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Short-Time Work and Precautionary Savings

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by

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Short-Time Work and Precautionary Savings

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Abstract

During the Covid-19 crisis, most OECD countries used short-time work (subsidized reductions in working hours) to preserve employment. This paper documents that short-time work affects the behavior of firms (supply) and households (demand). First, using household survey data from Germany, we show that the consumption risk of short-time work is lower than that of unemployment. Second, we construct a New Keynesian model with heterogeneous workers and firms, incomplete asset markets, and labor market frictions. Short-time work weakens workers' precautionary savings motive and lowers labor costs. This reduces the level and volatility of both the separation and unemployment rate at the cost of tying workers to less productive firms. Quantitatively, the positive employment effects dominate the productivity losses.

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

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

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1 Introduction

Most OECD countries used short-time work (STW henceforth) to secure jobs and stabilize the economy during the Covid-19 crisis and the Great Recession. In Germany, Europe's largest economy, almost every fifth employee was affected by STW in spring 2020. Even higher numbers were observed in Italy, Spain, France, Belgium, Austria and the UK (illustrated in Appendix Figure 11). Yet, knowledge of the dynamic effects of this labor market policy remains limited. On the one hand, major arguments in favor of STW are that it prevents layoffs by reducing firms' labor costs and that it stabilizes aggregate demand by lowering unemployment risk and encouraging consumption over precautionary savings. On the other hand, there is the risk that the policy ties workers to unproductive firms.

In this paper, we analyze these arguments formally. In comparison to the existing literature, we provide the first analysis of the demand effects of STW and their interaction with the supply side. We use a quantitative macroeconomic model with search frictions, heterogeneous workers and firms, and incomplete markets to establish three main results. First, we show that STW generates productivity losses, but these turn out to be moderate compared to the positive effects on employment. Employment is both higher on average and less volatile with STW in place. Second, the reduction of firms' labor costs is the dominant channel through which the policy operates in normal business cycles. However, the demand channel operating through precautionary savings becomes as important when monetary policy is constrained by the zero lower bound. Third, STW can be a strong business-cycle stabilizer, but its effectiveness depends on the implementation details.

This paper studies the case of Germany, where STW has a long tradition and excellent data is available. In the German system, a firm has to provide evidence of a significant and temporary shortfall in demand to the public employment agency to be eligible for STW.¹ The firm is then allowed to reduce workers' hours and pay proportionally. This makes it more attractive to retain workers until conditions improve, rather than laying them off. Workers receive a compensation of the net wage loss equal to the unemployment benefit replacement rate, paid out of the unemployment insurance fund. To understand why STW may stabilize demand, it is important to note that workers affected by STW are typically better off compared to unemployment. Unless hours worked are reduced to zero, which is rare, STW income exceeds unemployment benefits.² More importantly, the employment prospects of workers on STW are substantially better compared to those of the unemployed. Moreover, workers who are not currently on STW anticipate that they might be placed on STW in the future, instead of being laid off.

To analyze how STW interacts with demand and precautionary savings, we proceed in two steps. First, we provide empirical evidence from household survey data on consumption in and transitions between different employment states, including STW. Using data on Germany from the Bundesbank Household Online Panel, we show that STW spells are much less persistent compared to unemployment. Average consump-

¹In practice, the eligibility criteria are multidimensional and involve firm and worker characteristics (e.g., workers have to be covered by social security) and involvement of the social partners. See e.g., Hijzen and Martin (2013) for a detailed discussion and a comparison of the criteria in different countries.

²The feature that hours worked do not have to be reduced to zero differentiates STW from recalls and temporary layoffs as used in the US and from the British furlough scheme that applied only to jobs that were completely suspended. From March to May 2020, the average STW hours reduction in Germany was 41% (source: Federal Employment Agency, Germany).

tion is around a third lower during unemployment compared to employment, while we find only a moderate and mainly insignificant average consumption difference during STW spells compared to employment. This is direct evidence that short-time workers face less consumption risk at the microeconomic level. However, assessing the impact on precautionary savings and aggregate demand requires a structural macroeconomic model.

To this end, in a second step, we construct a New Keynesian DSGE model with search and matching frictions, endogenous separations and rigidities in prices and real wages. We add a STW policy and incomplete asset markets. Because of the search and matching frictions, firms retain temporarily unprofitable matches (labor hoarding) and only fire if current operating losses are large. We model STW based on Balleer et al. (2016) and extend their setup to persistent firm-level productivity shocks. When match profitability falls below a certain threshold, the government allows the firm to reduce hours and wage payments and, therefore, operating losses. This reduces firing directly and raises hiring indirectly because it increases the value of a worker from the firm's perspective. Persistent firm-level shocks imply an adverse effect of STW on aggregate productivity, which ties workers to firms with low productivity. Due to incomplete asset markets, unemployment and STW risk are not fully insurable, and workers save for precautionary reasons. A non-degenerate wealth distribution arises as workers experience different employment histories, which affect their savings in liquid government bonds. Workers with low asset holdings reduce their consumption already in anticipation of unemployment (and STW) risk without necessarily suffering job loss. The combination of nominal rigidities and endogenous labor market risk creates demand-side amplification. By reducing the need for precautionary savings, STW can then stabilize employment fluctuations through an aggregate demand channel. We combine our empirical results from the survey data with findings from the literature to discipline the different channels in the model quantitatively when calibrating the model to the German economy.

Our first main finding is that the positive employment effects dominate the productivity losses that STW creates by keeping less productive firms alive. This is true both in the model's steady state and in response to adverse shocks. In comparison to a counterfactual economy in which no such policy is implemented, STW reduces the average unemployment rate by 1.3 percentage points and raises output by 0.9%, while aggregate labor productivity is only 0.3% lower in the STW economy. STW also raises the safe real interest rate from 1.5% to 2%, showing that it provides substantial insurance against labor market risk and reduces workers' demand for precautionary savings. When both economies are exposed to business cycle shocks, fluctuations in the unemployment rate are reduced by 16% with STW. A central result is that STW has a positive effect overall because it raises employment not only in unproductive but also in productive firms. This is possible because (i) the productivity of firms that retain workers on STW may recover and (ii) productive firms benefit from potential future access to STW and hire more.

Our second main result relates to the importance of the demand and supply side effects of STW. During normal business cycles, the demand channel operating through lower unemployment risk and precautionary savings accounts for one-fifth of the total reduction in unemployment fluctuations. Although substantial, this figure indicates that the reduction of firms' labor costs is usually the major channel through which the policy operates. However, when monetary policy is constrained by the zero lower bound, the demand channel becomes more important and increases overall STW stabilization. In

this case, the unemployment increase following an adverse shock is reduced by 25% and half of the reduction can be attributed to demand side effects. There are two reasons for this: first, with STW, the nominal interest rate is higher in steady state giving more room before the zero lower bound binds, and second, STW reduces the deflationary pressure caused by workers demand for precautionary savings.

As our final main result, we find that STW stabilizes business cycle fluctuations, but its effectiveness depends on the exact implementation. In our baseline results, we assume that STW rules do not change over time. However, in recent deep recessions, policymakers in Germany adjusted these rules in a discretionary manner in two ways, which we evaluate in the model. First, we consider an extension of STW eligibility to a larger set of firms in response to a decline in aggregate productivity, in line with the German data during the Great Recession. In this case, STW prevents more than 30% of the rise in the unemployment rate. Second, we document that discretionary increases in STW compensation are ineffective. Such policies have been implemented during the Covid-19 recession and could be expansionary in theory, by reducing income losses in STW. In the data and in the model, we observe that short-time workers behave rather similarly to full-time workers and, in particular, they have similar marginal propensities to consume (MPCs). The positive effect of redistributing to short-time workers on their consumption is then outweighed by the wealth effect resulting from the higher taxes required to fund the policy. In contrast, a similar-sized increase in unemployment benefits has large expansionary effects on output and employment as unemployed workers consume a larger share of additional transfers that they receive compared to short-time workers. Lastly, we find that generous STW in good times has the potential risk of making the policy less effective as an automatic stabilizer. Intuitively, elevated STW usage is accompanied by a higher share of low-productivity firms, which fire workers more easily in response to negative shocks. If the goal of STW policy is to primarily stabilize business cycle fluctuations, it should be reduced to a minimum outside of recessions.

Related literature This paper contributes to the existing literature by providing a quantitative model analysis of STW with a focus on the demand effects from lower unemployment risk. We underpin our model with evidence on consumption differences and transition rates from microeconomic data. Given this, our paper contributes to different strands of literature. First, our study relates to the growing literature on heterogeneous agent New Keynesian models with search and matching frictions (Gornemann et al., 2016, Challe, 2020, Ravn and Sterk, 2017, 2021, Albertini et al., 2021). These studies have a similar precautionary savings mechanism as in our model. However, our labor market features endogenous separations and STW, whereas the existing literature studies only exogenous separations. One exception with endogenous separations is Broer et al. (2021). We also connect to the literature that assesses the impact of fiscal policy with incomplete markets, but without labor market frictions (e.g. Brinca et al., 2016, Hagedorn et al., 2019, Guerrieri et al., 2022).

Second, we contribute to the growing literature on STW. Giupponi et al. (2022), Cahuc (2024) and Gehrke (2024) provide recent overviews. We are the first to study the aggregate demand effect of STW and its interaction with the supply side. Quantitative macroeconomic studies with STW and complete markets include among others Krause and Uhlig (2012), Faia et al. (2013) and Balleer et al. (2016). We follow Balleer et al. (2016) in how we model STW and endogenous separations and in line with their findings document the business cycle stabilization due to STW from the reduction of firms' labor cost. In similar spirit to us, Cooper et al. (2017) and Díaz Rodríguez et al. (2024) study

STW in models with heterogeneous firms and reallocation effects. Stiepelmann (2024) provides an analysis of the optimality of STW which we do not consider in this paper.

Lastly, there is a growing empirical literature on the effects of STW. Recent studies, which focus on supply-side effects, include Giupponi and Landais (2022), Cahuc et al. (2018), Kopp and Siegenthaler (2021) and Gehrke and Hochmuth (2021). These papers suggest stabilizing effects of STW on unemployment. In contrast, Brinkmann et al. (2024) find no significant employment stabilization of an extension of potential STW duration in Germany. Kagerl (2024) provides empirical evidence for Germany during Covid-19 suggesting that the employment stabilization of the policy may only be temporary. The recent contribution by Dao and Aiyar (2022) considers the demand side and documents a stabilizing effect of STW in Germany during the Covid-19 crisis. Complementary to the recent empirical literature that focuses on identifying quasi-random variation in STW access at the microeconomic level (Giupponi and Landais, 2022, Kopp and Siegenthaler, 2021, Brinkmann et al., 2024), we provide descriptive empirical evidence on differences in consumption risk between unemployment and STW, as well as transition rates in and out of STW. Moreover, our structural model provides a quantification of the aggregate effects of the policy, including a decomposition to assess the demand effects and policy counterfactuals.

Outline The rest of the paper is structured as follows. Section 2 presents empirical evidence on transition rates in and out of STW and consumption risk due to unemployment and STW spells. Section 3 develops the model. Section 4 discusses the calibration and model properties. Section 5 uses the model to document the STW stabilization in empirically relevant settings. Section 6 concludes.

2 Empirical evidence

2.1 Data description

We obtain our empirical evidence from the Bundesbank Online Panel-Households (BOP-HH) which surveys German households.³ The survey is conducted at monthly frequency in waves from May to July 2019 and runs continuously since April 2020; our current data vintage covers the period until December 2023. The number of participants varies between 2,000 and 9,000 in each wave. The survey is representative of the German online population, which implies that older female respondents and respondents with lower educational attainment are underrepresented and has a panel component. Participants are asked about their labor status (including STW) since May 2020. We further have information on expenditures, wealth and several sociodemographic variables. Appendix B provides details on the data, including the main questions of interest and summary statistics. In the following, we will, first, provide evidence on transition rates including STW, second, document distributions on income and wealth across different labor market states, and third quantify the consumption risk during STW and unemployment.

2.2 Transition rates

Our data allows us to examine transitions between (1) regular employment (E), (2) STW, and (3) unemployment (U). Given the monthly frequency of the survey, we

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

	06/2019-12/2023			04/2022-12/2023		
	Median	p10	p90	Median	p10	p90
E-to-E-rate	0.995	0.978	0.999	0.997	0.988	0.999
U-to-U-rate	0.928	0.769	1.000	0.967	0.841	1.000
STW-to-STW-rate	0.744	0.353	0.926	0.466	0.301	0.833
U-to-E-rate	0.107	0.032	0.250	0.093	0.033	0.170
E-to-U-rate	0.001	0.001	0.008	0.002	0.001	0.007
STW-to-E-rate	0.292	0.076	1.000	0.635	0.181	1.000
E-to-STW-rate	0.006	0.001	0.022	0.003	0.001	0.012

Table 1: Descriptive statistics on monthly flow rates between employment (E), unemployment (U) and STW as computed from BOP-HH. The data is weighted according to sampling weights, comparing June 2019-December 2023 with a post-Covid period, i.e., April 2022-December 2023. The rates do not sum to one as the table shows percentiles rather than averages.

obtain monthly transition rates. Table 1 shows the flow rates defined as $(\text{stock}_t - \text{stock}_{t-1})/\text{stock}_{t-1}$. We find a median monthly job-finding rate (U-to-E) of 11 percent between 2019 and 2023, the corresponding separation rate (E-to-U) is 0.1 percent.⁴ Our data provide novel evidence on the flow rates into and out of STW. First, we document that the probability of leaving STW to employment is about three times higher than the job-finding rate out of unemployment. This suggests that workers affected by STW are much closer to employment than are the unemployed.⁵ As a result, the probability of staying in STW is substantially lower than the probability of remaining unemployed. We will use the persistence in the STW state as a key calibration target in our quantitative model. The transition rate from employment to STW is higher than that to unemployment in our full sample.

To understand this better, we compare the data for our full sample including the Covid-19 crisis and for a subsample after the Covid-19 recession. This comparison highlights the following observations. The flow rate out of STW to employment is more than twice as high after the Covid-19 recession, whereas the probability of entering STW from employment is only half as large and almost similar to the probability of becoming

⁴While the job-finding rate is well in line with other estimates for Germany (e.g., Hartung et al., 2022), the separation rate is lower. This is related to the fact that our survey data has too few observations on unemployment (see the discussion in Appendix B.3 for details).

⁵Using our survey data, we checked whether these STW-E transitions might be mismeasured. There are two potential reasons for mismeasurement: (1) the subsequent employment spells could represent job-to-job transitions to different firms and (2) the transitions may represent short spells of employment that are used by firms to circumvent employment guarantees for short-time workers. We cannot address (1) directly as the data does not have firm identifiers. However, we have evidence that on-the-job search is actually *lower* among short-time workers compared to employed workers. In our data, only 2 percent of short-time workers report active job search, whereas almost 9 percent of the employed do so. This suggests that STW is not a major trigger of job-to-job transitions. This is consistent with the evidence by Díaz Rodríguez et al. (2024) who find that the STW scheme in Spain actually discouraged job search and workers switching firms during Covid-19. To address (2), we document that there are 56 observations with a history of STW-E-X in our data. For none of these observations, we observe that $X=U$. We interpret this as evidence that transition rates from STW into employment are indeed high, while the risk of becoming unemployed is relatively low for workers on STW.

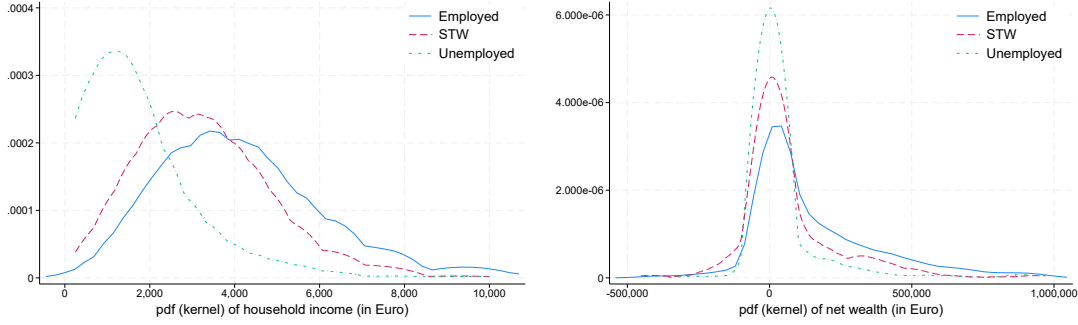


Figure 1: Empirical distributions of income and net wealth by labor market state in Germany. Source: Bundesbank Online Panel-Households, 2021-2023. Weighted according to sampling weights.

unemployed. This makes the STW state overall even less persistent.

