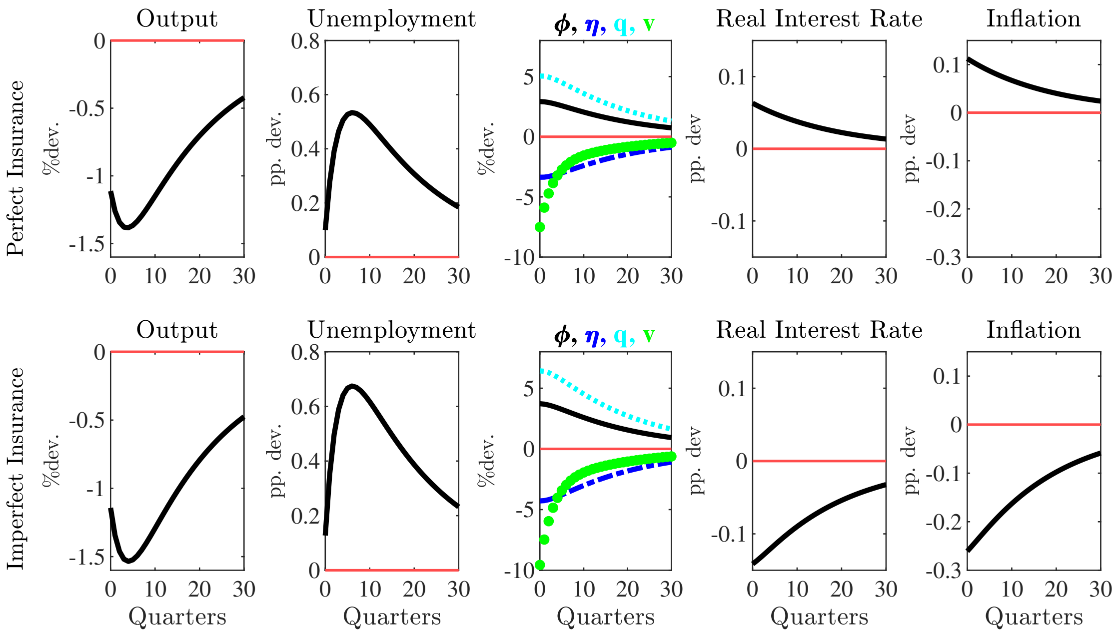

Figure 4: Impulse responses to a negative one percent shock to productivity with autocorrelation 0.95. First row displays IRFs with perfect insurance, second row displays IRFs with imperfect insurance in the model without STW. The separation rate is denoted by ϕ, the job-finding rate is η, the worker-finding rate is q, vacancies are v.

0.[16]

The deviation of the natural interest rate $\hat{R}_t^n$ from its steady state is determined by two competing channels: First, after a contractionary shock, the *intertemporal substitution channel* puts upward pressure on the natural interest rate. This channel is standard and known from representative agent models. The worker faces a rising expected wage profile ($\mathbb{E}_t \hat{w}_{f,t+1} > \hat{w}_{f,t}$) as the economy recovers from the initial shock, and therefore wants to consume more and save less in the current period. In other words, the worker wants to borrow against higher future income. In equilibrium, this drives up the market clearing natural interest rate. The reverse would be true for an expansionary shock associated with a falling wage (and consumption) profile. Second, the *precautionary savings channel* puts downward pressure on the natural interest rate after a contractionary shock. Under imperfect insurance, employed workers fear unemployment due to the increase in the expected separation rate ($\mathbb{E}_t \hat{\phi}_{t+1} > 0$), accordingly they want to reduce consumption and increase saving at the given interest rate. This puts downward pressure on the natural interest rate. Note that the precautionary savings channel works trough fluctuations in the separation rate, which sets this model apart from the models of Challe (2020) and Ravn and Sterk (2017), where fluctuations in the job finding rate determine unemployment risk, and separations are exogenous.

Which of the two channels dominates depends on the calibration. The precautionary savings channel is weaker the higher δ/w. Notably, in the limiting case of perfect insurance ($\delta/w = 1$), where households experience no income drop upon unemployment, the channel is inactive (row 1 of Figure 4). Similarly, the intertemporal substitution

[16]Similar decompositions can be found in Challe (2020) and Ravn and Sterk (2020), but in a model with exogenous separations only.

channel is stronger under more flexible wages, because the gap between current and expected wages ($\mathbb{E}_t\hat{w}_{f,t+1} - \hat{w}_{f,t}$) increases. Conversely, under perfectly rigid wages ($\mathbb{E}_t\hat{w}_{f,t+1} = \hat{w}_{f,t} = 0 \;\forall\; t$), only the precautionary savings channel is active. The fall in the real interest rate for the case of imperfect insurance (row 2 in Figure 4) shows that the precautionary savings channel dominates with the given calibration.[17]

Given sticky prices, the consumption-saving decisions of households feed back into employment. When workers are perfectly insured (row 1), the fall in productivity results in inflation as the supply of goods falls below demand by households. Households' demand for consumption goods remains high because only the intertemporal substitution channel is active (see Equation (45)) and households want to borrow against higher future income. This inflationary impact is the standard result for contractionary supply shocks such as productivity shocks and cost-push shocks with perfect insurance. In response to that the central bank raises the nominal interest rate according to the Taylor rule, which leads to a persistent increase in the real interest rate since $\psi_\pi > 1$.

By contrast, when workers are imperfectly insured against unemployment risk (row 2), their desire to save for precautionary reasons, i.e., to postpone consumption, generates deflationary pressures, as is visible in the last column. This is consistent with a decline in nominal and real interest rates. However, the cut in the nominal interest rate is not enough to prevent a deflationary feedback loop between unemployment risk and demand. Employed 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. For that reason, the separation rate increases over 4% on impact under imperfect insurance, while the response is only around 3% under perfect insurance. Accordingly, the difference in the response of the separation rate is reflected in the behavior of the unemployment rate and output. The peak response of unemployment is 0.56 percentage points in the perfect insurance case, compared to 0.66 percentage points in the imperfect insurance case. The drop in output is 1.39 percent compared to 1.58 percent. Compared to Ravn and Sterk (2017) and Challe (2020), the impact of precautionary savings is relatively modest here, due to the relatively low unemployment risk in the German calibration. We will show that this changes in a calibration with higher labor market flows in Section 4.2.2.

4.2 Adding the STW margin

4.2.1 German calibration

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 first consider the loglinearized Euler equation in the full model with the option of STW. As before, we assume flexible prices and unemployment benefits equal to a constant fraction of the wage in full time ($\delta_t/w_{f,t} = \delta/w$). This yields:

$$\frac{1}{\sigma}\hat{R}^n_t = \mathbb{E}_t\hat{w}_{f,t+1} - \hat{w}_{f,t} - \frac{1}{\sigma}\Theta_u\mathbb{E}_t\hat{\phi}_{t+1} - \frac{1}{\sigma}\Theta_{stw}\mathbb{E}_t\hat{\chi}_{t+1} + \beta R\chi(1-\phi^x)(\mathbb{E}_t\hat{w}_{stw,t+1} - \mathbb{E}_t\hat{w}_{f,t+1}), \tag{46}$$

where $\Theta_u = \beta R\phi\left[(\frac{\delta}{w})^{-\sigma} - 1\right] \geq 0$, and $\Theta_{stw} = \beta R\chi(1-\phi^x)\left[(\frac{w_{stw}}{w_f})^{-\sigma} - 1\right] \geq 0$. This equation is equivalent to the loglinear Euler equation without STW in Equation (45)

[17] In Section 4.5, we will investigate the robustness of our results with respect to these parameters.