2.3 Income and wealth distributions

Figure 1 shows the distributions of income and net wealth in the three different labor market states in Germany. The income distribution of the unemployed is clearly to the left of that of the employed. Interestingly, the income distribution of short-time workers lies between that of the employed and the unemployed, but substantially closer to that of the employed. This suggests that short-time workers are again more similar to the employed than the unemployed. The wealth distribution (assets net of debt, including liquid and illiquid assets, see right panel) highlights a large degree of wealth inequality and a substantial share of indebted individuals with negative net worth. Comparing different labor market states, the net wealth distribution of the unemployed is much more concentrated around zero than that of the employed. This implies that unemployed workers have fewer assets, but also less large-scale debt (as they face constraints e.g., on mortgages). As with the income distribution, the wealth distribution of the short-time workers lies between that of the employed and the unemployed workers.

2.4 Consumption risk

To quantify the consumption risk from STW and unemployment, we follow Chodorow-Reich and Karabarbounis (2016) and Graves (2024) and regress log consumption expenditure on a dummy of the labor market status.

$$\log C_{i,t} = \gamma^e + \gamma_u D_{i,t}^u + \gamma_{stw} D_{i,t}^{stw} + \beta \mathbf{X}_{i,t} + \epsilon_{i,t} \quad (1)$$

The coefficients γ_u and γ_{stw} measure the average difference in log consumption for unemployed workers or workers affected by STW compared to the employed. Our estimation differs from those by Chodorow-Reich and Karabarbounis (2016) and Graves (2024) who use annual data and the fraction of time spent unemployed in a given year. We have high-frequency survey data and can thus directly investigate consumption across different labor market states. However, we do not observe the duration of unemployment

	(1)	(2)	(3)	(4)	(5)
γ_u	-0.39*** (-8.74)	-0.36*** (-8.04)	-0.34*** (-7.65)	-0.34*** (-7.62)	-0.34*** (-6.35)
γ_{stw}	-0.09*** (-3.83)	-0.06** (-2.47)	-0.05** (-2.21)	-0.06** (-2.26)	-0.06** (-2.07)
$\gamma_u \times D_{nocovid}$	-0.15*** (-2.58)	-0.13** (-2.27)	-0.15*** (-2.59)	-0.15*** (-2.58)	-0.10 (-1.50)
$\gamma_{stw} \times D_{nocovid}$	-0.14** (-2.20)	-0.13** (-2.05)	-0.13** (-2.02)	-0.13** (-1.97)	-0.10 (-1.15)
Skill		×	×	×	×
Homeown			×	×	×
Homeown × city size				×	×
Wealth/debt					×
Observations	36,538	35,748	35,519	35,519	22,510

Table 2: Consumption expenditure across labor market states. The parameter γ_u (γ_{stw}) gives the log difference of the consumption of an unemployed (short-time) worker compared to an employed worker. The estimation uses the BOP-HH that covers monthly data for 2020 to 2023. The dummy $D_{nocovid}$ is zero from 2020m3 to 2022m4. t -statistics are in parentheses, standard errors are clustered at the individual level, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Dependent variable is log consumption of non-durables and services for individuals between ages 25-55. The set of control variables in all regressions includes time-fixed effects, age and age squared, gender, household size (squared), an indicator for region and city size. Skill is measured using an indicator of eight categories of education, wealth is measured using indicators across 10 categories each for gross assets, secured debt, and unsecured debt.

and STW spells. Therefore, our estimates reflect the difference of average consumption in each state to the average consumption in employment. Importantly, this is not necessarily the same as the immediate drop of consumption upon a transition into unemployment or STW. In line with Chodorow-Reich and Karabarbounis (2016) and Graves (2024), consumption is measured as the spending on non-durables and services by excluding spending on durables such as cars and furniture and housing (rent, mortgages, etc). Consumption refers to the flow in the preceding month, the employment status measured at the current point in time.⁶ To estimate Equation (1), we restrict the sample to individuals between ages 25 to 55.

We start by using cross-sectional variation to identify the consumption differences. This implies that we rely on the assumption that we can control for all relevant variables to avoid omitted variable bias. Our set of controls in $\mathbf{X}_{i,t}$ is large and includes age and age squared, gender, an indicator for eight categories of education, household size and household size squared, an indicator for city size, home-ownership interacted with city size and wealth. To control for, among other things, consumption drops due to (regional)

⁶This implies that our estimates suffer from attenuation error to the extent that workers switch their labor market status within a month. In a robustness check, we estimate the same regression but using the lagged employment status. The results are displayed in Table 5 in the Appendix. They turn out to be very similar, but the number of observations drops.

lockdowns during the Covid-19 pandemic, we add time-region fixed effects.

The results are displayed in Table 2. Average consumption is around 35% lower during unemployment (γ_u), whereas consumption during STW episodes is only between 5-10% lower. This suggests that the consumption risk from STW is considerably smaller compared to that from unemployment and validates our argument that STW may stabilize demand by reducing risk. Given that our sample covers a particular period with the Covid-19 crisis, we add an interaction with a no-Covid dummy to control for different responses across these two periods (for Germany, we define the Covid-19 crisis to last from 2020m3 to 2022m4). This dummy, however, turns out to be insignificant in our tightest specification. For other specifications, it is estimated to be significantly negative, suggesting an even stronger consumption difference outside the Covid-19 crisis. While this may be surprising at first sight, we interpret this as a result of composition effects as the pool of unemployed changed substantially during the crisis.

This points to the fact that selection may not be fully accounted for by our large set of control variables. Possible unobserved heterogeneity may render a causal interpretation of the coefficients difficult. To address this, we estimate the same regression as in Equation (1) but add an individual fixed effect to control for time-invariant individual heterogeneity. The results are presented in Table 6 in the Appendix. Our main result on the smaller difference in consumption during STW compared to unemployment remains, while the overall consumption difference during unemployment becomes quantitatively smaller at approximately 15%. With fixed effects, the consumption difference across labor market states is identified by workers who switch their employment status. Because we typically observe individuals for only three months, the estimated coefficient now basically measures the change in consumption upon changing employment status, rather than the average consumption difference between the different states. The smaller magnitude of the coefficient might thus stem from two sources, which we cannot distinguish: (i) better identification of the causal effect, or (ii) the fact that consumption differences grow with the length of unemployment spells. Notwithstanding these differences in interpretation, the size of the consumption difference in the fixed effects regression is comparable to existing studies. For the US, Chodorow-Reich and Karabarbounis (2016) find a difference of 21%, while Graves (2024) estimates numbers between 20-25%. Using Swedish data, Kolsrud et al. (2018) find an average consumption difference of 4.4% for short-term unemployed workers, that increases to 9.1% for longer unemployment spells. Their finding hence supports explanation (ii) above. In Appendix C, we provide further evidence on the lower consumption risk during STW compared to unemployment using a different data set and a more granular definition of the STW affectedness that accounts for the extent of the STW hours reduction.

3 The model

We model a New Keynesian economy with search and matching frictions and incomplete financial markets. The economy is populated by workers, firms, firm owners, a government and a monetary authority. There is ex-ante heterogeneity between risk-averse workers and risk-neutral firm owners who receive and consume all profits in each period. Productivity of firm-worker matches varies over time with an aggregate and an idiosyncratic component. Firms that are hit by an adverse shock have the choice to use STW or separate. The labor market thus creates income risk that workers want to self-

insure against. However, the only asset available is a one-period government bond, so full insurance is impossible. Job risk and thus the incentive for self-insurance fluctuate endogenously over the business cycle because of time-varying separation and job-finding rates. Real wages are determined by collective bargaining subject to a real rigidity. Nominal prices are set by firms under monopolistic competition and nominal rigidities. The government pays out social insurance through unemployment benefits and STW compensation. These transfers are financed by levying taxes and issuing government debt. The monetary authority sets the nominal interest rate. In the following, we will discuss the full model setup. To keep the model description concise, we defer a detailed discussion of the main model assumptions to Section 3.5.

3.1 Worker households

There is a continuum of unit mass of workers. Time is discrete and indexed by subscript $t \in \{0, 1, \dots\}$ for aggregate variables. We suppress the time index for variables specific to the individual worker and denote their values in the following period with an apostrophe. In every period, each worker, depending on her individual labor market state x , receives income $E_t(x)$,⁷ which is taxed at rate τ_t , and the return on her savings in one-period bonds, $b(1+r_{t-1})$. Here, r_{t-1} is the risk-free real interest rate set in the previous period. The homogeneous final output and consumption good serves as the numeraire. The worker optimally chooses next period savings b' , which also determines consumption c . The savings choice is subject to a no-borrowing constraint. The value function $U_t(b, x)$ of a worker with savings b in labor market state x satisfies the recursion:

$$\begin{aligned} U_t(b, x) &= \max_{b'} u(c) + \beta_t \mathbb{E}_t \sum_{x' \in X} \mathcal{T}_{t+1}(x' | x) U_{t+1}(b', x') \\ \text{s.t. } c &= b(1+r_{t-1}) + (1-\tau_t)E_t(x) - b', \\ b' &\geq 0, \end{aligned} \tag{2}$$

where the period utility function $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$ exhibits constant relative risk aversion (CRRA) with risk aversion σ . The discount factor β_t is identical for all households and possibly time-varying due to aggregate (demand) shocks. The time index on U_t indicates that the value function depends on the equilibrium at time t , like all other variables. \mathbb{E}_t is the expectation with respect to aggregate uncertainty. Individual labor market risk is encoded in the endogenous and time-varying transition probabilities $\mathcal{T}_{t+1}(x' | x)$ which are defined later.

Workers' labor market state $x = (e, z)$ consists of an employment status e and a firm productivity type z . We denote the set of possible values for x as X . Employment status can take one of four values: i) full-time employed, ii) short-time employed, iii) short-term unemployed, and iv) long-term unemployed, i.e., $e \in E = \{fe, stw, su, lu\}$.⁸ For employed workers, z can take values in the set of (finitely many) possible firm types Z . For unemployed workers, the firm type is defined as 0. Income as a function of the

⁷ $E_t(x)$ is a function and a general equilibrium object. Therefore, it has a time index like scalar variables. We use this notation throughout. Alternatively, we could include the aggregate state explicitly as a function argument.

⁸The assumption of two unemployment types follows Moyen and Stähler (2014).

labor market state is:⁹

$$E_t(x) = \begin{cases} w_t & \text{if } x = (fe, z) \\ w_{stw,t} & \text{if } x = (stw, z) \\ \delta_{su,t} & \text{if } x = (su, 0) \\ \delta_{lu,t} & \text{if } x = (lu, 0) \end{cases}, \quad (3)$$

where w_t , $w_{stw,t}$, $\delta_{su,t}$ and $\delta_{lu,t}$ are the wages of full-time and short-time workers as well as the benefits paid out to short-term and long-term unemployed. The firm type z does not directly affect current income as we assume collectively-bargained wages, but matters for the worker as it affects the transition probabilities $\mathcal{T}_{t+1}(x' | x)$. Labor income risk creates a precautionary savings motive to self-insure. As explained in detail later, this incentive for self-insurance is time-varying, since income risk fluctuates in response to aggregate shocks through changes in state-specific income and transition probabilities.

Workers' only choice is the consumption-savings decision and we denote the policy function for b' as $b_t^*(b, x)$. Wages and labor market transitions are exogenous to the individual, but in general equilibrium both are endogenous labor market outcomes. Wages are determined by collective bargaining between workers and intermediate goods firms. Transition probabilities arise from hiring, firing and STW decisions of these firms. Worker's savings decisions and labor market transitions give rise to a joint distribution over assets and labor market states $\mathcal{Q}_t(b, x)$ in equilibrium, which we characterize along with its evolution in Appendix H.2.

3.2 Intermediate good producers and the labor market

Intermediate good-producing firms are owned by risk-neutral entrepreneurs who discount the future with the constant factor β^e . Each firm employs a single worker who operates a technology which is linear in hours worked. Productivity of the technology fluctuates due to aggregate and firm-specific shocks. In each period, firm and worker might separate endogenously, due to low realized productivity, or exogenously, due to a job destruction shock. Continuing firms sell their product in a perfectly competitive market and entrepreneurs can set up new firms by posting vacancies v_t subject to a cost. At the end of the period, entrepreneurs consume all profits net of the vacancy posting costs.

The labor market with STW builds on Balleer et al. (2016) and Gehrke et al. (2019). There are matching frictions, i.e., only entering firms that are matched with unemployed workers start production in the subsequent period. Under normal conditions, firms cannot adjust hours per worker along the intensive margin. However, firms which face severe adverse shocks have access to STW which allows them to reduce hours worked and thereby the wage bill. The wage is collectively bargained and subject to a real rigidity. The sequence of events in a given period t is shown in Figure 2.

3.2.1 Matching technology

The mass of new matches m_t that form at the end of a period depends on the mass of posted vacancies v_t as well as the mass of unemployed workers, u_t which is equal to

⁹For completeness, $X = \{fe, stw\} \times Z \cup \{(su, 0), (lu, 0)\}$.

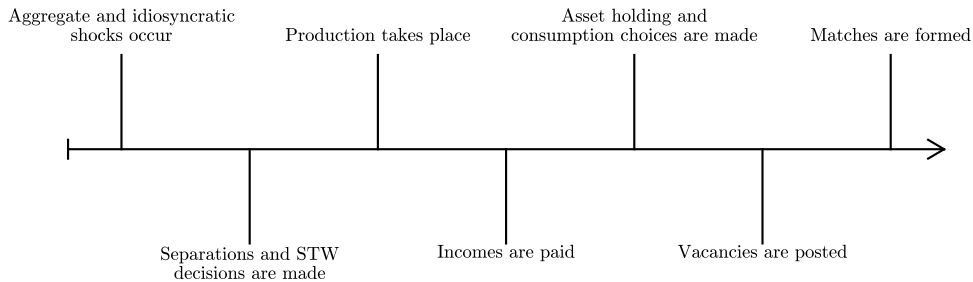


Figure 2: Illustration of the sequence of events in a given period t in the model.

the sum over masses of short-term and long-term unemployed, $u_t = u_{su,t} + u_{lu,t}$. The matching technology is of Cobb-Douglas form:

$$m_t = \mu u_t^\alpha v_t^{1-\alpha}. \quad (4)$$

The parameter $\alpha \in (0, 1)$ is the elasticity of matches with respect to unemployment and $\mu > 1$ is the efficiency of the matching technology. Workers who are unemployed at the end of the current period find jobs at rate $\eta_t = \mu \theta_t^{1-\alpha}$, where $\theta_t \equiv v_t/u_t$ is labor market tightness. Conversely, the probability of a firm filling a vacancy is given by $q_t = \mu \theta_t^{-\alpha}$.

3.2.2 Production technology, firm-specific shocks and profits

As for households, we omit time indices for firm-specific variables and denote next-period variables with an apostrophe. A firm that operates with a full-time employee in period t generates flow profits:

$$\pi_t(z, \epsilon) = a_t z p_{I,t} - w_t - \epsilon, \quad (5)$$

where a_t and z are aggregate and firm-specific productivity, both of which follow stochastic processes with some persistence, and $p_{I,t} = P_{I,t}/P_t$ is the real price of intermediate goods in the current period. Furthermore, there is a stochastic idiosyncratic profitability shock ϵ , which is independent and identically distributed (*i.i.d.*) in every period and drawn from a distribution with probability density function $g(\epsilon)$. Aggregate productivity follows an AR(1) process in logarithms, $\log(a_t) = \rho_a \log(a_{t-1}) + \sigma_a \varepsilon_t$, where ρ_a is the autocorrelation, σ_a the standard deviation and ε_t a standard normal innovation.

The firm-specific productivity component z takes one of N positive real values in the set $Z = \{z_1, z_2, \dots, z_N\}$. Newly matched firms draw an initial value for z at the beginning of their first period of operation from the distribution $\mathcal{P}^n(z)$, which assigns probabilities $\{p_1^n, p_2^n, \dots, p_N^n\}$ to each $z_i \in Z$. If a firm separates from its worker for endogenous or exogenous reasons, it exits the market. For continuing firms, z follows a discrete first-order Markov chain with conditional transition probabilities $\mathcal{P}(z' | z)$. In the following, we refer to the idiosyncratic productivity draw z as the “type” of a firm. New matches, separations and transitions give rise to a time-varying distribution over firm types. We denote the mass of firms of type z which are active in a given period, i.e., firms left *after* separations, as $n_t(z)$.

Cross-sectional differences in z represent persistent fluctuations in the profitability across similar firms over time. They are not meant to capture the full heterogeneity across firms (by size, sector, ...) or jobs (by occupation, qualification, ...) that exists

in the data, which we consider beyond the scope of this paper. Instead, we interpret z as capturing supply *and* demand conditions at the firm level. For example, a low realization of z could be caused by the failure of a large supplier or customer of a firm.¹⁰ We add the *i.i.d.* profitability shock ϵ for technical reasons, as it allows to solve the model using the Reiter (2009) method of linearization in aggregate states. While the model could still be solved without this shock, the linearized solution would not generate time variation in separation or STW rates.¹¹

3.2.3 Firm value, separation and short-time work decisions

Separation and STW decisions follow Balleer et al. (2016), extended to persistent firm heterogeneity in z . All existing matches, irrespective of firm type, might end due to an exogenous separation shock in each period with probability ϕ^x . Next to exogenous separations, firms and workers can separate endogenously in the spirit of Mortensen and Pissarides (1994). Among remaining matches, there exists a type-specific firing threshold $v_t^f(z)$ for the *i.i.d.* profitability shock, such that the firm surplus of a filled job turns negative if $\epsilon > v_t^f(z)$ and the worker is fired.

In reality, firms can only use STW if they temporarily face adverse conditions, defined by the relevant policy institution. In our model, we capture STW policy by an eligibility criterion which depends on both persistent productivity and current *i.i.d.* shock of the firm. The exact formulation of the eligibility criterion is given in Equation (14) (below). For now, note that it results in a type-specific threshold $v_t^k(z)$, such that a firm can use STW if $\epsilon \geq v_t^k(z)$.

How firing and STW depend on ϵ is illustrated in Figure 3. If ϵ falls between the STW threshold $v_t^k(z)$ and the firing threshold $v_t^f(z)$, workers are not profitable enough to be full-time employed, but they are not fired because their value to the firm is larger than the firing cost. A lower value of $v_t^k(z)$ implies that the eligibility criterion becomes less stringent and more profitable firms use STW.

The value of a firm with a full-time worker is

$$J_t(z, \epsilon) = \pi_t(z, \epsilon) + \beta^e \mathbb{E}_t \sum_{z' \in Z} \mathcal{P}(z' | z) J_{t+1}(z') \quad \text{if } \epsilon < v_t^k(z), \quad (6)$$

with the continuation value $J_{t+1}(z')$ defined below in Equation (13).¹²

If a firm is eligible for STW ($\epsilon \geq v_t^k(z)$), it can choose the optimal working time reduction K subject to convex adjustment costs $C(K)$ with $\frac{\partial C(K)}{\partial K} > 0$ and $\frac{\partial^2 C(K)}{\partial K^2} > 0$ to ensure interior solutions. The firm chooses the optimal level of hours reduction $K_t^*(z, \epsilon)$ by maximizing the contemporaneous profit of a worker on STW:

$$\pi_{stw,t}(z, \epsilon) = \max_K \pi_t(z, \epsilon)(1 - K) - C(K). \quad (7)$$

The optimal choice of K trades off the proportional reduction in operating loss against

¹⁰For simplicity, we model z as a pure productivity shifter, but a very similar formulation is possible in which intermediate goods firms produce differentiated goods and experience idiosyncratic fluctuations in demand.

¹¹Without the *i.i.d.* shock, infinitesimal aggregate shocks would not change the separation or STW decision for firms of a given productivity type.

¹²Observe the slight but convenient abuse of notation, as $J_t(z)$ is a *different function* from $J_t(z, \epsilon)$. The latter term conditions on a realization of the *i.i.d.* shock ϵ .

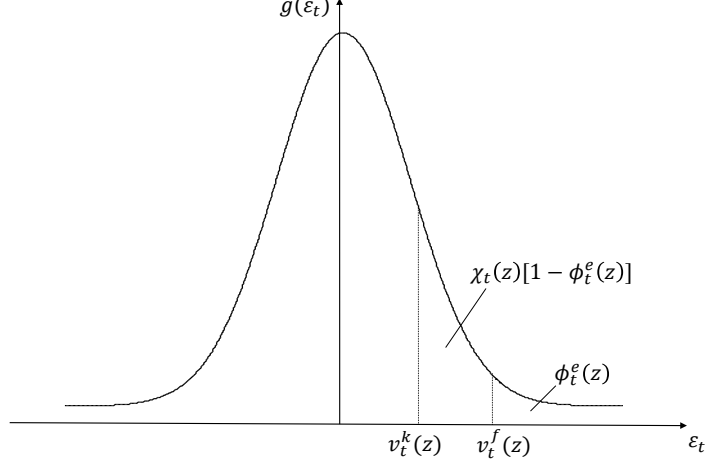


Figure 3: Illustration of the distribution of the idiosyncratic *i.i.d.* profitability shocks with STW threshold $v_t^k(z)$ and $v_t^f(z)$ following Balleer et al. (2016). In the depicted case $v_t^k(z) < v_t^f(z)$, so the firm uses STW if the *i.i.d.* shock falls between the two values.

the convex cost. Assuming a quadratic functional form for the costs of STW,

$$C(K) = \frac{c_k}{2} K^2, \quad (8)$$

the first-order condition yields an optimal STW hours reduction for a firm of type z with profitability shock ϵ

$$K_t^*(z, \epsilon) = -\frac{\pi_t(z, \epsilon)}{c_k}, \quad (9)$$

which is linearly increasing in ϵ . Equation (9) shows that it is optimal for eligible firms to reduce hours if they operate at a loss in the current period. Moreover, the optimal hours reduction decreases in c_k and approaches zero as c_k approaches infinity. Our calibration ensures that $K_t^*(z, \epsilon)$ lies in the interior of the interval $(0, 1)$ for all eligible, continuing firms.

The value of a firm using STW is

$$J_t(z, \epsilon) = \pi_{stw,t}(z, \epsilon) + \beta^e \mathbb{E}_t \sum_{z' \in Z} \mathcal{P}(z' | z) J_{t+1}(z') \quad \text{if } \epsilon \geq v_t^k(z). \quad (10)$$

Firms fire their workers if continuing is more costly than the cost of firing, $J(z, \epsilon) < -f$.¹³ The firing threshold $v_t^f(z)$ is the value of ϵ at which the firm is indifferent between firing and retaining a worker. This depends the relevant alternative to firing, which can be

¹³Ex-ante it is not obvious that workers prefer employment independently of z and ϵ . We verify numerically that workers would never choose to separate.

full-time or short-time employment. For a firm which is not eligible for STW, the firing threshold is

$$v_t^f(z) = \pi_t(z, 0) + f + \beta^e \mathbb{E}_t \sum_{z' \in Z} \mathcal{P}(z' | z) J_{t+1}(z') \quad \text{if } v_t^f(z) < v_t^k(z), \quad (11)$$

using $\pi_t(z, \epsilon) = \pi_t(z, 0) - \epsilon$, because of linearity. For a firm which is eligible for STW the threshold is implicitly defined by:

$$v_t^f(z) = \pi_t(z, 0) + \frac{f + \beta^e \mathbb{E}_t \sum_{z' \in Z} \mathcal{P}(z' | z) J_{t+1}(z')}{1 - K_t^*(z, v_t^f(z))} - \frac{C(K_t^*(z, v_t^f(z)))}{1 - K_t^*(z, v_t^f(z))} \quad (12)$$

if $v_t^f(z) \geq v_t^k(z)$. STW is used only if some eligible firms prefer it over separation, i.e., $v_t^f(z) \geq v_t^k(z)$ for some z .

The value of a firm of type z , before the realization of ϵ and the exogenous separation shock is

$$J_t(z) = (1 - \phi^x) \int_{-\infty}^{v_{t+1}^f(z)} J_{t+1}(z, \epsilon) g(\epsilon) d\epsilon, \quad (13)$$

where $J_t(z, \epsilon)$ is defined in Equations (6) and (10) for the intervals $(-\infty, v_t^k(z))$ and $[v_t^k(z), v_t^f(z)]$. Jointly with (13), these equations recursively define the value of an existing firm.

We can now define STW eligibility in terms of current firm value. A firm can use STW only if

$$\pi_t(z, \epsilon) + \beta \mathbb{E}_t J_{t+1}(z) \leq \zeta(z), \quad (14)$$

All firms of type z with a current value under full-time employment below the eligibility criterion $\zeta(z)$ can use STW. This defines the STW threshold $v_t^k(z)$ in terms of the *i.i.d.* shock as

$$v_t^k(z) = \pi_t(z, 0) + \beta \mathbb{E}_t J_{t+1}(z) - \zeta(z). \quad (15)$$

In the calibration section, we set the eligibility criterion $\zeta(z)$ to generate STW hours reduction and persistence in STW spells in line with the data. To match observed dynamics, firms must experience both, a low persistent productivity state z and a strong negative *i.i.d.* profitability shock ϵ at the same time, to use STW.

The present value of a vacancy is then:

$$V_t = -\kappa + \beta^e q_t \mathbb{E}_t \sum_{z' \in Z} \mathcal{P}^n(z') J_{t+1}(z') + \mathbb{E}_t \beta^e (1 - q_t) V_{t+1}. \quad (16)$$

Here, κ is the vacancy posting cost and $\mathcal{P}^n(z')$ are the probabilities of a firm entering with productivity z . Assuming free entry to vacancy posting ($V_t = 0 \forall t$) results in the job-creation condition:

$$\frac{\kappa}{q_t} = \beta^e \mathbb{E}_t \sum_{z' \in Z} \mathcal{P}^n(z') J_{t+1}(z'). \quad (17)$$

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

For a firm of type z , the endogenous separation rate $\phi_t^e(z)$ and STW rate $\chi_t(z)$ are

$$\phi_t^e(z) = \int_{v_t^f(z)}^{\infty} g(\epsilon) d\epsilon \quad \text{and} \quad \chi_t(z) = \frac{1}{1 - \phi_t^e(z)} \int_{v_t^k(z)}^{v_t^f(z)} g(\epsilon) d\epsilon. \quad (18)$$

This is illustrated in Figure 3. The separation rate, including endogenous and exogenous separations, is $\phi_t(z) = \phi^x + (1 - \phi^x)\phi_t^e(z)$. Note that these rates are measured among different groups of firms. The exogenous and total separation rates are defined for all firms present before any separations, the endogenous separation rate is defined for firms left after endogenous separations and the STW rate is defined only for firms which do not separate.

Above we have defined $n_t(z)$ as the mass of firms which are active in this period, so $\frac{n_t(z)}{1 - \phi_t^e(z)}$ is the mass before endogenous separations. Aggregating over all intermediate goods firms, total period-by-period dividends paid out to firm owners are

$$d_t^I = \sum_{z \in Z} \frac{n_t(z)}{1 - \phi_t^e(z)} \left(\int_{-\infty}^{v_t^k} \pi_t(z, \epsilon) g(\epsilon_t) d\epsilon_t + \int_{v_{H,t}^k}^{v_t^f} \pi_{sw,t}(z, \epsilon) g(\epsilon_t) d\epsilon_t - \phi_t^e(z) f \right), \quad (19)$$

which consist of profits of full-time and short-time operating firms, net of cost for firing.

3.2.4 Distributions and flows in the labor market

We are now ready to describe the distribution and aggregate flows between labor market states as well as the individual worker's transition probabilities $\mathcal{T}_{t+1}(x' | x)$. Recall that x consists of match type z and employment status e .

Define $Q_t(x)$ as the mass of workers in state x when they make their consumption savings-decision after all uncertainty in period t has been resolved. Since each matched firm employs a single worker, the mass of firms of type z , $n_t(z)$, corresponds to the mass of workers whose match type is z . The distribution over employment states then is

$$Q_t(x) = \begin{cases} (1 - \chi_t(z)) n_t(z) & \text{if } x = (fe, z) \\ \chi_t(z) n_t(z) & \text{if } x = (stw, z) \\ u_{su,t} & \text{if } x = (su, 0) \\ u_{lu,t} & \text{if } x = (lu, 0) \end{cases} \quad (20)$$

Total employment includes full-time and short-time workers and is defined as $n_t = \sum_{z \in Z} n_t(z)$. Aggregate separation and STW rates are¹⁴

$$\phi_t = \frac{\sum_{z \in Z} \phi_t(z) \frac{n_t(z)}{1 - \phi_t(z)}}{\sum_{z \in Z} \frac{n_t(z)}{1 - \phi_t(z)}} \quad \text{and} \quad \chi_t = \frac{\sum_{z \in Z} \chi_t(z) n_t(z)}{n_t}. \quad (21)$$

We next turn to worker's transition probabilities $\mathcal{T}_{t+1}(x' | x)$. For a full-time or short-time worker at a firm of type z , transition probabilities are

$$\mathcal{T}_{t+1}(x' | (e, z)) = \begin{cases} \mathcal{P}(z' | z)(1 - \phi_{t+1}(z'))(1 - \chi_{t+1}(z')) & \text{if } x' = (fe, z') \\ \mathcal{P}(z' | z)(1 - \phi_{t+1}(z'))\chi_{t+1}(z') & \text{if } x' = (stw, z') \\ \sum_{z' \in Z} \mathcal{P}(z' | z)\phi_{t+1}(z') & \text{if } x' = (su, 0) \\ 0 & \text{if } x' = (lu, 0) \end{cases} \quad (22)$$

for $(e, z) \in \{(fe, z), (stw, z)\}$. Worker-firm matches draw a new productivity state z' from the distribution $\mathcal{P}(z' | z)$ at the beginning of the next period, which then determines

¹⁴The rescaling with $1 - \phi_t(z)$ in the definition of ϕ_t is necessary because the separation rate is computed on all firms present *before* separations.

the worker's probability to be full-time or short-time employed, or separate and enter short-term unemployment. The zero in the last line represents the fact that workers cannot enter long-term unemployment immediately upon losing their jobs.

Conditional on the match type z , the transition probabilities apply irrespective of whether workers are currently employed full-time or short-time. Due to the *i.i.d.* assumption on the profitability shock ϵ and because the STW decision of firms is static, the firing and STW probability in $t + 1$ is independent of whether a worker is employed or on STW in t , *within* a match type. Does this mean that the average full-time and short-time worker have the same transition probabilities? The answer is no, because short-time workers are in more low-productivity matches, which raises their probability of remaining in STW. Indeed, the average current short-time worker has a far higher probability of working short-time in the following period than the average full-time worker. We will use this fact in our calibration strategy.

It remains to characterize the transition probabilities for currently unemployed workers. For short-term unemployed workers these are

$$\mathcal{T}_{t+1}(x' | (su, 0)) = \begin{cases} \eta_t \mathcal{P}^n(z')(1 - \phi_{t+1}(z'))(1 - \chi_{t+1}(z')) & \text{if } x' = (fe, z') \\ \eta_t \mathcal{P}^n(z')(1 - \phi_{t+1}(z'))\chi_{t+1}(z') & \text{if } x' = (stw, z') \\ (1 - \eta_t)(1 - \omega_l) + \sum_{z' \in Z} \mathcal{P}^n(z')\phi_{t+1}(z') & \text{if } x' = (su, 0) \\ (1 - \eta_t)\omega_l & \text{if } x' = (lu, 0) \end{cases} \quad (23)$$

Short-term unemployed workers are matched with probability η_t and then draw a match type from the distribution of entering firms. Conditional on the match type, they then have the same probability as incumbent workers to become full-time or short-time employed or separate immediately. These three possibilities can be seen in the first two lines and the second term in the third line respectively. Those who are not matched remain in short-term unemployment at rate $1 - \omega_l$ and transition into long-term unemployment at rate ω_l .

For brevity, we relegate the full specification of the transition probabilities for the long-term unemployed to Equation (A-47) in Appendix H.3. Their probabilities to enter employment are identical to those of the short-term unemployed (lines 1 and 2). If they are not matched, they remain in long-term unemployment.