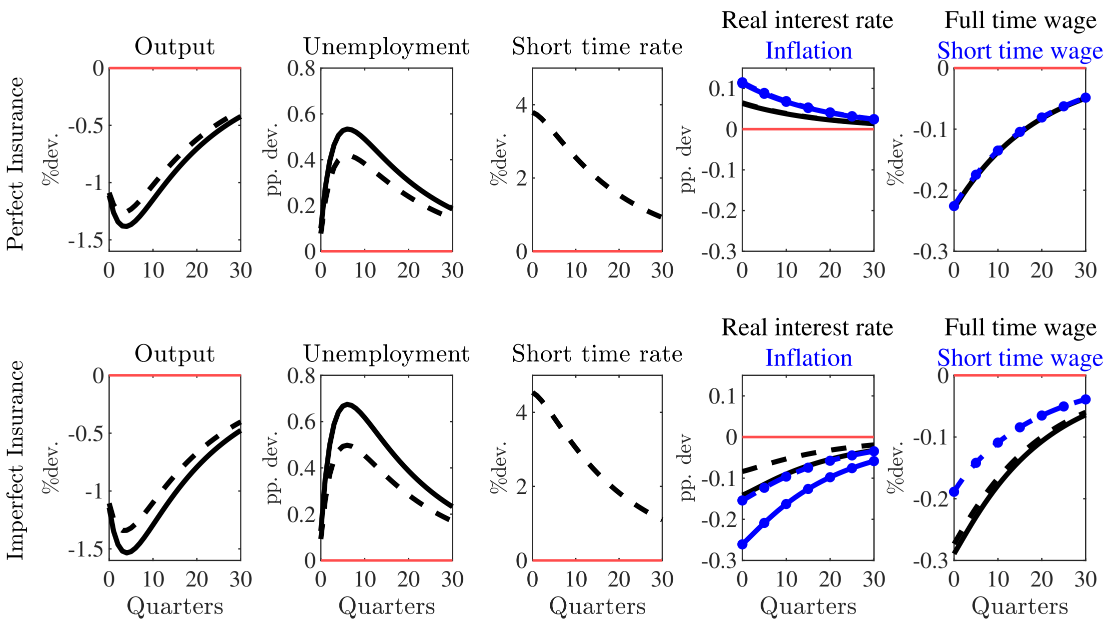

Figure 5: Impulse responses to a negative one percent shock to productivity with autocorrelation 0.95. First and second row show IRFs under perfect and imperfect insurance. Dashed lines indicate IRFs when firms can use STW, solid lines indicate IRFs when firms have no such option.

except for the latter two terms. In addition to the possibility of unemployment, there is now also the (fluctuating) risk of becoming a worker on STW in the next period ($\hat{\chi}_{t+1}$). As for the term associated with unemployment risk ($\hat{\phi}_{t+1}$), short-time risk negatively affects the natural interest rate due to precautionary savings, because of the expected loss of income. However, $\Theta_{stw} < \Theta_u$, so any increase in the expected short-time rate induces less desire for precautionary savings compared to increases in the expected unemployment rate. The last term captures the expected change in income of a full-time worker relative to a worker on STW. The wage of a worker on STW also depends on the hours reduction. The sign of the last term is unclear a priori and depends on the calibration. If, following a recession, the expected wage in STW falls by less than the wage in full-time ($\mathbb{E}_t\hat{w}_{stw,t+1} - \mathbb{E}_t\hat{w}_{f,t+1} > 0$), then the term enters positively. In a sense, becoming short-time employed would provide some insurance against income fluctuations and would positively affect desired demand for consumption goods, driving up the natural interest rate.

To test whether the above intuition holds numerically, we compare in Figure 5 an economy with and without STW, respectively under the assumption of perfect insurance and imperfect insurance. First, we discuss the case of perfect insurance as displayed in row 1 to clarify the stabilizing role of STW through its effect on firm's firing decision (the firm channel). The effects of STW are similar to the ones described by Balleer et al. (2016). 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, some firms choose to place workers on STW (dashed line, consider the increase in the short-time rate as shown in the third column of Figure 5), 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.[18] In addition, because firms have the STW option also in the future, they will also reduce hiring by less. Naturally, this leads to a smaller increase in unemployment and a smaller drop in output with STW. Unemployment fluctuations are reduced by 21 percent (see also Table 3). This number is similar to what Balleer et al. (2016) find. Output fluctuations are reduced by less, because firms use the option of STW to reduce the hours worked of workers with lower match quality.

In contrast to that, consider the differential response of inflation and the nominal interest rate between the model with and without STW in the economy with imperfect insurance. 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%[19]), this is preferred, and the precautionary savings motive is weaker. Consequently there is a smaller contraction in desired demand, reflected in a more moderate 16 basis points drop in inflation compared to a 27 basis points drop in the model without STW.[20] The central bank responds by cutting the nominal interest rate, more so in the economy without STW. Section 4.4 will discuss how the results change when monetary policy is constrained. 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 imperfect insurance case (row 2) leads to additional unemployment and output stabilization of STW on top of the mere firm channel that is active with perfect insurance (row 1). In 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 as well 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 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 3, column 1 to 3. The table displays the business cycle volatility of output and unemployment across the different models. STW reduces unemployment fluctuations by roughly 26% in a model with imperfect insurance (compared to 21% in the case with perfect insurance). This implies that a shock that would imply an increase of the unemployment rate by 3 percentage points with STW stabilization would increase unemployment by 4 percentage points without STW. Out of the total stabilization of 1 percentage point, 0.2 percentage points would be due to the reduction of precautionary savings. Given that the STW response differs across the two models, in an attempt to isolate the risk channel from the firm channel, we normalize the unemployment stabilization by the standard deviation

[18]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.

[19]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 8 in the Appendix.

[20]In line with that consumption falls by less in the model with STW. Because of zero net supply of bonds and the no borrowing constraint, consumption is equal to the wage as shown in Figure 5.

of the STW rate relative to output (see the third row of Table 3). Even when isolating the risk channel in this way, the stabilization remains larger when taking precautionary savings into account. Note, however, that the fiscal cost of STW rise less than proportionally with the number of workers affected because the hours reduction falls in a recession when the short-time workers are on average more productive.