Generally, the job-finding rate η_t , the short-time rate χ_{t+1} and the separation rate ϕ_{t+1} fluctuate in response to aggregate shocks, thereby making employment and consequently income risk endogenous. The latter aspect is a feature of the search and matching labor market. However, the complexity of the labor market e.g., in terms of endogenous separations sets this model apart from simpler search models where only fluctuations in the job-finding rate drive precautionary savings (e.g., Ravn and Sterk, 2021, Challe, 2020).

With the distribution of workers and individual transition probabilities, we can now characterize aggregate flows in the labor market. The laws of motion for employment of

type z are:¹⁵

$$n_t(z) = (1 - \phi_t(z)) \left(\sum_{z^l \in Z} \mathcal{P}(z | z^l) n_{t-1}(z^l) + \mathcal{P}^n(z) m_{t-1} \right), \quad (24)$$

which aggregate to

$$n_t = (1 - \phi_t)(n_{t-1} + m_{t-1}). \quad (25)$$

Short-term and long-term unemployment evolve according to

$$u_{su,t} = (1 - \omega_l)(1 - \eta_{t-1})u_{su,t-1} + \sum_{z \in Z} \phi_t(z) \left(\sum_{z^l \in Z} \mathcal{P}(z | z^l) n_{t-1}(z^l) + \mathcal{P}^n(z) m_{t-1} \right) \quad (26)$$

and

$$u_{lu,t} = (1 - \eta_{t-1})(\omega_l u_{su,t-1} + u_{lu,t-1}). \quad (27)$$

Finally, the average hours reduction among firms using STW, which is an important calibration target, is given by

$$K_t^{av} = \frac{\sum_{z \in Z} n_t(z) \int_{v_t^k(z)}^{v_t^f(z)} K^*(z, \epsilon) g(\epsilon) d\epsilon}{\sum_{z \in Z} \chi_t(z) n_t(z)}. \quad (28)$$

3.2.5 Wage determination

For wages, we assume collective bargaining that captures labor market institutions in continental Europe. The bargained wage between the median firm with productivity type \bar{z} and the median worker assigns a share of γ of the surplus *in the current period* to the worker:

$$w_{N,t} = \gamma a_t \bar{z} p_{I,t} + (1 - \gamma) \delta_{su,t}. \quad (29)$$

We show in Appendix H.1 how this wage equation can be rationalized from the bargaining setup described by Hall and Milgrom (2008) and Lechthaler et al. (2010).

Following Shimer (2005a) and Hall (2005), we add a real wage rigidity. 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 4.4.1. The actual wage paid in period t then is

$$w_t = (w_{N,t})^{1-\gamma_w} (w_{ss})^{\gamma_w}. \quad (30)$$

The real wage is a weighted average between the bargained wage and the wage at the steady state. A higher value of $\gamma_w \in (0, 1)$ implies more rigid real wages. Every worker who is working full-time earns this wage.

¹⁵Since we are tracking the evolution of a distribution now, the sum is over possible *past* states z^l , which lead to the current state z . This is in contrast to the expected values of individuals above, which involve sums over possible *future* states z' . We use this notation throughout.

A short-time worker is paid the wage for the remaining working time $1 - K_t^*(z, \epsilon)$ and receives STW compensation that is equal to the unemployment benefit for the share $K_t^*(z, \epsilon)$. This STW wage is then given by

$$w_{stw,t} = \frac{\sum_{z \in Z} n_t(z) \int_{v_t^k(z)}^{v_t^f(z)} (1 - K_t^*(z, \epsilon)) w_t + \delta_{su,t} K_t^*(z, \epsilon) g(\epsilon) d\epsilon}{n_t \chi_t}.^{16} \quad (31)$$

Since being on STW is a convex combination of full-time employment and unemployment, workers generally prefer STW to being laid off.

3.3 Wholesale and final goods firms

Wholesale firms use intermediate goods as their only input in production, turn it into a specialized good and monopolistically resell it to the final goods sector. They use one unit of the input to produce one unit of output, so their real marginal cost is $p_{I,t}$. Final good firms produce homogeneous consumption goods with a Dixit-Stiglitz aggregator over varieties of the specialized wholesale good 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 for their variety $y_{j,t}$:

$$y_{j,t} = \left(\frac{P_{j,t}}{P_t} \right)^{-\epsilon} y_t, \quad (32)$$

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

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

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^e \left[\left(\frac{P_{j,t}}{P_t} - p_{I,t} \right) y_{j,t} - \frac{\Psi}{2} \left(\frac{P_{j,t} - P_{j,t-1}}{P_{j,t-1}} \right)^2 y_t \right], \quad (33)$$

subject to the demand constraint (32). The first order condition, using that all firms set the same price, becomes

$$0 = (1 - \epsilon) + \epsilon p_{I,t} - \Psi (\Pi_t - 1) \Pi_t + \beta^e \mathbb{E}_t \left\{ \Psi (\Pi_{t+1} - 1) \frac{y_{t+1}}{y_t} \Pi_{t+1} \right\}, \quad (34)$$

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

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

$$d_t^W = (1 - p_{I,t}) y_t - \frac{\Psi}{2} (\Pi_t - 1)^2 y_t. \quad (35)$$

¹⁶Similarly to the full-time wage, ensuring that the short-time wage does not depend on idiosyncratic productivity eases the computational burden, in the sense that one does not need to keep track of a non-degenerate wage distribution.

3.4 Government and market clearing

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

$$\frac{1 + i_t}{1 + r_{ss}} = \Pi_t^{\psi_\pi}, \quad (36)$$

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

$$T_t + B_t = (1 + r_{t-1})B_{t-1} + \delta_t \sum_{z \in Z} n_t(z) \int_{v_t^k(z)}^{v_t^f(z)} K_t^*(z, \epsilon) g(\epsilon) d\epsilon + \delta_t u_{su,t} + \delta_{lu,t} u_{lu,t}, \quad (37)$$

where tax income T_t is obtained by taxing all workers' income from either employment or unemployment benefits with tax rate τ_t . In the baseline specification, government debt is determined exogenously by a deficit rule:

$$\frac{B_t}{B} = \left(\frac{B_{t-1}}{B} \right)^{\rho_B} \left(\frac{n_t}{n} \right)^{(1-\rho_B)\gamma_B}, \quad (38)$$

so that government debt expands in a countercyclical manner when the labor market is slack, governed by the elasticity parameter $\gamma_B < 0$, with some inertia, controlled by parameter ρ_B . Taxes then adjust such that the government's budget constraint (37) holds. The bond market clears when bonds supplied by the government are equal to the aggregate savings of the respective agents $B_t = \int_0^\infty (1 - \mathcal{A}_{t+1}(b)) db$, where $\mathcal{A}_{t+1}(b)$ is the cumulative distribution of worker's assets holdings at the end of period t .¹⁷

Total dividends paid out to entrepreneurs and entrepreneur consumption are

$$d_t = d_t^W + d_t^I \quad \text{and} \quad c_{e,t} = d_t - \kappa v_t. \quad (39)$$

Market clearing in the intermediate goods market implies

$$y_t = \sum_{z \in Z} n_t(z) \left[\int_{-\infty}^{v_t^k(z)} a_t z g(\epsilon) d\epsilon + \int_{v_t^k(z)}^{v_t^f(z)} a_t z (1 - K^*(z, \epsilon)) g(\epsilon) d\epsilon \right]. \quad (40)$$

Finally, adding up the budget constraints of all households and entrepreneurs, one obtains the aggregate resource constraint. Aggregate consumption equals production minus frictional costs

$$\begin{aligned} c_{w,t} + c_{e,t} &= \sum_{z \in Z} \int_{-\infty}^{v_t^k(z)} (a_t z - \epsilon) g(\epsilon) d\epsilon + \int_{v_t^k(z)}^{v_t^f(z)} (a_t z - \epsilon) (1 - K^*(z, \epsilon)) g(\epsilon) d\epsilon \\ &\quad - \frac{n_t}{1 - \phi_t^e} \phi_t^e f - \kappa v_t - \frac{\Psi}{2} (\Pi_t - 1)^2 y_t, \end{aligned} \quad (41)$$

where $c_{w,t}$ denotes the aggregate consumption of workers, which must be consistent with integrating over consumption of individual workers implied by the policy function $b_t^*(b, x)$. In Appendix H, we define the model equilibrium, provide a summary of the model equations and discuss our solution method.

¹⁷Note the use of the mean of a non-negative variable x with cumulative distribution function $F(x)$ as $\int_0^\infty (1 - F(x)) dx$.

3.5 Clarifying the main model assumptions

Our model abstracts from many real-world features that might interact with STW. These include physical capital, extensive and intensive job search decisions, and match-specific human capital. We exclude these features not because these interactions are not interesting, but because we want to maintain the focus of our analysis. In this section, we explain the rationale for our modeling choices directly related to STW. These assumptions are designed to capture real-world features in a parsimonious way and mostly follow Balleer et al. (2016).

Eligibility criterion. In reality, firms cannot simply decide to use STW, but they must apply to the relevant government agency and prove that they are facing substantial, but temporary difficulties. In our model, we capture this in terms of an eligibility criterion, $\zeta(z)$, for current firm value (see Equation (14)). While these criteria are not spelled out in terms of firms' value in reality, and in fact, they are multidimensional in terms of firm and worker characteristics, our formulation ensures that firms cannot use STW in response to small shocks. When calibrating $\zeta(z)$, we take care to choose a data moment that is informative about the importance of these criteria in the data. We observe that the hours of workers on STW are reduced by a substantial amount, 40% on average, implying that these firms face severe difficulties. We set $\zeta(z)$ to match this average hours reduction. Without an eligibility criterion, most firms in the model would use STW to reduce hours by trivial amounts, which is counterfactual. Alternatively, one may set $\zeta = -f$ such that only firms that would otherwise separate are eligible for the policy. This is the strategy proposed by Balleer et al. (2016). Stiepelmann (2024) shows that such an eligibility criterion is part of an optimal implementation of STW. We do not assume that policymakers are able to perfectly identify firms that would separate without STW. In our data-driven calibration, many firms use STW that would not separate in absence of the policy.

Quadratic cost of STW. In the data, hours reductions of 100% are rare for workers and most firms prefer interior values (documented in our data in Figure 12, left panel, in Appendix C). As a result, the benefit of reducing hours with STW must be decreasing in reality. As argued by Balleer et al. (2016), the quadratic STW cost is a stand-in for many possible factors, such as firm-level decreasing returns, finite price elasticity of demand (market power), administrative barriers or rising worker resistance with large hours reductions. For example in the German context, the workers' representation has to agree to using STW.

For more intuition about the role of the quadratic cost, it is useful to rewrite the profit function of a STW firm (7) in terms of hours l , instead of the hours reduction $K = 1 - l$, and explicitly write out the quadratic cost term

$$\pi_t(l, z, \epsilon) = (a_t z p_{I,t} + c_k - \epsilon)l - \frac{c_k}{2}l^2 - \frac{c_k}{2} - wl \quad \text{s.t.} \quad 0 \leq l \leq 1. \quad (42)$$

The quadratic cost function thus implies both “decreasing returns to scale” ($c_k l - \frac{c_k}{2}l^2$) and “fixed cost of production” ($\frac{c_k}{2}$), which remain even when hours are reduced to zero. Both are pinned down with only one parameter, c_k . In reality, fixed costs for a firm that uses STW to reduce hours to zero are likely substantial and include social security for workers, rent, capital cost, insurance, etc.¹⁸ In our calibration, a natural target for the

¹⁸Most of these costs are not truly fixed, but simply cannot be adjusted in the very short run which is the relevant time-dimension for STW. Thus, they should not be compared to other measures of fixed costs that are used in the literature.

STW costs will be the separation rate of STW firms. Without STW costs, firms with access to STW would not separate endogenously, as they could instead reduce hours to zero until conditions improve.

No hours adjustment along the intensive margin without STW. This assumption is motivated by the fact that the hours adjustment occurs mainly along the extensive margin in Germany (Balleer et al., 2016). In recessions, adjustment along the intensive margin occurs predominantly through STW (Burda and Hunt, 2011) as in our model. Cooper et al. (2017) and Giupponi and Landais (2022) develop models with STW that also feature endogenous hours adjustment, which must then be limited to small amounts to be in line with the data. In our model, STW is only used for substantial hours reductions, due to the eligibility criterion. As a result, these two types of hours adjustments would be used by different types of firms.

Collective bargaining and real wage rigidity. Wages in our model do not necessarily adjust to ensure that firms receive a positive surplus even if the total surplus of the match is positive. Since the firm surplus determines the separation and STW decisions, these decisions could be inefficient. This inefficiency is rationalized by institutional constraints and bargaining frictions such as wage floors. Empirical evidence for inefficient separations is provided by Jäger et al. (2023) and Giupponi and Landais (2022) for Austria and Italy. Inefficient separations are important in our context, because they create the possibility for STW to preserve matches with positive surplus to society, which would otherwise be lost.

Endogenous job search during STW. STW may in principle interact with on-the-job-search if workers interpret STW as a signal that firm prospects have worsened encouraging them to quit. While we do not want to rule out this mechanism, the information on on-the-job-search in our survey data contradicts the idea that this mechanism is quantitatively strong. In fact, we find that job search activity by short-time workers is substantially lower (2 percent) compared to that of employed workers (almost 9 percent). This is consistent with the evidence by Díaz Rodríguez et al. (2024) for Spain who document that reallocation out or STW is rare and the literature documenting that job-to-job transitions are in general procyclical (Shimer, 2005b; Mukoyama, 2014).

4 Quantitative analysis of short-time work and precautionary savings

4.1 Calibration

Our baseline model is calibrated to the German economy at quarterly frequency. Table 3 summarizes our calibration strategy. Here, we shortly explain the calibration of important parameters related to STW and precautionary savings. More details along with the relatively standard calibration of the New Keynesian and labor market blocks are delegated to Appendix D.

To calibrate the parameters determining STW dynamics, we use our findings from Section 2 and results by Balleer et al. (2016). We choose a simple process for firm-specific productivity with two states $z_1 = z_h$ (“high”) and $z_2 = z_l$ (“low”). We interpret the former as normal operations and the latter as a state of distress. We make two assumptions which are conservative with respect to the benefits of STW in the sense that they maximize the potential adverse effect on productivity: (i) All new firms enter in the normal state ($p_1^n = 1$) and (ii) firms in the normal state are not eligible for STW,

	Description	Value	Explanation/Target
<i>Parameters</i>			
β	Discount factor	0.9865	2% real interest rate
Ψ	Price adjustment costs	220	Slope of New Keynesian Phillips curve
ϵ	Elasticity of subst. between varieties	6	McKay et al. (2016)
ψ_π	Taylor weight on inflation	1.5	Kaplan et al. (2018)
σ	Relative risk aversion	1.5	Standard value
α	Matching elasticity w.r.t. unemployment	0.6	Balleer et al. (2016)
δ_{su}/w	Replacement rate	0.6	German replacement rate in ALG I
δ_l/w	Replacement rate for long-term unemployed	0.3	Avg. consumption diff. employed-unemployed
μ	Matching efficiency	0.4316	Target labor market flows
f/z_h	Firing costs	2.0	60% Annual productivity
ω_l	Transition probability long-term unemployment	0.2	Average duration of ALG I
s	Scale parameter of profitability distribution	0.68	Target labor market flows
κ	Costs of posting a vacancy	0.58	Target labor market flows
c_k	Costs of STW usage	6.174	Target labor market flows
$\zeta(z_l)$	STW eligibility criterion	-1.53	40% avg. STW hours reduction (Balleer et al., 2016)
γ_w	Wage rigidity parameter	0.69	Elasticity of wages w.r.t productivity
γ	Worker bargaining power	0.88	Volatility of unemployment
p_h^h	Probability to enter in h productivity state	1	Conservative assumption
$\mathcal{P}(z_2 z_1)$	Transition from high to low	0.030	STW rate in steady state
$\mathcal{P}(z_1 z_2)$	Transition from low to high	0.467	Flow prob. STW-STW
z_l/z_h	Relative productivity	0.375	STW semi-elasticity w.r.t. exp. firm output
γ_B	Reaction of debt to employment	-0.2	Countercyclical fiscal policy
ρ_B	Inertia of debt	0.9	Galí and Perotti (2003)
ρ_a	Auto-correlation of aggr. productivity	0.95	Standard value
τ	Income tax rate	0.055	Liquid assets to output ratio
<i>Important steady-state values</i>			
Y	Output level	1	Normalization
q	Worker-finding rate	0.7	Christoffel et al. (2009)
ϕ	Overall job-destruction rate	0.03	Christoffel et al. (2009)
u	Unemployment rate	0.09	Christoffel et al. (2009)
$\frac{sd(u)}{sd(Y)}$	Volatility of unemployment	0.36	German data 1993-2019
χ	STW rate	0.007	Balleer et al. (2016)
$\epsilon_{\chi,y}$	STW semi elasticity w.r.t. exp. firm output	-0.03pp	Balleer et al. (2016)
Π	Inflation	1	Standard value
B	Liquid asset (bond) to output ratio	1	25% of annual GDP (Kaplan et al., 2018)

Table 3: Calibration.

i.e., $\zeta(z_h)$ is such that $v^f(z_h) < v^k(z_h)$. For distressed firms, we set $\zeta(z_l) = -1.53$ to generate an average hours reduction among short-time workers of 40%, the average in German data (Balleer et al., 2016). To determine the productivity difference between the two states, we use the estimate of Balleer et al. (2016) for the semi-elasticity of STW use with respect to firm-level variation in expected revenue of -0.04 .

The probability of workers remaining in STW, as calculated in Section 2, informs the persistence of the distress state. We transform the quarterly transition rates in the model to monthly frequency and target a monthly transition probability from STW to STW of 0.4. We target a steady-state share of short-time workers in total employment of 0.7% which results in a probability of firms becoming distressed $\mathcal{P}(z_2|z_1) = 0.030$.¹⁹ The last parameter related to STW is, c_k , which scales the quadratic cost function. It determines the rate of endogenous separations at firms with access to STW. Our data does not show that separations are common for short-time workers. We therefore choose $c_k = 6.17$ to bring their separation rate in line with that of full-time workers, which is calibrated to 3%. This means that distressed firms, even though they are less productive, do not

¹⁹We only need the persistence and steady-state share of STW to pin down the two-by-two productivity transition matrix.

separate more often than normal firms because they can use STW. This is arguably a strong assumption. To investigate the role of this assumption, we provide an alternative calibration in Appendix G with higher separations in distressed firms. In particular, we consider the case that endogenous separations occur *only* in distressed firms.

In steady state, the share of distressed firms is 5.7% of which 12.3% use STW. Distressed firms remain in their state with a probability of 53.3% in the next quarter, while the probability of normal firms to become distressed is only 3.0%. Because all workers on STW are employed at distressed firms, they have a far higher average probability of being in STW in the next quarter (6.4%) than full-time workers (0.36%), who are mostly employed at normal firms. In contrast, the probability of workers in STW to return to full-time employment is 90.6% and much higher than the average job-finding rate of unemployed workers (30%).

Next, we discuss the parameters that matter for precautionary savings and the demand channel of the model. First, key parameters are the replacement rates of short-term unemployed δ_{su}/w and long-term unemployed δ_l/w workers. We set the former to 0.6, equal to the typical replacement rate in Germany upon unemployment. We adjust the latter to obtain an average consumption difference between employment and unemployment in line with the empirical results from Section 2 (a discussion follows in the next section). Second, the degree of wage rigidity is important as a driver of the cyclicity of labor income. The wage rigidity parameter γ_w is calibrated to match an elasticity of real wages with respect to labor productivity of 0.55, a value within the range of the literature (Den Haan et al., 2018). This implies a value of $\gamma_w = 0.69$. Third, the bond supply by the government is set to 1, implying a ratio of liquid assets to GDP of 25% as in Kaplan et al. (2018). The response of public debt to employment, denoted as γ_B , is set at -0.2 , while the autoregressive parameter, ρ_B , is set at 0.9. This is consistent with slightly countercyclical fiscal policy with a high degree of inertia, a standard assumption supported by empirical evidence, including the estimates provided by Galí and Perotti (2003) for the Euro area. For robustness, we discuss the sensitivity of our results to different choices for the replacement rate, the wage-, and price rigidity and the fiscal policy rules in Appendix Section F.

4.2 Short-time work in the cross-section: Model vs. data

We begin the model analysis by discussing how STW affects workers' choices relative to unemployment and by relating these results to our empirical findings. Figure 4 displays the steady-state asset distributions and policy rules over the asset grid, differentiated by the different employment states. The stationary asset distributions conditional on employment states in the upper left panel show that, relative to full-time employment, the distributions of the short-time employed and the short-term unemployed are shifted to the left. Of the long-term unemployed workers, a significant fraction holds zero assets. Qualitatively, this shift of the conditional asset distributions is similar to the one documented in the data (Section 2, Figure 1). Quantitatively, the distributions differ from the empirical ones as assets are normalized to a minimum of zero in the model, while they may be negative in the data. Further, the asset distribution in the data is more dispersed, implying more wealth inequality, compared to that in the model. It is a well-known fact that models with endogenous wealth distributions have difficulty matching the actual data (see the literature that started with Krusell and Smith, 1998), even when sophisticated productivity processes are used to approximate empirical income

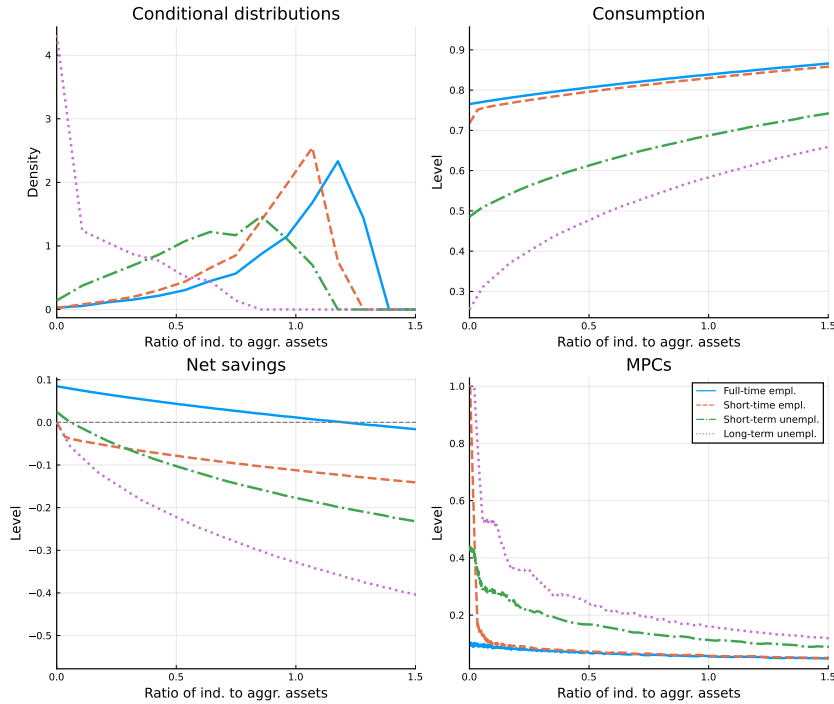


Figure 4: Model properties in steady state. The figure shows the steady state asset distributions, policy rules for consumption and net savings and marginal propensities to consume (MPCs) in the baseline model.

distributions. Our model includes only a very simple productivity process and abstracts from income inequality within employment states. Consequently, our model falls short in matching the wealth distribution. Instead, in line with our primary focus on income risk across employment states, we match the average consumption differences between employment states.²⁰

The upper right panel plots these consumption differences. For a given asset level, short-term (long-term) unemployed consume between 14% (23%) and 35% (66%) less than full-time workers. For short-time workers, the difference lies between 1% and 16% and only becomes meaningful at very low asset levels when these workers reach the borrowing constraint. On average, consumption is 33.9% lower during unemployment and 1.9% lower during STW compared to full-time employment.²¹ The model thus replicates the findings of Section 2 that short-time workers are much closer to the full-time employed than to the unemployed in terms of consumption. The differences in average consumption arise because (i) full-time workers consume more for given assets and (ii) they have more assets on average. By computing the average consumption drop in response to a transition from full-time employment into unemployment (18.0%) and STW (1.0%), we find that (i) explains around half of both consumption differences. This is in line with the individual fixed-effects regression in Table 6, Appendix A. The regression is

²⁰Another reason for the mismatch between the asset distributions in the model and the data is that the model focuses solely on liquid assets. In contrast, the empirical data combines liquid as well as illiquid assets.

²¹The consumption difference in unemployment is a calibration target in line with our empirical results from Section 2. See Appendix D for details on how we compute these averages.

mostly identified by agents switching their employment status and similarly shows only 15% consumption difference between full-time employment and unemployment.

To understand the source of the remaining half, consider the net savings choices ($b' - b$) in the lower left panel. Upon leaving full-time employment, unemployed and short-time workers start to draw down their savings. As a result, consumption declines further with the length of the spells. At most asset levels, short-time workers reduce their savings faster than short-time unemployed, even though their current income is larger. This is the case because the probability of returning to full-time employment from STW is very high, so workers are well-insured. In contrast, short-term unemployed face a lower job-finding rate and might even become long-term unemployed. Despite dissaving faster, short-time workers have more assets than short-term unemployed workers on average. This is explained by the low persistence of short-time work spells, which gives workers little time to use up their savings.

Lastly, the lower right panel plots the MPCs, which are obtained as a numerical derivative of the consumption rules. In line with the consumption rules, MPCs are very high for low assets in the unemployment states, especially in long-term unemployment, as well as the short-time employment state. However, the high MPCs of the short-time employed will turn out to not matter quantitatively because these workers tend to have higher assets. This is consistent with the empirical evidence by Giupponi et al. (2022) who extract information on MPCs from an online survey (the IAB HOPP, see Appendix C.1 for details). They find that the average MPCs of STW recipients are only slightly larger compared to those of the employed, but considerably smaller compared to those of the unemployed. By looking at the lower right panel in combination with the upper left panel, a prediction can be made that transfers to unemployed workers will yield the highest fiscal multiplier. We will analyze this last point in Section 5.1.2.

The policy functions in this section show that short-time workers have a weaker precautionary savings motive than unemployed workers, which is a central result of this paper. However, choices conditional on the worker's state are not yet conclusive for the effect of STW on consumption risk. It matters whether the relevant alternative to STW is full-time employment or unemployment. To answer this question, we analyze the general equilibrium of the model next.

4.3 Insurance, job retention and reallocation in steady state

Here, we discuss the aggregate effects of STW in steady state. Figure 5 plots a set of steady-state variables against total hours affected by the policy (STW hours). For the variation in STW hours, we adjust the STW cost parameter c_k .²² The horizontal axis shows STW hours computed by multiplying the share of workers on STW by their average hours reduction. The values at 0.27 and zero correspond to our baseline economy and a counterfactual economy in which STW is not used. This no-STW economy is used as a point of comparison throughout the following Section 4.4.

The lower right panel shows that the real interest rate declines by half a percentage point relative to the baseline if STW is not available. This implies that STW, in line with the individual policy functions in the previous section, insures workers against income fluctuations and reduces the need to accumulate precautionary savings in general

²²These results should be interpreted as a theoretical study of how STW affects the economy, not necessarily as a policy exercise. We could draw a similar plot by varying the eligibility parameter $\zeta(z_l)$, but the limit, in this case, is not the no-STW economy.

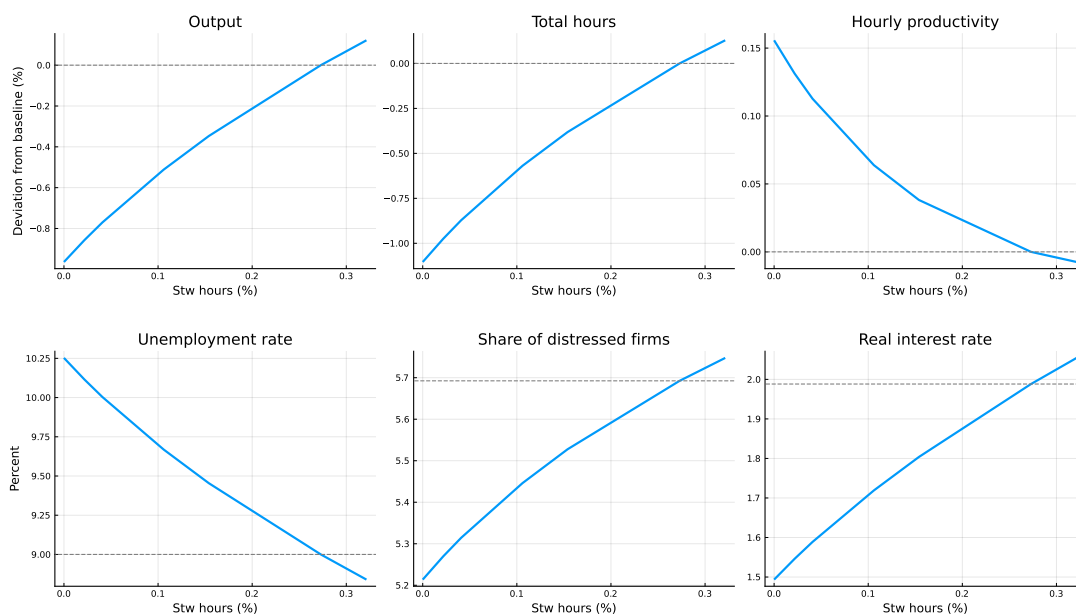


Figure 5: Illustration of the steady state trade-off associated with STW. STW hours are in percent of the total labor endowment in the economy. Different values for STW hours are achieved by varying the cost parameter c_K . The point at zero on the horizontal axis is the limit $c_k \rightarrow \infty$. The grey dashed lines indicate the steady state in the baseline model.

equilibrium. As a result, assets are less scarce, and the interest rate is higher by a substantial margin with STW.

Beyond providing insurance to households, STW has both positive and negative effects on the supply side of the economy. The remaining panels of Figure 5 decompose this trade-off. First, output and hours worked increase almost linearly with STW hours while the unemployment rate declines. Moving from the no-STW to the baseline economy, the decline in unemployment (-1.25 percentage points) corresponds to an increase in the number of employed by 1.4%. This exceeds the increase in hours (1.1%), because hours per worker fall. The increase in output is even smaller (0.9%) because hourly productivity declines (-0.16 percentage points). Hourly productivity falls because STW disproportionately raises employment in distressed firms, as shown by an increase in the share of these firms by 0.5 percentage points.

Why does STW ultimately affect output positively in the model? The main reason is that STW also raises employment in productive firms. While STW reduces separations in distressed firms and reallocation of workers to new firms, these effects are dominated by (i) a reduction in separations by productive firms who benefit from future access to STW and (ii) distressed firms recovering instead of separating. Overall, hours worked increase by similar proportions in productive and distressed firms, which explains why the decline in hourly productivity is small compared to the increase in the share of distressed firms.

Our results do not imply that more STW necessarily affects supply positively at all possible levels. According to Figure 5, the effects are close to linear but slightly concave in STW hours. This implies that, at high STW levels, they might flatten out

or even reverse. However, this point is far from the current model setup and cannot be achieved when restricting the model to generate maximal hours reduction of 100%. In the dynamic exercise (next section), we will discuss a further trade-off involving STW. In particular, we find that generous STW in good times has the potential risk of making the policy less effective as an automatic stabilizer as the economy becomes more vulnerable to adverse shocks. If more jobs are preserved in distressed firms in good times, a bad shock might cause more separations compared to the situation with ex-ante lower STW.

4.4 Short-time work, precautionary savings and aggregate fluctuations

In this section, we discuss how STW interacts with aggregate fluctuations. To this end, we compare dynamics in our baseline economy to a counterfactual economy without STW and otherwise identical parameters.²³ To decompose the effect of STW into supply and demand side channels, we compare these two economies to counterparts without *individual* unemployment risk, again holding all parameters constant. We do this by pooling all worker incomes, such that there is a representative worker, whose income only fluctuates with aggregate employment. In these no-unemployment-risk economies, the demand effect of time-varying labor market risk is fully shut down to isolate the supply effect of STW.

In the following, we focus on the response of our economies to productivity shocks. Figure 6 shows the responses to a one percent decline in productivity with autocorrelation 0.95. Row 1 illustrates the economies with unemployment risk, row 2 illustrates the economies without unemployment risk. We first discuss the responses in the counterfactual economy without STW and with unemployment risk. We show that the adverse productivity shock leads to a demand shortfall because of the time-varying unemployment risk (similar to e.g., Ravn and Sterk, 2021; Broer et al., 2021). This feature makes productivity shocks useful to study the stabilizing effects of STW on both the supply and the demand side. We then decompose these effects by contrasting the responses of all four economies (Figures 6 and 7) and complement the visual analysis by presenting business cycle moments in Table 4.