4.2.2 Calibration with higher labor market risk

So far, we have performed our analysis based on a calibration targeting the German labor market. To illustrate how this drives the results, we now run the same analysis with a calibration where labor market flows are considerably larger, and firing costs are lower.[21]

We increase the separation rate in steady state to 0.05, and target a vacancy filling rate of 0.7 and a job finding rate of 0.8 (as in Challe, 2020). Additionally, the firing costs are reduced to half the value of the German calibration (1.2). Matching these new steady state targets and the new value for the firing costs requires a higher efficiency of the matching function, lower vacancy posting costs and a lower value for the scale parameter of the profitability distribution. In this labor market, STW is relatively less attractive for firms, because firing and rehiring a worker is relatively cheaper compared to the German calibration. This implies that in order to achieve the same steady state level of STW, the cost parameter c_k needs to be lower. The targeted steady state values and parameters of the high flows calibration are summarized in Table 6 in the appendix. Figure 11 in the appendix shows the impulse responses to a negative productivity shock for the high flows calibration.

With higher labor market risk, we observe four main differences: (i) The volatility is higher overall and the response of the labor market variables is less sluggish; (ii) the stabilizing effect of STW via the firm channel is less strong even though the short-time rate responds more, visible from the smaller gap between the dashed and solid lines for output and unemployment for the high flows calibration compared to the German calibration (compare row 1 of Figures 11 and 5); (iii) the precautionary savings channel is stronger because of the higher unemployment risk (compare the difference in the peak response of unemployment in the model without STW (solid line) between row 1 and 2); (iv) the stabilization potential of STW given imperfect insurance, is more powerful (notice how the gap between the dashed and solid lines increases when comparing row 1 and 2).

The results are again quantified in Table 3. Column 1 to 3 are based on the German calibration, column 4 to 6 are based on the high flows calibration. Column 1 and 4 are based on the model without STW and show the strength of the precautionary savings mechanism by comparing the cases with perfect and imperfect insurance. For instance, compare the value for unemployment for the German calibration (-26.65) in column 1 to the value for the US calibration (-64.39) in column 4. This documents that the precautionary savings motive and the associated deepening of recessions is more of a concern in labor markets with large flow rates. The intuition follows from the linearized Euler equation in the model without STW (Equation 45). Fluctuations in the natural interest rate under flexible prices, and in the real interest rate, inflation, and marginal costs under sticky prices, are generally higher when the separation probability is higher.

[21] See for example Blanchard and Galí (2010) for a similar calibration exercise.

Difference of standard dev. in %	Low labor market risk			High labor market risk		
	No STW Perfect vs Imperfect ins.	STW vs no STW Perfect ins.	STW vs no STW Imperfect ins.	No STW Perfect vs Imperfect ins.	STW vs no STW Perfect ins.	STW vs no STW Imperfect ins.
	(1)	(2)	(3)	(4)	(5)	(6)
output	-8.65	-6.83	-9.95	-22.07	-4.86	-10.24
unemployment	-26.65	-21.19	-25.89	-64.39	-14.15	-21.91
unemployment (normalized)		-7.01	-7.54		-4.09	-4.86

Table 3: Difference of standard deviation conditional on productivity shock across different models in percent. For comparability reasons, we follow Balleer et al. (2016) and 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. The normalized standard deviation of unemployment is obtained by dividing by the standard deviation of the STW rate relative to output.

The potential for STW in stabilizing output and unemployment and the role of the firm channel vs the precautionary savings channel are displayed in columns 2-3 and 5-6. The columns with perfect insurance (2 and 5) isolate the firm channel, the columns with imperfect insurance (3 and 6) incorporate the additional stabilization that STW has by dampening precautionary savings. Both columns show how much lower the volatility of unemployment and output are when firms have the option of STW compared to the model without STW. Comparing the German calibration and the high flows calibration, it is clear that the STW stabilization is greater in the Germany case in general. This is the case because the firm channel is more powerful for the former calibration, due to the higher firing costs and lower labor market flows, which makes adjustments via the extensive margin more costly, and conversely, the option of STW more attractive and cheaper. This finding has already been documented Balleer et al. (2016).

However, one can see that with imperfect insurance (column 3 and 6), the stabilization values for the high flows calibration get closer to the German case. Again, the unemployment stabilization potential of STW is larger for the German calibration (-25.89 vs -21.91), but the additional stabilization that comes from the precautionary savings channel (-25.89 vs -21.19, i.e., 22%) is less substantial when compared to the high flows calibration (-21.91 vs -14.15, i.e., 55%). This shows that STW has the potential to stabilize the business cycle even in countries with more flexible labor markets, where STW is less effective through the firm channel. Then STW is effective through its effect on precautionary savings and therefore on households' consumption demand.

Lastly, it should be mentioned that the additional unemployment stabilization is again also a result of a higher STW volatility, because the firm channel and the risk channel are complementary. When investigating the normalized unemployment stabilization measure in the third row of Table 3 the above intuition holds: normalized unemployment stabilization is generally higher for Germany, but it is improved by relatively more for the high flows calibration when the precautionary savings mechanism is active, i.e., with imperfect insurance.

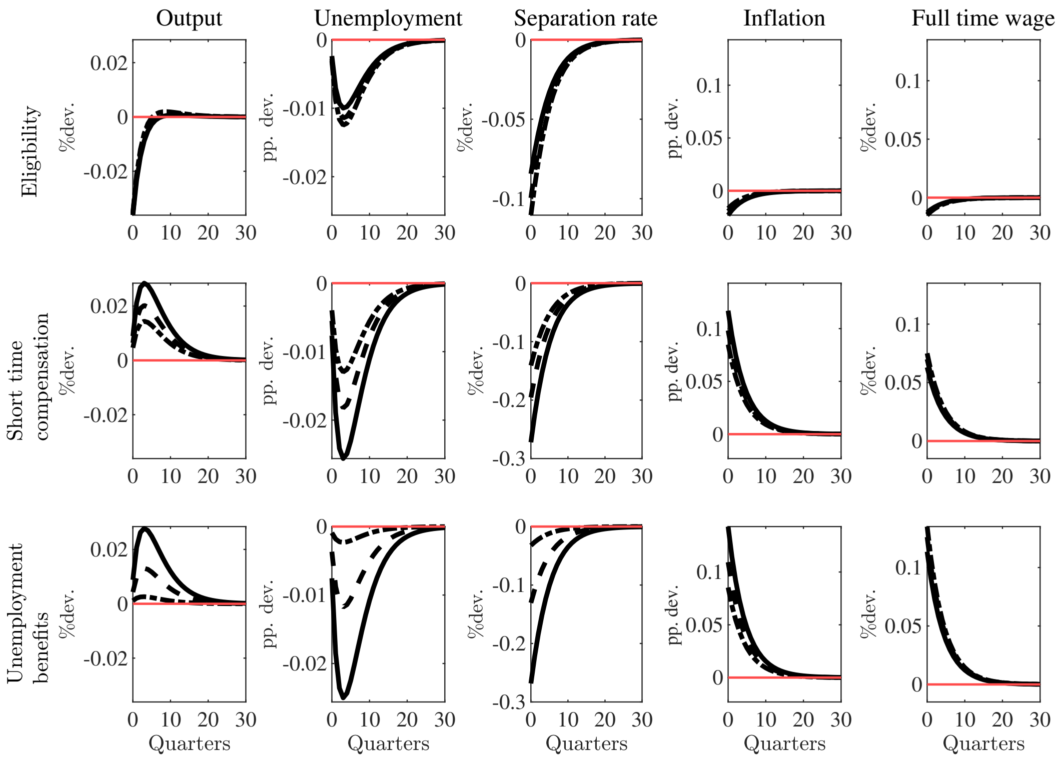

Figure 6: Model response to discretionary changes in fiscal policy under imperfect insurance for different degrees of wage rigidity. Solid lines indicate baseline case ($d \ln w / d \ln a = 0.3$), dashed lines ($d \ln w / d \ln a = 0.4$), dashed and dotted lines ($d \ln w / d \ln a = 0.5$). Autocorrelation of the shocks is equal to 0.8.

4.3 Discretionary changes to short-time work policy

In this section, we analyze the impact of discretionary changes to STW policy. For example, in the Covid-19-recession the German and the Austrian government increased the STW compensation and loosened the eligibility criteria for STW.[22] We analyze the baseline case, i.e., the German calibration. As discussed above, this is a more conservative way to quantify the impact of the precautionary savings channel compared to the calibration with higher labor market risk.

Figure 6 and Table 4 summarize the effects of three different discretionary measures: 1. Loosening the eligibility criterion of STW, 2. increasing the short-time work compensation, 3. and as a comparison, increasing unemployment benefits.[23]

In Figure 6, all shocks are normalized so that the change in government spending on impact is equal to 0.025% of GDP.[24] The coefficient of autocorrelation of all discretionary

[22] See e.g., Schnetzer et al. (2020) for Austria and `https://www.bundesregierung.de/breg-en/news/short-term-work-1787608` for Germany.

[23] We just show the imperfect insurance case, because the perfect insurance case would be an implausible counterfactual for measures that change incomes in different states. To maintain perfect insurance, the incomes of full-time, part-time and unemployed workers have to be the same. But the STW benefit shock directly increases the expected income for short-time workers, and less so the other incomes.

[24] The fraction of GDP is so small because STW workers make up only 0.7% of all workers in steady state. A more expensive fiscal package in the case of the increase of short-time wage compensation would require for example that short-time wages increase above full-time wages, which would not be consistent with our assumption that full-time workers price the bond.

shocks is equal to 0.8. The lines indicate different degrees of wage rigidity, in the range of available estimates.[25] Table 4 displays 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:

$$m_G^k = \frac{\sum_{t=0}^{k} \beta^t (u_t - u)}{\sum_{t=0}^{k} \beta^t (G_t - G)/Y}. \tag{47}$$

To compute the output multiplier, the numerator is replaced with the relative change in output.[26]

Loosening the eligibility criterion Row 1 of Figure 6 displays the impulse responses of a shock to the eligibility criterion ζ_t, that is set by the government to determine the ease at which firms can place workers on STW. For instance, existing rules for applying for STW may be interpreted less stringent by the agency in recessions. A positive shock to the eligibility criterion ζ_t moves the STW threshold v^k to the left according to Equation (6) and increases the STW rate χ.

As the STW threshold shifts, the STW rate increases drastically (not shown), but the separation rate only declines slightly. Firms anticipate that they will be able to use STW more easily in case of negative idiosyncratic profitability shocks. Because the shock is persistent, this also increases the value of a job J_t, vacancy posting and reduces firings. Unemployment falls, but output decreases as well on impact, and increases only slightly above steady state after ten periods. The decrease in output is the result of reduced hours worked by short-time workers. The effect of the eligibility shock on risk perceptions of imperfectly insured full-time workers are again most visible in the behavior of the real interest rate and inflation. Because the short-time wage is lower than the full-time wage, the perceived income risk of imperfectly insured full-time workers increases in response to a persistent rise in the short- time rate. Although the separation rate falls as well (decreasing the unemployment risk), it is much smaller in magnitude than the rise in the short-time rate. Overall, income risk increases. As a result, full-time workers lower their consumption demand and inflation and the real interest rate fall strongly. In line with the fall in inflation and therefore real marginal costs, real wages, as an important component of marginal costs, fall as well. In sum, the drop in consumption demand makes the loosening of the eligibility criterion less effective in terms of unemployment and output stabilization under imperfect insurance compared to the perfect insurance case (not shown). The different values for wage rigidity affect the results only slightly.

Increasing the short-time work compensation Row 2 of Figure 6 displays the impulse responses of a shock τ_t to the compensation paid for the reduced hours of workers on STW. Before, the compensation was equal to the replacement rate δ_t, now it

[25] See Gertler and Trigari (2009) or Blanchard and Galí (2010)

[26] The total amounts of short-time 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. In order 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). For the eligibility shock, the increase in spending is purely endogenous and reverts back to steady state monotonically, so we divide by those endogenous expenditures.

is potentially larger.[27] This shock affects the equation for the average short-time wage:

$$w_s^t = \int_{v_t^k}^{v_t^f} \frac{(1 - K(\epsilon_t))w_t + (1 + \tau_t)\delta K(\epsilon_t)}{\chi_t} g(\epsilon_t) d\epsilon_t \tag{48}$$

The additional benefits are financed by an equal increase in taxes to entrepreneurs. As a reference point, consider a representative agent model. Then, an increase of short-time compensation that is financed by lump-sum taxation to firms would have no aggregate effects, because the firms are owned by the representative agent.

The shock to the short-time wage affects the model economy through its impact on the full-time workers' Euler equation (46). A persistent shock to the STW compensation increases the expected short-time wage in the last term in Equation (46). This serves as an insurance for full-time workers, accordingly they increase their consumption demand.[28] This creates upward pressures on inflation and the real interest rate when monetary policy is aggressive. Higher inflation translates into rising marginal costs of production and higher intermediate goods prices. This increases the expected the value of the job J for intermediate goods firms and incentivizes less firing and more hiring. As a result, the expected income risk of full-time workers is reduced further and leads to even more desired consumption demand. The outcome is a persistent rise of output and less unemployment. However, the increase in the real interest makes saving more attractive, which counteracts the initial increase in desired demand, dampening the expansion. This changes when monetary policy is constrained by the ZLB, as section 4.4 will show. The responses of output and unemployment appear quantitatively small. As discussed previously, this is because the fiscal package represents a very small fraction of output in steady state, because short-time workers only make up 0.7% of employment.[29] Compared to the eligibility shock, the degree of wage rigidity plays a larger role for the impact of the increase in short-time compensation. In particular, the impact of the shock is falling when wages are more flexible. Then, the intertemporal substitution channel becomes more important, as explained in Section 4.1. A strong increase in wages and therefore consumption on impact creates desire to postpone consumption into the future. Additionally, strongly rising full-time wages depress intermediate goods firms' profits persistently, and discourage vacancy posting.

Increasing unemployment benefits Row 3 of Figure 6 displays the model response to an increase in unemployment benefits to newly unemployed workers.[30] Conceptually,

[27] Naturally, for this exercise, we drop the assumption that the replacement rate is always fixed to the same fraction of the wage.

[28] An alternative and viable interpretation would be to say, that full-time workers engage in expansionary intertemporal substitution or consumption smoothing. Future expected consumption is higher, therefore desired consumption today increases accordingly, leading to inflationary pressures.

[29] Fiscal multipliers can be sizable as Table 4 and a subsequent discussion shows.