4.4.1 Aggregate fluctuations without short-time work

Without STW (Figure 6, solid lines), with and without unemployment risk, a fall in productivity reduces the value of a job, which induces firms to reduce hiring and increase separations. As a result, unemployment rises and output falls. The increase in separations is much higher in distressed firms as these are closer to the firing threshold. This implies that the share of low-productivity firms decreases in response to the shock and the recession triggers some ‘cleansing’. The latter responses are shown in Figure 7 for the case with unemployment risk (row 1). We will return to this figure later.

Unemployment risk affects the behavior of the real interest rate and inflation (Figure 6, column 4). When workers are insured against unemployment risk (row 2), lower productivity is inflationary and puts upward pressure on the real interest rate (Taylor weight $\psi_\pi > 1$). The opposite is true with rising unemployment risk in the recession. Then, workers increase their precautionary savings and postpone consumption. This

²³All parameters that are present in both economies are the same, with one exception, the tax rate τ . We have chosen to adjust τ such that the steady-state debt level is identical. It is well known that safe asset supply is important for the size of demand effects, so we consider this as a better point of comparison.

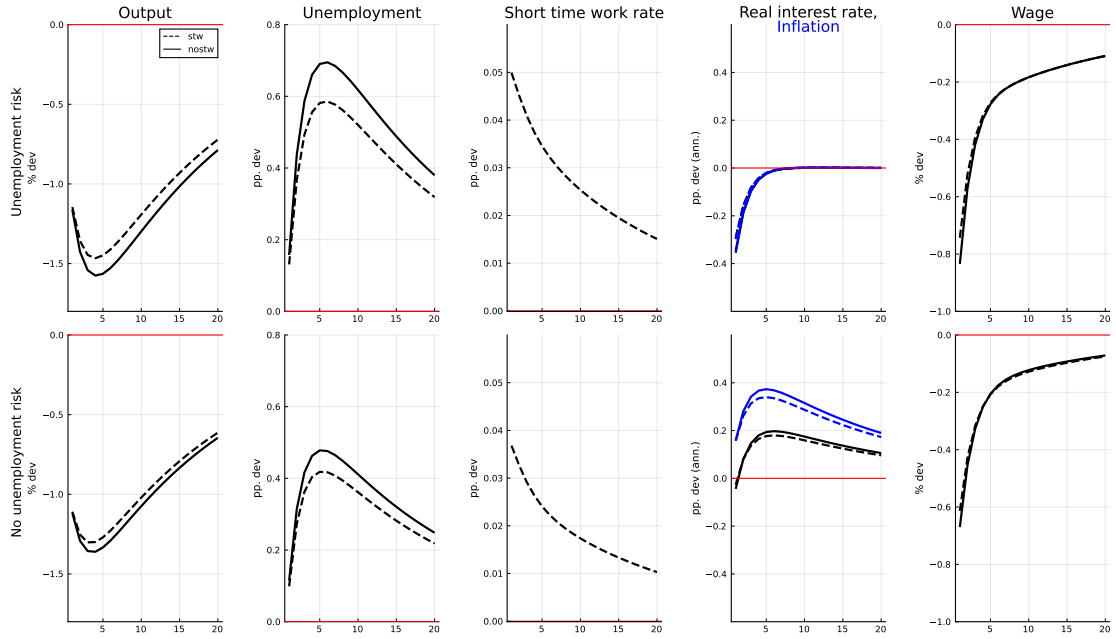


Figure 6: Impulse responses to a negative one percent shock to productivity with autocorrelation 0.95. First and second row show responses under unemployment risk and without unemployment risk. Dashed lines indicate responses when firms can use STW, solid lines indicate responses when firms have no such option.

reduces aggregate demand and generates deflationary pressure, consistent with a decline in nominal and real interest rates. However, the cut in the nominal interest rate by the monetary authority is not enough to prevent a deflationary feedback loop between unemployment risk and demand. This feedback loop results in larger responses of the separation rate, unemployment, and output compared to the case without unemployment risk to the same initial shock.

4.4.2 Adding the short-time work margin

Figure 6 compares the responses to a negative productivity shock with STW (dashed) and without STW (solid). First, consider the economies without unemployment risk (row 2). These show the stabilizing role of STW through its effect on firms' labor demand and the supply side.²⁴ Both with and without STW, firings increase and hirings decrease, which results in contractions in employment and output. With STW available, some firms choose to keep workers employed at reduced hours instead of firing them, such that the STW rate rises (third column). Firms anticipate that STW is an option in the future, so there are relatively more hires and fewer separations even among firms that do not currently use it. This leads to a smaller increase in unemployment and a smaller drop in output with STW. In both cases without unemployment risk, the shock is inflationary, as expected for a supply shock.

With unemployment risk (row 1), the supply shock instead leads to deflation and lower aggregate demand. The presence of unemployment risk adds two new channels

²⁴Strictly speaking, the effect we measure here includes the entire aggregate supply and demand feedback loop to the firms' labor demand.

Difference of standard dev. in %	Productivity shocks		Demand shocks	
	STW	STW	STW	STW
	vs	vs	vs	vs
	no STW	no STW	no STW	no STW
	Risk	No risk	Risk	No risk
	(1)	(2)	(3)	(4)
Output	-5.93	-3.64	-15.52	-12.37
Unemployment	-15.72	-12.61	-15.57	-12.63
Total hours	-6.07	-3.78	-15.74	-12.54

Table 4: Difference of standard deviation across different models in percent. We use HP-filtered deviations from steady state (smoothing parameter 1,600). For output, we use log-deviations, for unemployment level-deviations since this variable is already denoted in percentage points.

through which STW affects business cycle fluctuations. First, if workers anticipate that they may be placed on STW instead of being fired, the precautionary savings motive is not as strong and demand declines less. Second, the contraction in aggregate demand also amplifies the supply side effects of STW. Since firm profits decline more, additional firms choose to use STW, multiplying the supply side effects of STW.

To quantify the STW stabilization, in Table 4, we compute the change in business cycle volatility of output, total hours worked and unemployment across the different models. With income pooling (column 2), STW reduces unemployment fluctuations by around 13% and output and hours fluctuations by less than 4%. The stabilization of output is smaller than that of unemployment because (i) the policy cannot mitigate the direct output effect of the shock and (ii) STW stabilizes hours less than employment. With unemployment risk (column 1), the numbers increase to 16% and 6%, respectively. This implies that the interaction of STW with precautionary savings generates an increase of 25% for unemployment stabilization and 60% for output stabilization. For illustration, this implies that a shock that raises unemployment by 4 percentage points in the absence of STW, raises unemployment by only 3.5 percentage points with STW. Out of the total stabilization of 0.5 percentage points, one fifth is due to the reduction in precautionary savings. Table 4, columns 3 and 4, illustrate that the STW stabilization for unemployment is similar in response to demand (discount factor) shocks. Appendix E discusses these results and the corresponding model responses in more detail.

The first row of Figure 7 presents additional responses for the model with unemployment risk. The figure sheds more light on the productivity effects of STW. In panel 1, we show output per hour together with exogenous aggregate productivity (dashed-dotted line). The responses are almost identical, which makes clear that STW does not have large adverse effects on productivity by saving distressed firms. Qualitatively, output per hour declines less than exogenous productivity in both economies because of a cleansing effect, which is slightly stronger without STW.²⁵ Distressed firms separate disproportion-

²⁵In the STW economy, hourly productivity is additionally stabilized by the reduction of hours among distressed firms. This effect is not large enough to overturn the ordering in terms of hourly productivity.

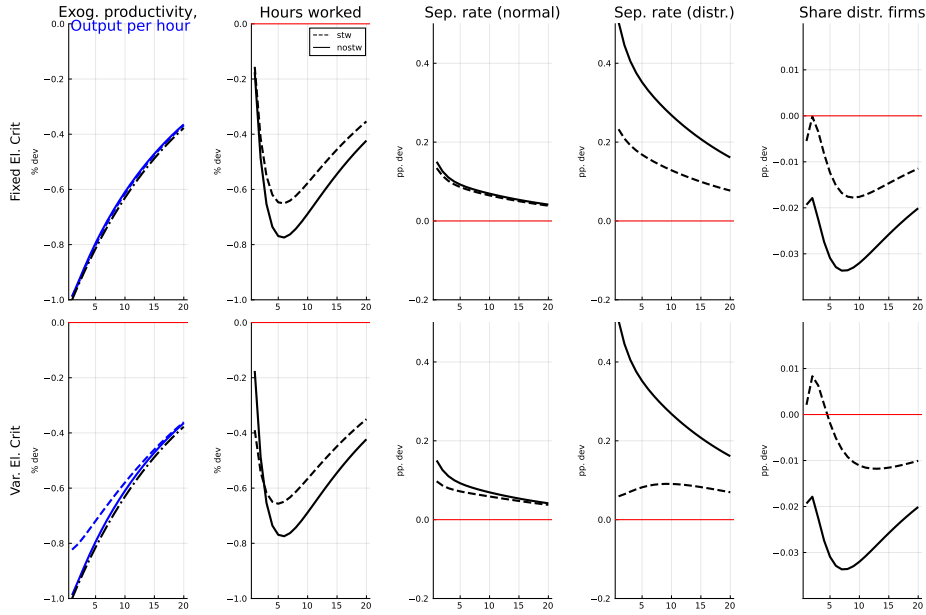


Figure 7: Impulse responses to a negative one percent productivity shock with autocorrelation 0.95 (additional variables). Models with unemployment risk only. Blue lines show the exogenous productivity process. The first row shows the responses with a fixed eligibility criterion, the second row shows the responses with an adjustment of STW eligibility. Output per hour is computed as $y/[(1 - \chi) + \chi(1 - K^{av})]$.

ately more than normal firms (compare panel 4 to panel 3) such that their share declines (panel 5).²⁶ The observation that distressed firms fire more in response to a given shock illustrates an important trade-off that STW creates. If STW is high in steady state, this raises the share of distressed firms (see Section 4.3). While this reduces unemployment in steady state, it simultaneously makes the economy more responsive to shocks.

5 When short-time work is effective and when it is not

The results in the previous section show that STW stabilizes the economy, but the magnitude is thus far overall limited. Here, we investigate two reasons for this. First, the share of firms that use STW rises as output declines, but the magnitude is small (Figure 6, panel 3). The increase is much smaller than the actual STW usage in recent recessions. Second, active monetary policy limits the importance of the precautionary savings mechanism. As documented in panel 4 of Figure 6, the real interest rate falls in response to a decline in productivity with unemployment risk as the central bank reduces the nominal rate.

Next, we investigate how the previous results change when policymakers adjust STW in recessions in a discretionary way and when monetary policy is constrained at the zero lower bound (ZLB). Both cases are empirically relevant, as governments have adjusted

²⁶The irregular shape of the response in panel 5 is driven by the timing of new hires. In the first period, new hires are pre-determined such that the effect of fewer vacancy postings only sets in afterwards, temporarily raising the share of distressed firms as fewer firms with normal productivity enter.

STW rules during Covid-19 and the Great Recession, and over the last two decades, the German economy (as a part of the Eurozone) spent most of the time at the ZLB on nominal interest rates, which hindered active monetary policy by the ECB.

5.1 Discretionary short-time work policy

There were two major types of government interventions related to STW in recent recessions: (1) governments typically make the eligibility criteria less stringent and (2) they may adjust the STW transfers. Based on our model, we will now analyze both interventions by adjusting the STW eligibility criterion and the STW wage.

5.1.1 Adjusting short-time work eligibility

During the Great Recession, German output reached a trough of -7% below the pre-crisis level while the share of short-time workers increased by 5 percentage points at the peak. In contrast, unemployment did not rise by more than 1%. The economy with STW in Figure 6 does not replicate these dynamics as employment falls by around half as much as output and the increase in STW is an order of magnitude smaller.

Why does the model not generate a larger increase in STW? The answer lies in the dynamics of separations. While there are additional firms that use STW due to the adverse shock, this effect is mostly offset by firms that choose to separate but would have used STW without the shock. This can be seen in panel 4 of Figure 7 which shows a strong increase in separations among distressed firms. However, in reality, separations increase in bad times and yet the STW rate rises strongly. One candidate explanation for the discrepancy between model and data is that policymakers adjust STW eligibility to give firms easier access to STW in crises. This was the case both during the Great Recession and during Covid-19. We capture discretionary changes in STW access in our model by introducing a shock $\epsilon_{\zeta t}$ to the eligibility criterion. In particular, the eligibility criterion follows $\zeta_t(z_l) = (1 - \rho_\zeta)\zeta(z_l) + \rho_\zeta(1 - \zeta_{t-1}(z_l)) + \epsilon_{\zeta t}$. The autocorrelation parameter is set to $\rho_\zeta = 0.85$ to match the persistence in German STW data.

In Figure 8, we plot the model responses to a productivity shock that is accompanied by a simultaneous negative shock to $\zeta_t(z_l)$, i.e., a discretionary loosening of the eligibility criterion (dashed lines). We scale the eligibility shock to match the relative peak increase in STW to the output drop in the Great Recession. This implies that the STW rate increases by 1 percentage point in this case. The solid lines for the case without STW are identical to before (Figure 6). The loosening of the eligibility criterion generates additional stabilization in employment. This holds in particular in the economy with unemployment risk where the peak unemployment increase is reduced by more than a third. The reduction in unemployment risk weakens the precautionary savings motive and strongly reduces deflation. However, compared to above (Figure 6), the additional stabilization is relatively smaller compared to the magnitude of the STW extension.²⁷ This suggests that STW policy through the eligibility criterion is overall less effective as the policy increasingly benefits firms that would not have fired anyhow.

To understand the additional stabilization reconsider Figure 7. The second row shows the counterpart with the time-varying eligibility criterion in addition to our base-

²⁷The additional stabilization is 0.1 percentage points in unemployment, while STW goes up by 1 percentage point. This ratio is in line with empirical evidence for the Great Recession, see e.g., Boeri and Bruecker (2011).

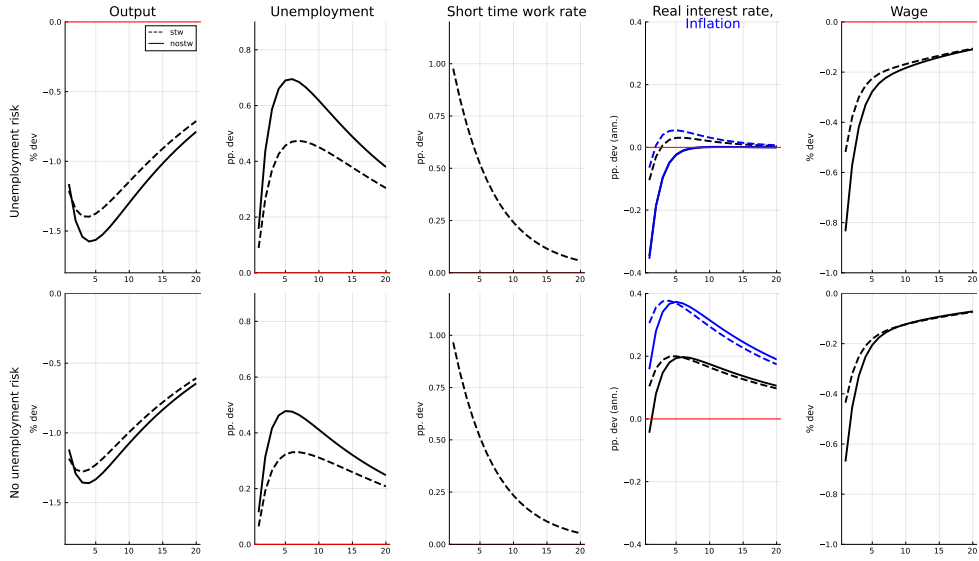


Figure 8: Impulse responses to a negative one percent shock to productivity with a simultaneous loosening of the STW eligibility criterion. First and second row show responses under unemployment risk and without unemployment risk. Dashed lines indicate responses when firms can use STW, solid lines indicate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

line economy with constant STW rules and unemployment risk in the first row. With active STW policy, the separation rate in distressed firms rises by less, such that their share increases. Despite this, hourly productivity falls notably less than in the other economies (first panel), because distressed firms strongly reduce hours. As a result, aggregate hours worked decline *more* than without STW on impact, even though the rise in unemployment is reduced. Hours recover quickly, however, and the economy with active STW policy experiences the mildest contraction in output overall. Intuitively, active STW policy stabilizes the economy not by increasing the amount of hours worked in distressed firms, but by allowing these firms to reduce hours which gives them a chance to recover to normal productivity. Empirical evidence on the effects of such discretionary STW policy changes is rare. While Balleer et al. (2016) argue that discretionary STW policy does not have additional stabilization effects on average, Gehrke and Hochmuth (2021) find, in line with our results, that discretionary policy may stabilize in recessions.