[30] We make this assumption so that the comparison to an increase in short-time compensation is "fair" and conservative. Increases in unemployed benefits to workers that have been employed for longer than one period would not matter for full-time workers risk perception, but they would represent a lot of additional fiscal expenditure. In other words, they would not increase the numerator in 47 but increase the denominator, biasing the fiscal multiplier downwards. This is an artifact of the zero-liquidity assumption jointly with the fact that STW duration is shorter than unemployment duration. If one looks beyond the risk channel in a model with positive savings, the long-term unemployed would be the most likely to be borrowing constrained, so transfers to those agents would potentially be most effective in boosting demand.

Horizon	Eligibility: Unemployment (1)	Eligibility: Output (2)	Short-time compensation: Unemployment (3)	Short-time compensation: Output (4)	Unemployment benefits: Unemployment (5)	Unemployment benefits: Output (6)
	Wage rigidity $d\ln w/d\ln a = 0.3$					
5	-0.45	-1.05	-1.18	1.32	-1.16	1.29
10	-0.64	-0.84	-1.67	1.85	-1.62	1.80
Long run	-0.74	-0.73	-1.91	2.13	-1.87	2.08
	Wage rigidity $d\ln w/d\ln a = 0.4$					
5	-0.52	-0.98	-0.84	0.94	-0.55	0.61
10	-0.73	-0.74	-1.18	1.31	-0.76	0.85
Long run	-0.85	-0.61	-1.36	1.51	-0.88	0.98
	Wage rigidity $d\ln w/d\ln a = 0.5$					
5	-0.56	-0.93	-0.60	0.67	-0.11	0.13
10	-0.80	-0.67	-0.84	0.94	-0.15	0.17
Long run	-0.93	-0.52	-0.97	1.07	-0.17	0.19

Table 4: 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.

the shock is fairly similar to the increase in short-time compensation, in the sense that both shocks directly affect the full-time workers' Euler equation (46), thereby stimulating desired consumption demand, resulting in higher inflation and real interest rates. However, there are two major differences. On the one hand, due to risk aversion, moving the income in the worst state (unemployment) and the best state (full-time employment) closer together reduces risk more compared to narrowing the income gap between STW and full-time employment. This makes an increase in unemployment benefits more effective relative to an increase in short-time compensation. On the other hand, a wage channel works in the opposite direction. An increase in unemployment benefits results in direct upward pressure on real full-time wages (see Equation 19), which discourages vacancy posting and triggers intertemporal substitution, as mentioned above. In contrast, an increase in short-time wages does not directly affect the bargained wage. This makes an increase in unemployment benefits relatively less effective, the more flexible the wage response. Generally, when real wages are rigid, the rise in consumption demand through the precautionary savings motive is enough to outweigh any dampening effect on profit and on demand via intertemporal substitution. Figure 6 shows that the effects of an increase in short-time compensation and unemployment benefits are similar for the baseline calibration. However, with more flexible wages (a smaller value of γ_w), the unemployment extension becomes less and less effective and the gap between the two policies widens.

Fiscal multipliers and discussion Table 4 compares fiscal multipliers for unemployment and output between the different fiscal measures. In the baseline calibration, both the increase in short-time compensation and the increase in unemployment benefits yield sizable multipliers. A one percent of GDP increase in spending decreases unemployment by roughly 1.9 percentage points in the long run in both cases, output rises by more then 2 percent. The shock to the eligibility criterion is considerably less effective. The latter finding is consistent with the results by Balleer et al. (2016), but we find that eligibility shocks are even less effective when taking precautionary savings into account. Output multipliers are even negative because of a strong reduction in hours worked, confirming the impression from Figure 6. With more flexible wages, the relative effectiveness of polices changes drastically. Consider the scenario with more flexible wages ($d \ln w / d \ln a = 0.5$). Compared to the baseline case, the multipliers of the eligibility shock increases very slightly, the multipliers for short-time compensation are cut in half, and the increase in unemployment benefits remains only barely expansionary. In sum, an increase in unemployment benefits becomes relatively less and less effective compared to the other two policies, when wages are allowed to adjust flexibly to an increase in the outside option. In contrast, an increase of unemployment benefits becomes more effective if we calibrate the model to a high risk economy as in Section 4.2.2 (see also Table 7 in the Appendix for the multipliers). With a higher separation risk, reducing the income risk of the unemployment state stabilizes demand by more.

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.[31] 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 (2020) and Kekre (2021) 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 and, hence, boosts their consumption demand. In reality, two additional channels may play a role that are absent from our model (see e.g., Kekre, 2021). On the one hand, the redistribution across agents with differing marginal propensities to consume, i.e, from wealthy to poor households, would make an extension of unemployment benefits relatively more effective if unemployed workers have a higher marginal propensity to consume compared to short-time workers. On the other hand, higher benefits discourage search effort. Given that employment prospects are worse for the unemployed compared to workers affected by STW, a reduction of search effort is more problematic for the former and may render the extension of the STW compensation relatively more effective. Hence, in sum, we argue that our model provides reasonable conditions under which an increase in STW compensation is more effective in stabilizing demand compared to unemployment benefits.[32]

[31] 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.

[32] Lastly, it is known that in zero-liquidity models, any discretionary increase in future income translates one to one to increase in expected future consumption, whereas in reality, some of that future income is saved. Since current desired consumption rises accordingly, this may bias our demand effects somewhat upwards. However, this bias affects both the increase in short-time compensation and unemployment benefits and does not affect the comparison.

4.4 Analysis at the zero lower bound

We now consider the effects STW and precautionary savings when monetary policy is constrained at the ZLB. We assume that the ZLB is binding in period $t = 0$ when the shock occurs. We follow Christiano et al. (2016) and consider a case where the nominal interest rate is simply fixed at its steady state value for 8 quarters. After the ZLB period ends, monetary policy follows the Taylor rule again. The top row of Figure 7 compares the unemployment response in an economy with STW and without STW to a negative productivity shock for the German calibration. In the economy without STW (solid line), unemployment rises by more at the ZLB. Because of the rising unemployment risk, full-time workers reduce their consumption demand, increase their precautionary savings and inflation falls. If monetary policy is constrained and cannot cut the nominal interest rate, the real interest rate rises. Then, there is no countervailing effect from monetary policy that stimulates demand. In contrast, demand falls even more. The deflationary spiral is more severe at the ZLB.

In the economy with STW (dashed lines) unemployment risk rises by less and the motive for precautionary savings is weaker. Hence, the ZLB constraint on the monetary policy response is less severe here (the dashed line in the top right panel is only slightly above the dashed line in the top left panel). Because STW also stabilizes precautionary savings, the policy is able to partly replace the missing monetary policy response here. This also implies that the stabilization potential of STW is considerably larger at the ZLB (the difference between the solid and the dashed line in the top right panel is larger than the difference in the top left panel). Whereas unemployment rises at the peak by 0.9 percentage points at the ZLB, with STW stabilization, it would only rise by roughly 0.6 percentage points. In an analysis without precautionary savings, the negative productivity shock would be inflationary instead of deflationary and the ZLB would be almost irrelevant for the stabilization potential of STW because inflation behaves similarly in the model with STW and the one without STW (see Figure 8). Hence, such an analysis would overlook the additional stabilization potential from the policy.

Now consider an expansionary shock to short-time compensation in the bottom row of Figure 7. Unemployment falls by considerably more at the ZLB (bottom right panel) compared to normal times (bottom left panel). The increase in short-time wage compensation, as an expansionary fiscal policy, has an inflationary impact. The monetary authority reacts by raising the nominal interest rate, causing the real rate to rise if monetary policy is aggressive. This discourages consumption. When monetary policy is constrained and inactive, the real interest rate falls instead. This boosts consumption, discourages precautionary savings, and makes the policy change even more effective at the ZLB. In sum, at the ZLB, rule-based and discretionary STW policy that targets the STW compensation becomes more effective because the precautionary savings mechanism is reinforced.[33] This finding is in line with the empirical results by Gehrke and Hochmuth (2021) who document that STW policy is the most effective in recessions. They find the highest multiplier of the policy in the Great Recession, i.e., a period when monetary policy was constrained at the ZLB. In line with out findings, Kekre (2021) also documents that an increase in unemployment benefits is more effective at the ZLB.

[33] In contrast, a shock to the eligibility criterion would be less effective at the ZLB, because the precautionary savings mechanism works in the opposing direction.

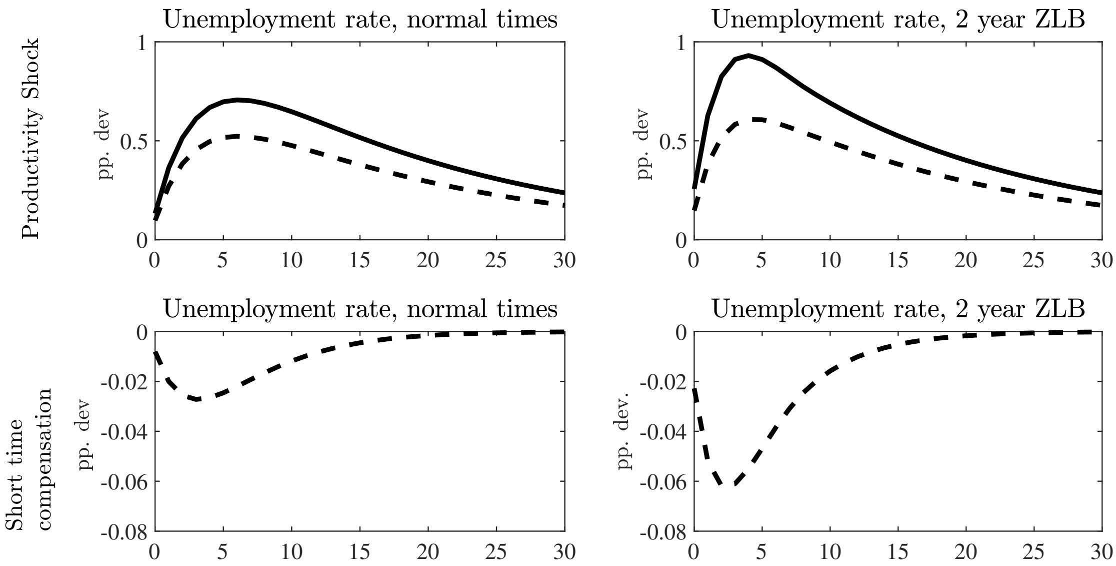

Figure 7: Short-time work in normal times (left column) and at the ZLB (binding for 8 quarters, right column). The top row plots the model responses to a negative one percent productivity shock. Solid lines are model responses without STW, dashed lines are model responses with STW. The bottom row plots the model responses when increasing the short-time compensation by ten percent.

	Baseline	Replacement rate δ/w		Wage rigidity $d\ln w/d\ln a$		Price rigidity Ψ		Taxation Distortionary	Taxation Workers
Increase in stabilization (%)		0.7	0.9	0	0.6	413	96		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Unemployment	22.2	46.9	8.13	33.79	12.69	49.54	9.66	23.49	21.93
Output	45.7	105.29	15.96	65.47	27.29	114.66	19.02	47.25	45.47

Table 5: This table documents the increase in stabilization of STW due to precautionary savings (in percent) in a comparison of the models with perfect and imperfect insurance for different parameter combinations compared to the baseline model.

4.5 Sensitivity Analysis

In this paper, we have shown that taking into account the precautionary savings channel that results from incomplete markets increases the potential for STW to stabilize the business cycle. The strength of this channel may vary depending on the choice of parameters. In particular, we have argued that the size of the assumed consumption drop upon unemployment and the degree of wage rigidity drive the cyclicality of income risk and are therefore relevant for the precautionary savings channel. We shall begin by changing those parameters. This is documented in Table 5 that displays the stabilization of unemployment and output due to precautionary savings in percent across the model with and without imperfect insurance. The baseline case in column 1 compares the stabilization of 25.89 and 21.19, i.e., 22.2 percent as documented in Table 3 for the German calibration.

Consumption drop upon unemployment In our baseline calibration, we set $\delta/w = 0.8$, implying a consumption drop upon unemployment of 20% , in line with the empirical estimates of Chodorow-Reich and Karabarbounis (2016) for the US. There are no available estimates of this parameter for Germany, still we think it appropriate to use this value (see also the evidence in Table 1 that suggests that a large share of unemployed workers experiences a significant loss of income). One the one hand, the unemployment benefits system is more generous in Germany compared to the US. On the other hand, borrowing to finance consumption is less common. However, alternative empirical estimates exist. For example, Kolsrud et al. (2018), using Swedish data, find that expenditures drop on average only around 9%. Therefore, column 3 in Table 5 shows what happens to the strength of the precautionary savings channel when we set $\delta/w = 0.9$. Taking precautionary savings into account increases unemployment stabilization of STW in response to productivity shocks by roughly 8% and output stabilization by 16%. This is still a significant difference in volatility compared to the baseline case, but it is clearly reduced. As we have shown in Table 3, the firm channel is overall more important than the precautionary savings channel for the German calibration, because adjustments along the extensive margin are costly in this institutional framework. So, income risk is relatively low in the first place, because the likelihood to become unemployed fluctuates less compared to the literature analysing the US labor market. Additionally, STW lowers income risk relatively more the lower the replacement rate, since the short-time wage is a weighted average of the full-time wage and the replacement rate (the weight on the former being around 70% in steady state). The lower the replacement rate, the larger is the relative income gain from STW compared to unemployment. If we set $\delta/w = 0.7$ instead, a value close to the replacement rate in Germany (0.67), we see that the stabilization due to precautionary savings increases by a lot (column 2).

Different levels of wage rigidity Column 4 and 5 of Table 5 show the importance of precautionary savings for different levels of wage rigidity. As mentioned in section 4.1, more flexible wages strengthen the desire for intertemporal substitution and weaken the precautionary savings channel. By contrast, when wages are perfectly rigid ($d \ln w/a = 0$), the intertemporal substitution effect is turned off completely. In that case , the stabilization potential of the risk channel is greatly increased. When wages are twice as flexible as in the baseline case ($d \ln w/d \ln a = 0.6$), it is reduced but remains substantial.