5.1.2 Adjusting short-time work compensation

Another margin that policymakers adjust during crises is the STW compensation. Here, we assume that the STW wage, see Equation (31), is increased exogenously with an autocorrelation of 0.85. Figure 9 shows the model responses to a negative productivity shock in three cases: (1) with a simultaneous increase in STW compensation, (2) with a simultaneous increase in unemployment benefits, and (3) as in our baseline STW model with no active STW adjustment (compare Figure 6). We normalize both benefit shocks to 0.5% of GDP on impact and both are financed by an increase in the tax rate τ_t on workers' income. Figure 9 documents strong quantitative differences between the three cases. An increase in STW benefits (dashed-dotted lines) does not additionally

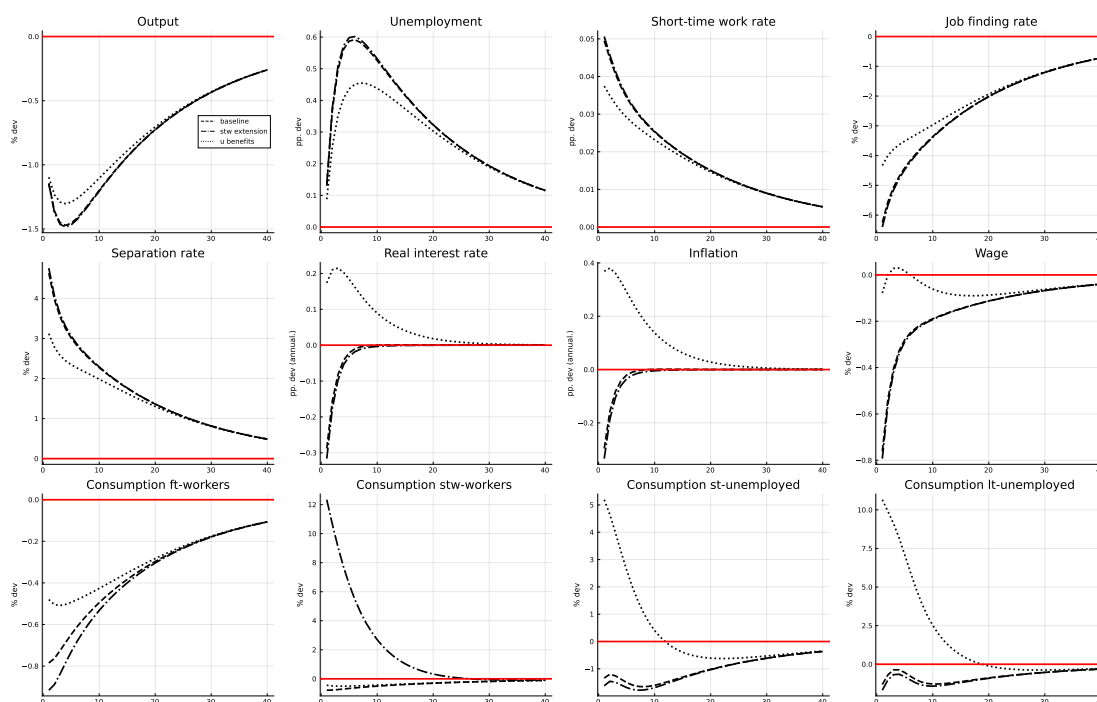


Figure 9: Impulse responses to a negative one percent shock to productivity with a simultaneous increase in (1) STW compensation (dashed-dotted line) and (2) unemployment benefits (dotted line), both normalized to 0.5% of GDP on impact. The dashed line shows the baseline case without active STW adjustment.

stabilize output or employment. By contrast, the increase in unemployment benefits (dotted lines) has noticeable stabilizing effects. Consider first the increase in unemployment benefits. Average consumption of unemployed workers increases, more so for long-term unemployed workers, since their average MPC is higher (see the discussion in Section 4.2). Since the increase in benefits is financed by agents with lower MPCs (full-time employed workers), this redistribution raises aggregate demand relative to the baseline. In a representative agent model without unemployment risk and MPC heterogeneity, these effects would be absent. Higher aggregate demand leads to a persistent increase in the price of intermediate goods, which stabilizes the expected value of a filled position (see Equation (17)) and causes inflation. Accordingly, the job-finding rate and the separation rate are stabilized as well, and unemployment risk increases less than in the baseline. This plays a crucial role for full-time employed worker’s consumption, lowering precautionary savings motives and boosting consumption demand relative to the baseline (bottom left panel). This channel is only partially counteracted by a negative wealth effect resulting from the increase in taxation. By contrast, when the STW compensation is increased (dashed-dotted line), full-time workers’ consumption and consumption of the unemployed decline by more than in the baseline. For full-time workers this difference emerges because the consumption risk in STW is not large in any case, so the higher compensation has a small effect on precautionary savings and the wealth effect dominates. Only short-time employed workers raise their consumption, who make up a small share of the population. Accordingly, the policy is ineffective overall.

To quantify our results, we compute unemployment fiscal multipliers following Mona-

celli et al. (2010). The unemployment multiplier of an increase in STW compensation by one percent of GDP is close to zero, whereas a similar-sized increase in unemployment benefits yields an unemployment multiplier of around -0.34 percentage points after five quarters and -0.52 percentage points in the long run (see Appendix Table 7).

Our results are in line with papers that find that extensions to unemployment benefits can stabilize the business cycle with incomplete markets (McKay and Reis, 2021, Kekre, 2022, Gorn and Trigari, 2024). In contrast, with representative agents and income pooling, higher unemployment benefits increase unemployment (Hagedorn et al., 2013, Christiano et al., 2016). Our results are also in line with the empirical results by Brinkmann et al. (2024) who find that an increase of the potential STW benefit duration was ineffective at stabilizing employment. Even though we model a slightly different policy experiment, our model would also predict that an increase in the potential STW benefit duration would be ineffective as our calibration implies that firms hardly ever exhaust the maximum STW duration of 12 months.

Lastly, our finding that STW benefit increases have limited effects provides insight into the origin of the STW demand stabilization, as discussed in Section 4.4.2. It turns out that the demand channel operates through the precautionary savings behavior of full-time workers, as the redistribution toward short-time workers does not, on its own, contribute to stabilization as documented here.

5.2 Short-time work at the zero lower bound

This section evaluates the effects of STW when monetary policy is constrained by the effective zero lower bound (ZLB). For this exercise, we return to our baseline economy with constant eligibility criterion and replacement rate for STW and again compare it to the no-STW economy. We consider a contractionary aggregate demand shock, that is an increase in workers' discount factor β_t , large enough that the Taylor rule implies a negative nominal interest rate. When the implied nominal interest rate is negative, the central bank instead sets it to zero. We scale the shock size such that the duration of the ZLB is 8 quarters in the no-STW economy.²⁸

Figure 10 shows impulse responses for the STW and no-STW economies at the ZLB. The negative demand shock causes deflation, such that the Taylor rule implies a cut in the nominal interest rate, which is then partially prevented by the ZLB. As a result, the nominal interest rate does not decline enough to offset deflation, and the real interest rate *rises* above steady state, even though the natural rate has declined due to the shock. Therefore, the contraction in aggregate demand is amplified and leads to a stronger recession and a larger rise in unemployment.

The magnitudes of these effects are much smaller with STW. With STW, workers are better insured against income risk, both in the steady state and in response to aggregate fluctuations. This has two effects. First, the nominal interest rate is higher in steady state and, as a result, has more room to decline before it hits the ZLB. Second, the demand shock itself is less deflationary, thus it is not necessary to cut the nominal rate as much to maintain employment. In combination, these two effects imply that the economy

²⁸We use a demand shock because productivity shocks have, as common in business cycle models, small effects on interest rates and inflation in our model, and a very large shock would be required to reach the ZLB (see Figure 6). As a reference point, we show and discuss the effect of a demand shock without the ZLB in Appendix E. To enforce the ZLB computationally, we follow Bodenstein et al. (2013) and rely on a sequence of anticipated monetary policy shocks in our linear model with perfect foresight. See also Dobrew et al. (2023) for a detailed treatment of the computational algorithm.

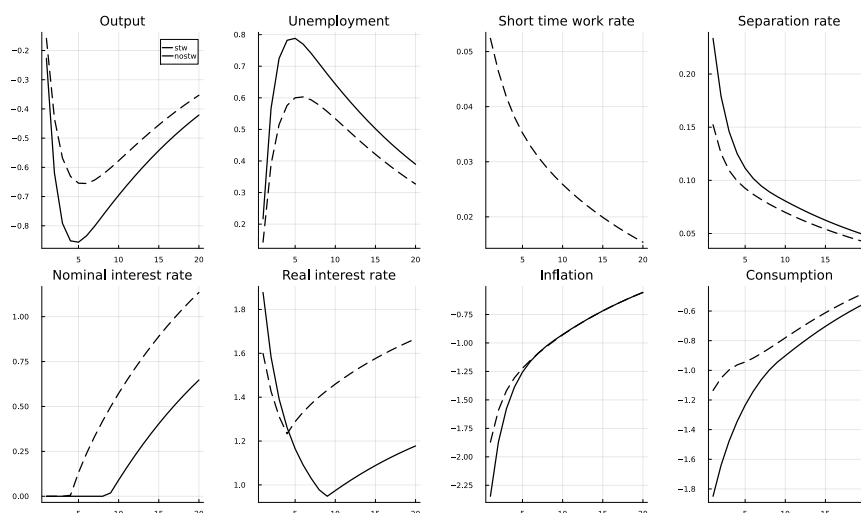


Figure 10: Impulse responses of the model economies with unemployment risk to a discount factor shock which leads to a ZLB episode of eight quarters. Dashed lines indicate responses when firms can use STW, solid lines indicate responses when firms have no such option.

spends only four quarters at the ZLB with STW compared to eight quarters without STW. Then, the peak response of the unemployment rate is 0.8 percentage points in the no-STW model compared to only 0.6 percentage points in the STW model. This implies an unemployment stabilization of 25 percent. Without the ZLB, the implied stabilization of the peak unemployment rate is only 16 percent (see Figure 14 in Appendix E). Without unemployment risk, the economy would not reach the ZLB in response to an identical demand shock, because of the higher nominal rate in steady state. Accordingly, the STW stabilization of the peak unemployment rate remains unchanged in the ZLB case and equal to 13 percent (see bottom row in Figure 14 in Appendix E). This implies that the additional stabilization at the ZLB comes purely from the unemployment risk channel. As a result, this channel accounts for half of the STW stabilization in this case.

6 Conclusions

This paper is the first to investigate the effects of STW over the business cycle while allowing for aggregate demand effects through precautionary savings. We document that precautionary savings matter for assessing the effectiveness of STW. In particular, STW becomes more effective over the business cycle as STW reduces the income risk for full-time workers and their precautionary savings motive. The stabilization is particularly strong if STW rules are adjusted by the government in response to the business cycle and at the zero lower bound. In contrast, a discretionary increase in STW compensation is not expansionary.

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A Additional figures and tables

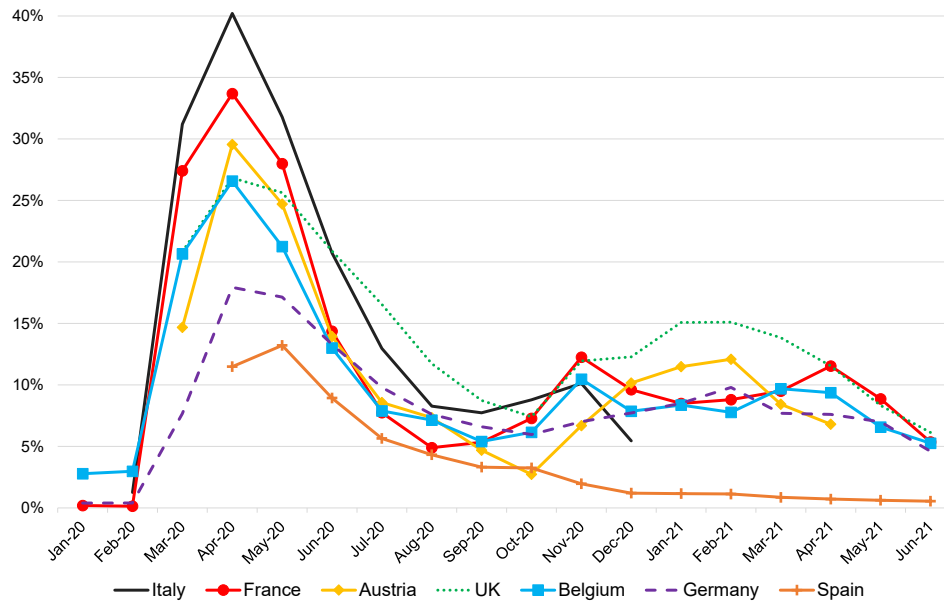


Figure 11: Share of employees affected by STW across different countries during the Covid-19-recession. Source: Eurostat, except for Germany: Federal Employment Agency and UK: ONS and CJRS.

	(1)	(2)	(3)	(4)	(5)
γ_u	-0.47*** (-4.68)	-0.42*** (-4.02)	-0.40*** (-3.71)	-0.40*** (-3.79)	-0.38** (-2.54)
γ_{stw}	-0.10** (-2.19)	-0.07 (-1.51)	-0.06 (-1.24)	-0.06 (-1.28)	-0.11* (-1.67)
$\gamma_u \times D_{nocovid}$	-0.15 (-1.44)	-0.15 (-1.35)	-0.16 (-1.46)	-0.15 (-1.40)	-0.12 (-0.76)
$\gamma_{stw} \times D_{nocovid}$	-0.10 (-1.04)	-0.09 (-1.00)	-0.09 (-0.93)	-0.10 (-1.00)	-0.11 (-1.02)
Skill		×	×	×	×
Homeown			×	×	×
Homeown \times city size				×	×
Wealth/debt					×
Observations	12,417	12,410	12,394	12,394	8,786

Table 5: Consumption expenditure across labor market states using the lagged labor market state. The parameter γ_u (γ_{stw}) gives the log difference of the consumption of an unemployed (short-time) worker compared to an employed worker. The estimation uses the Bundesbank Household Online Panel that covers monthly data for 2020 to 2023. The dummy $D_{nocovid}$ is zero from 2020m3 to 2022m4. t -statistics are in parentheses, standard errors are clustered at the individual level, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Dependent variable is log consumption of non-durables and services for individuals between ages 25-55. The set of control variables in all regressions includes time-fixed effects, age and age squared, gender, household size and household size squared, an indicator for region and city size. Skill is measured using an indicator of eight categories of education, wealth is measured using indicators across 10 categories each for gross assets, secured debt, and unsecured debt.

	(1)	(2)	(3)	(4)	(5)
γ_u	-0.15** (-2.22)	-0.14** (-2.01)	-0.14** (-2.01)	-0.15** (-2.18)	-0.15** (-2.18)
γ_{stw}	-0.05 (-1.56)	-0.05 (-1.56)	-0.05 (-1.54)	-0.06* (-1.80)	-0.06* (-1.85)
Household size, region, city size		×	×	×	×
Skill			×	×	×
Homeown				×	×
Homeown × city size					×
Individual-fixed effect	×	×	×	×	×
Observations	34,072	33,994	33,973	33,744	33,744

Table 6: Consumption expenditure across labor market states using person fixed-effects. The parameter γ_u (γ_{stw}) gives the log difference of the consumption of an unemployed (short-time) worker compared to an employed worker. The estimation uses the Bundesbank Household Online Panel that covers monthly data for 2020-2023. t -statistics are in parentheses, standard errors are clustered at household level, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Dependent variable is log consumption of non-durables and services for individuals between ages 25-55. The set of control variables in all regressions includes time-fixed effects. Skill is measured using an indicator of eight categories of education.