Different levels of price rigidity With fully flexible prices, fluctuations in aggregate demand would play no role in shaping aggregate employment dynamics in this model and the precautionary savings mechanism would therefore be relevant for the determination of the natural interest rate, but not for output. Consequently, when we lower the price rigidity compared to our baseline case to a value consistent with a Calvo parameter of 0.8 ($\Psi = 96$), the importance of the precautionary savings mechanism is reduced as well, and the opposite result is obtained when prices are more rigid.

Different financing So far we have assumed that all expenditures for STW are financed via flat taxes to entrepreneurs. Now we test the robustness of our results to alternative ways of financing. In column 8 of Table 5, we assume that additional expenses due to the cyclical variation in STW are financed by an immediate increase in distortionary proportional income tax levied on workers, as in Balleer et al. (2016).[34] The results are very close to the baseline model.

As discussed above, the cyclicality of income risk may in theory also be affected by the cyclicality of transfers. We have abstracted from that channel so far, but now we assume that STW expenditures are financed by flat taxes to full-time workers instead of entrepreneurs. Again, as shown in column 9 the baseline results remain robust. Generally, the minor importance of the financing channel of STW is due to the relatively low costs of STW.

5 Conclusions

This paper is the first to investigate the effects of STW over the business cycle, while allowing for aggregate demand effects via precautionary savings. We document that precautionary savings matter for the effectiveness of STW. In particular, the rule-based component of STW becomes more effective as STW reduces the income risk for full-time workers and their precautionary savings motive. The same is true for a discretionary increase of the STW compensation. In contrast, a loosening of the eligibility criterion is less effective in terms of stabilizing the labor market as it increases the labor market risk. At the ZLB, the precautionary savings mechanism is reinforced by even more. These results challenge the common narrative that STW is less effective in a high flows economy with flexible labor markets. In fact, if the precautionary savings mechanism is strong enough and labor market risk is high because of high labor market volatility, the stabilization potential of STW can be large also with flexible labor markets. This paper focuses on precautionary savings due to labor market risk. In times when a large share of workers is affected by STW as it is the case in the current situation additional demand stabilization may emerge from the redistribution of income from wealthy to poor households with differing marginal propensities to consume. We leave an analysis of STW and this redistribution channel for future research. Finally, the demand channel through labor market risk that we discuss in this paper matters most in crisis times when risk is high. If STW is applied for a long time period, it may trigger biases and inefficiencies. For example, STW may hinder the reallocation of labor to growing and productive firms or it may lead to excessive hours reductions. As a result, STW is a well-suited policy for temporary crisis situations, but should never be a long-run phenomenon.

[34] The bargained wage therefore changes to $w_t^f = \gamma a_t + (1-\gamma)\delta_t/(1-\tau_t)$.

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A Additional figures and tables

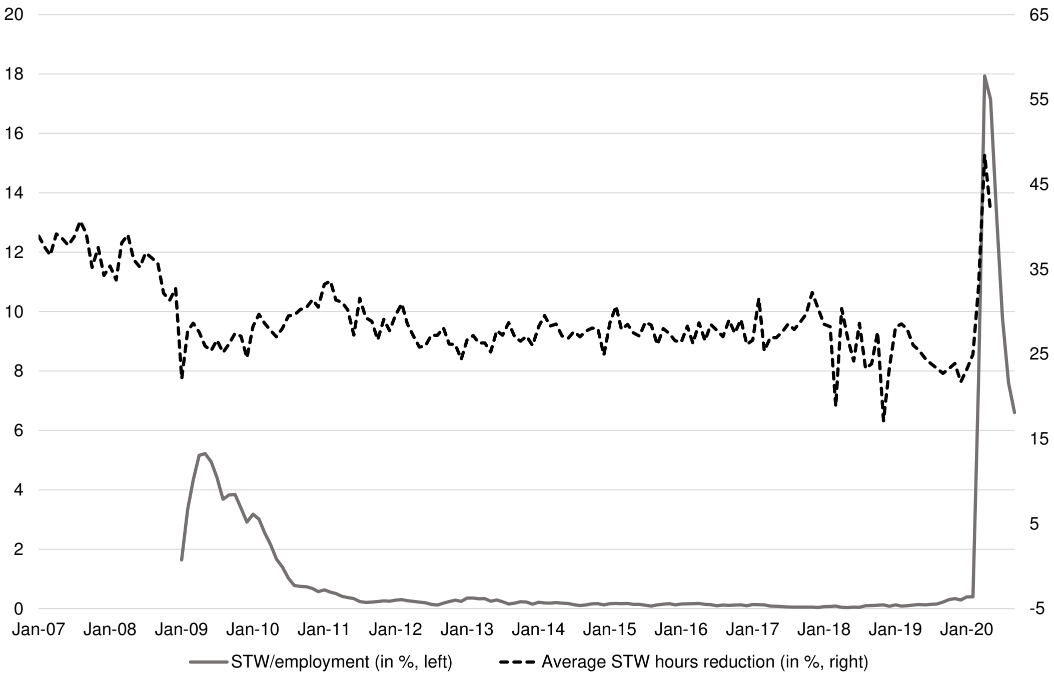

Figure 8: STW as a percentage of total employment (left axis) and average hours reduction in Germany (right axis). Source: Federal Employment Agency.

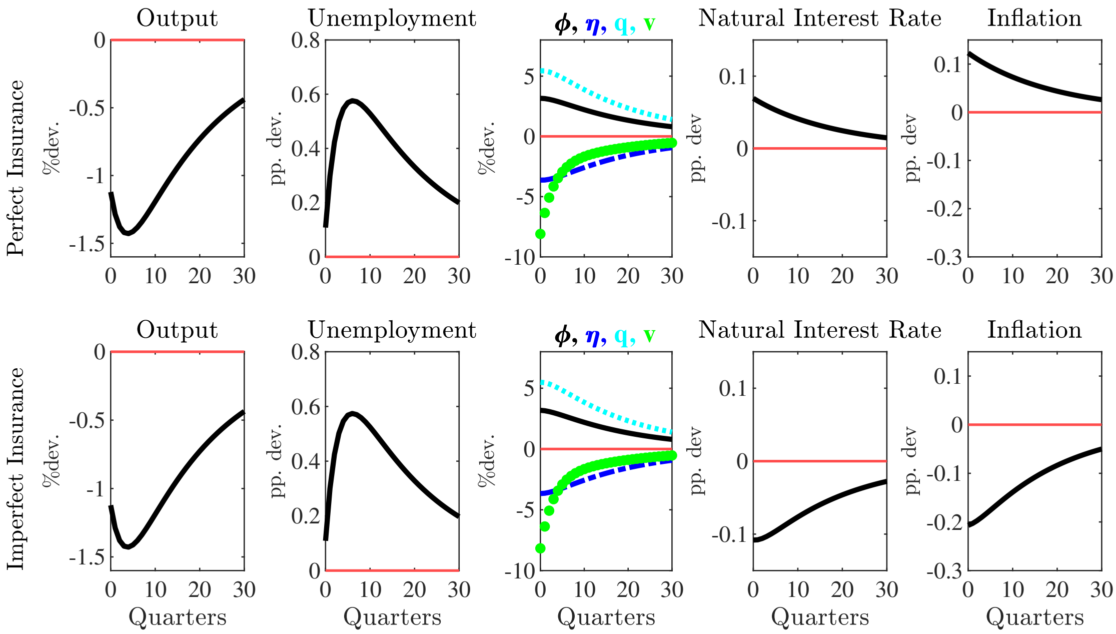

Figure 9: Impulse responses to a negative one percent shock to productivity with autocorrelation 0.95 for the German calibration with flexible prices. First and second row show IRFs under perfect and imperfect insurance, in the model without STW. There is no apparent difference between perfect and imperfect insurance because the consumption-savings decision of full-time workers does not affect real variables.

	ϕ	q	η	μ	f	s	κ	c_k	$p^z a - w$
German	0.03	0.7	0.31	0.43	2.4	0.85	0.69	16.49	0.025
US	0.05	0.7	0.81	0.76	1.2	0.51	0.48	11.87	0.025

Table 6: German calibration vs high flows calibration

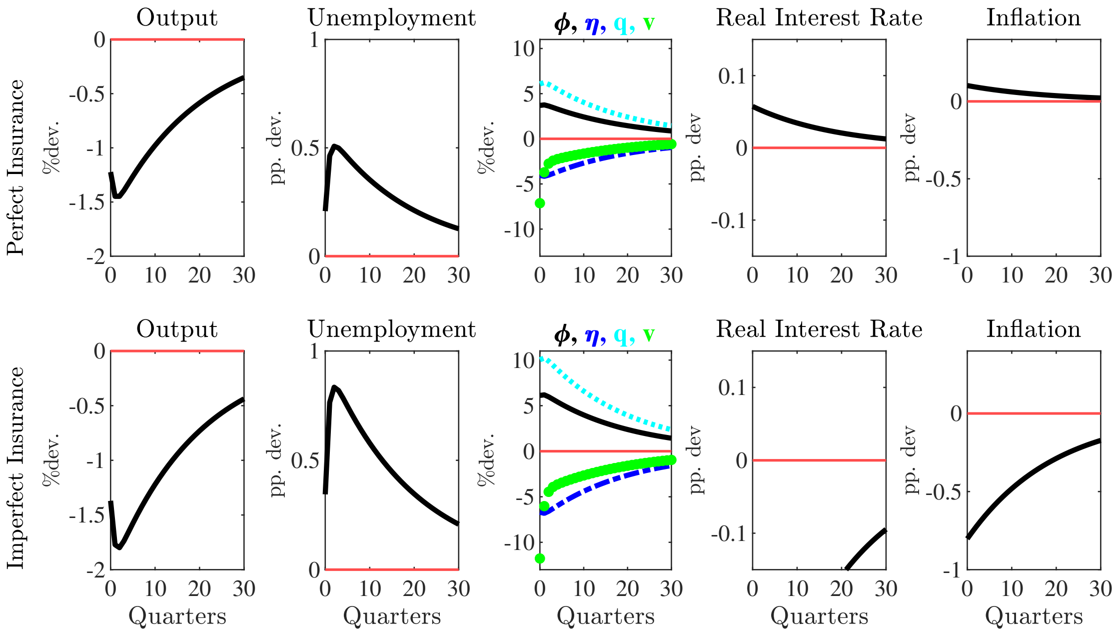

Figure 10: Impulse responses to a negative one percent shock to productivity with autocorrelation 0.95 for the US calibration. First and second row show IRFs under perfect and imperfect insurance, in the model without STW. Prices are sticky.

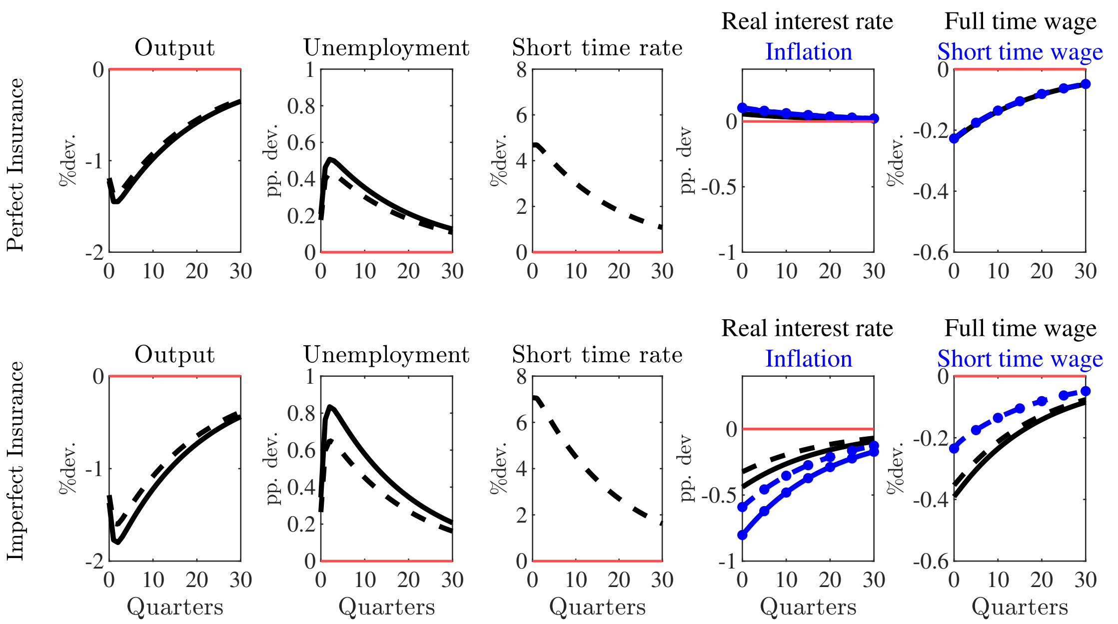

Figure 11: Impulse responses to a one percent negative shock to productivity with autocorrelation 0.95 for a high flows calibration. First and second row show IRFs under imperfect and perfect insurance. Dashed lines indicate IRFs when firms can use STW, solid lines show IRFs when firms have no such option.

	Eligibility		Short-time compensation		Unemployment benefits	
	Unemployment	Output	Unemployment	Output	Unemployment	Output
Horizon	(1)	(2)	(3)	(4)	(5)	(6)
	Wage rigidity $d \ln w / d \ln a = 0.3$					
5	-0.11	-1.43	-1.78	1.92	-2.21	2.38
10	-0.12	-1.42	-1.93	2.08	-2.4	2.58
Long run	-0.13	-1.41	-1.98	2.13	-2.45	2.64
	Wage rigidity $d \ln w / d \ln a = 0.4$					
5	-0.21	-1.32	-1.25	1.35	-1.31	1.41
10	-0.23	-1.3	-1.36	1.46	-1.41	1.52
Long run	-0.24	-1.29	-1.39	1.49	-1.45	1.56
	Wage rigidity $d \ln w / d \ln a = 0.5$					
5	-0.28	-1.24	-0.89	0.96	-0.70	0.75
10	-0.31	-1.21	-0.97	1.04	-0.75	0.81
Long run	-0.32	-1.21	-0.99	1.07	-0.77	0.83

Table 7: High flow calibration: 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.