Horizon	Short-time compensation		Unemployment benefits	
	Unemployment	Output	Unemployment	Output
	(1)	(2)	(3)	(4)
5	0.031	-0.034	-0.343	0.378
10	0.039	-0.042	-0.456	0.498
Long run	0.041	-0.045	-0.524	0.57

Table 7: Cumulative present value 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 (Faia et al., 2013). The present value multiplier of government spending in terms of unemployment in percentage points at horizon k is defined as $m_G^k = \frac{\sum_{t=0}^k \beta^t (u_t - u)}{\sum_{t=0}^k \beta^t (G_t - G)/Y}$. To compute the output multiplier, the numerator is replaced with the relative change in output.

B Information on survey data

B.1 Information on the survey and the panel structure

The Bundesbank Online Panel Households (BOP-HH) is a rotating panel. The rotating design follows a schedule of three waves on and three waves off until the panelists have been invited to participate in a total of 12 waves. They then rotate out of the panel. After they have been rotated out of the panel, respondents take a break from participation in the BOP-HH for at least one year.

The mean number of observations by wave is 4,566, with a maximum of 8,996 observations (wave 32, August 2022) and a minimum of 2,009 observations (wave 1, May 2019).

Out of a total of 197,424 observations in waves 1-48, 137,292 (70 percent) are available for three consecutive waves in a row and 22,779 (12 percent) for two waves in a row.

B.2 Main questions

The main questions are translated from German. The original questions are provided by the Deutsche Bundesbank Research Data Center.

- Employment status (variable name: employ)

Question: Which of the following employment statuses currently applies to you?

1. Employment (including apprenticeship) in full-time
2. Employment in part-time (including partial retirement)
3. Marginally or irregularly employed (including paid internships and integration measures)
4. On maternity leave/parental leave/extended sick leave/other leave of absence. Return to employment is planned.
5. Unemployment (officially registered)
6. At school, studying or doing an unpaid internship
7. Pensioner or retiree
8. Early retiree or early retiree (also incapacitated for work, incapacitated for work, incapacitated or reduced earning capacity, incapacitated for service)
9. Federal voluntary service/voluntary year
10. Housewife/househusband
11. Other out-of-the-labor-force

Based on this question, we define respondents as employed for answers 1 and 2 and as unemployed for answer 5.

- Short-time work (variable name: employ2)

Question: Are you currently receiving short-time work benefits?

1. Yes
2. No

- Past consumption expenditure (variable name: spentlastmon_[a-i])

You can now see some items for which you can or must spend money in everyday life. *Question:* Thinking about the last month, approximately how many euros did you spend on each of the following items last month? Note: Please enter an amount in each field (without decimal places). If you do not know exactly, please estimate.

- Major purchases (e.g., car, furniture, electrical devices, etc): *[Input field]* Euro
- Articles of daily use (e.g., food and luxury foods, non-food articles such as cleaning agents, etc.): *[Input field]* Euro
- Clothing and shoes: *[Input field]* Euro
- Leisure activities (e.g., going to a restaurant, cultural event, gym): *[Input field]* Euro
- Mobility (e.g., fuel, vehicle loans and running costs, bus and train tickets): *[Input field]* Euro
- Services (e.g., hairdresser, childcare, medical costs): *[Input field]* Euro
- Travel, vacations: *[Input field]* Euro
- Housing costs (e.g., rent, mortgage loan, ancillary costs): *[Input field]* Euro
- Savings (e.g., savings account, shares, bonds): *[Input field]* Euro

We define spending on non-durable consumption as the sum of categories b to g.

B.3 Summary statistics

We compute aggregate time series for STW and unemployment from the survey data and compare these data to official statistics on the German labor market. As illustrated in Figure 12, the fit for the STW series is very good. However, we underestimate the number of unemployed. This could be related to the facts that the survey has limited participation of people with low education and that the definition of the different employment statuses is different compared to official data.

See Table 8 (overall) and Table 9 (by employment status) for summary statistics on the individuals in the survey data.

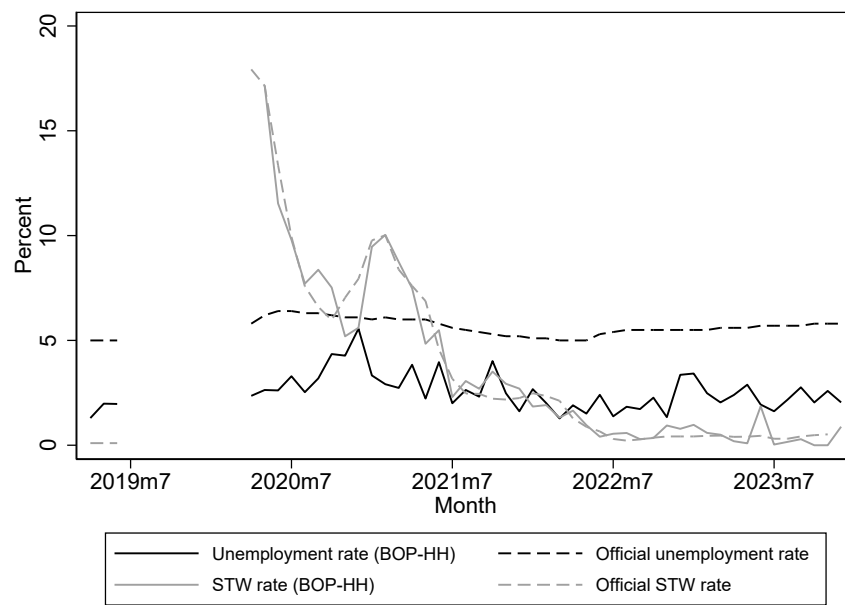


Figure 12: Unemployment (grey) and STW (black) rate over time (BOP-HH survey vs. official data). The official data is obtained from the statistics of the Federal Employment Agency Germany (all seasonally adjusted).

Age	40.5 (8.9) [25.0;40.0;55.0]
Household size	2.6 (1.2) [1.0;2.0;6.0]
Non-durable consumption expenditure	1400.6 (2803.7) [110.0;920.0;9850.0]
Consumption expenditure (total)	3305.3 (6200.5) [300.0;1950.0;32490.0]
Gender	
male	51.0
female	49.0
Region	
north	16.2
west	24.6
south	39.5
east	19.6
Labor market status	
Employed	94.9
STW	2.6
Unemployed	2.5
Profession	
blue collar worker	8.6
white collar worker	75.9
civil servant	8.7
self-employed (no employees)	3.4
self-employed (with employees)	1.7
in training/internship	0.4
contributing family worker	0.1
other	1.3
Education	
Vocational training (apprenticeship)	37.0
Vocational training (school)	10.9
Completed training (Meister)	12.8
Bachelor	11.1
Master	20.6
PhD	2.4
Other	2.1
None	3.1
Household income	
<500 EUR	1.0
500-<1,000 EUR	1.8
1,000-<1,500 EUR	4.3
1,500-<2,000 EUR	6.9
2,000-<2,500 EUR	10.1
2,500-<3,000 EUR	10.4
3,000-<3,500 EUR	11.2
3,500-<4,000 EUR	11.3
4,000-<5,000 EUR	18.5
5,000-<6,000 EUR	12.1
6,000-<8,000 EUR	9.0
8,000-<10,000 EUR	2.0
10,000 EUR and more	1.4

Table 8: Summary statistics for waves 4-48 (April 2020-December 2023) for respondents with age between 25 to 55 (excluding students). The table reports mean, standard deviation, and percentiles (1st, 50th, 99th) for age, household size and expenditures (in Euros). The table reports percentages of all observations for the remaining variables. All statistics were computed using survey weights.

	Labor market status		
	Employed	STW	Unemployed
N (%)	94.9	2.6	2.5
Age	40.8 (8.7) [25.0;41.0;55.0]	41.7 (8.2) [26.0;41.0;55.0]	40.0 (9.0) [25.0;39.0;55.0]
Household size	2.6 (1.2) [1.0;2.0;5.0]	2.5 (1.3) [1.0;2.0;6.0]	2.0 (1.2) [1.0;2.0;6.0]
Non-durable consumption	1454.2 (2069.9) [150.0;970.0;10100.0]	1248.3 (3647.6) [130.0;720.0;10400.0]	690.6 (931.1) [40.0;430.0;5400.0]
Consumption (total)	3412.2 (5920.4) [390.0;2050.0;33160.0]	2916.8 (6000.0) [390.0;1640.0;36000.0]	1674.8 (2646.1) [215.0;1075.0;13050.0]
Gender			
male	53.9	57.7	53.7
female	46.1	42.3	46.3
Region			
north	15.8	13.6	20.7
west	24.3	19.4	31.1
south	40.1	45.2	28.1
east	19.8	21.8	20.1
Profession			
blue collar worker	8.1	23.9	.
white collar worker	76.6	74.8	.
civil servant	9.0	0.0	.
self-employed (no employees)	3.5	0.6	.
self-employed	1.9	0.1	.
in training/internship	0.3	0.0	.
contributing family worker	0.0	0.0	.
other	0.6	0.4	.
Education			
Vocational training (appr.)	36.4	52.6	46.1
Vocational training (school)	11.0	10.3	9.6
Completed training	13.5	14.2	5.7
High school degree	8.5	3.9	4.8
Technical college degree	14.4	9.0	7.7
Other	16.1	10.0	26.1

Table 9: Summary statistics for waves 4-48 (April 2020-December 2023) for respondents with age between 25 to 55 (excluding students). The table reports mean, standard deviation, and percentiles (1st, 50th, 99th) for age, household size and expenditures (in Euros). The table reports percentages of all observations for the remaining variables. All statistics were computed using survey weights.

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 10: 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).

C Additional empirical results

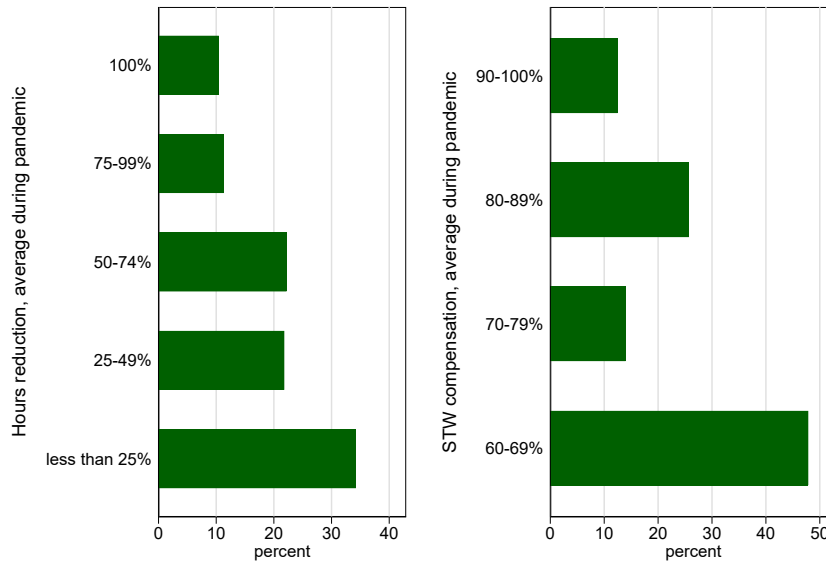
C.1 Income risk during STW spells in the IAB HOPP dataset

We find similar qualitative results on income risk as in Section 2 in a different data set, namely the IAB HOPP as provided by the Research Data Center of the Institute for Employment Research (IAB). The IAB HOPP is an online survey of individuals during the Covid-19 crisis (see Haas et al., 2021). In spring 2020 at the first peak of the Covid-19 crisis in Germany, more than half of those who lost their job reported a considerable income loss, see Table 10. In contrast, only 37% of those affected by STW reported a considerable income loss. Instead, workers on STW reported, to a larger extent, a more moderate income loss. In similar spirit to us, Giupponi et al. (2022) extract information on marginal propensities to consume (MPCs) from the IAB HOPP. They find that the MPCs of STW recipients are slightly larger compared to that of the employed, but considerably smaller compared to those of the unemployed (see also the discussion in Section 4.2 in the main text).

C.2 More granular measurement of STW affectedness

Thus far, we measure the average effect of STW, but we do not control for the extent to which a worker is affected by STW. There are two dimensions in this regard: the hours reduction and the STW compensation. We are able to shed light on this issue, as we were allowed to add specific survey questions to the BOP-HH in August 21 (wave 20). The results show that the hours reduction and STW compensation vary widely across workers that were affected by STW during the Covid-19 crisis. As shown in Figure 13, more than 50% of workers experienced an hours reduction of less than 50%, more than 30% of less than 25%. Only around 10% reduced their working hours to zero, i.e., by 100%. Almost half of all workers received a STW compensation between 60-69% of their net wage, whereas the other half received a higher STW compensation. This can be due to the fact that the German government introduced a higher compensation (80-89%) for workers affected by STW for a long period during the Covid-19-crisis or because many (in particular large firms) pay top-ups on the STW compensation (as agreed on in wage agreements).

Based on these observations, we define a measure of ‘STW affectedness’ that combines these two variables. For example, we define a worker as strongly affected by STW if she



Source: Bundesbank Household Online Panel, wave 20, August 2021

Figure 13: Average hours reduction and STW compensation during the pandemic (weighted summary statistics). Source: Bundesbank Household Online Panel, wave 20, August 2021.

faces a large hours reduction and only a moderate STW compensation.²⁹ Unfortunately, the data has this information only in wave 20 (August 2021). We run the cross-sectional regression as described above for this month adding dummies for the extent of STW affectedness as control variables. As documented in Table 11, these regressions reveal that workers that are strongly affected by STW reduce their consumption by more, compared to workers that are only more moderately affected. In particular, we observe 29% lower average consumption, which is borderline significant. This consumption difference is nevertheless still around a third smaller, compared to the consumption difference of an unemployed worker. This implies that the consumption risk is still smaller even if we focus on workers that are strongly affected by STW.

²⁹Strong STW affectedness summarizes workers that experience a 100% hours reduction and either a 60-69% or 70-79% STW compensation, workers that experience a 75-99% hours reduction and either a 60-69% or 70-79% STW compensation, and workers that experience a 50-74% hours reduction and only a 60-69% STW compensation. Low affectedness is defined for workers with 50-99% hours reduction, but a STW compensation higher than 89%, and for hours reductions below 50% and STW compensation higher than 79%. The remainder is defined as median affectedness.

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

Table 11: Consumption expenditure across labor market states including STW affectedness. The parameter γ_u ($\gamma_{stw,\cdot}$) gives the log difference of the consumption of an unemployed (short-time) worker compared to an employed worker. Short-time workers are categorized by their degree of affectedness in terms of the hours reduction and the STW compensation. The estimation uses the Bundesbank Household Online Panel that covers monthly data for 2020/2021, wave 20. t -statistics are in parentheses, standard errors are clustered at the individual level, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Dependent variable is log consumption of non-durables and services for individuals between ages 25-55. The set of control variables in all regressions includes age and age squared, gender, household size and household size squared, an indicator for region and city size. Skill is measured using an indicator of eight categories of education, wealth is measured using indicators across 10 categories each for gross assets, secured debt, and unsecured debt.

D Calibration details

Internally calibrated parameters and fitted moments Many parameters in the model are internally calibrated to match targets in terms of steady state values or simulated moments and each parameter potentially affects all targets. As is common practice, when explaining the calibration, we assign parameters one-to-one to targets which are important in pinning them down. In our numerical implementation, all parameters are chosen jointly to match the targets. Table 12 shows the fit of the model to the respective data moments.

Moment	Symbol	Target Value	Model Value
Unemployment rate	u_{stst}	0.09	0.09
Worker finding rate	q_{stst}	0.7	0.7
Overall job-destruction rate	ϕ_{stst}	0.03	0.03
STW rate	χ_{stst}	0.007	0.007
Avg. STW hours reduction	K_{stst}^{av}	0.40	0.39
Volatility of unemployment	$\frac{sd(u)}{sd(y)}$	0.36	0.36
Real interest rate	r_{stst}	0.02	0.02
Elasticity of wages w.r.t productivity	see text	0.55	0.55
STW semi elasticity w.r.t. exp. firm output	see text	-0.04	-0.045
Flow prob. STW-STW (monthly)	see text	0.40	0.40
Consumption difference unemployment	see text	0.35	0.34

Table 12: Calibration fit of internally calibrated parameters.

The New Keynesian block For the New Keynesian block of the model, we use standard values. The discount factor β is 0.986 which, given fixed bond supply in steady state, delivers an annual real interest rate of 2%. Inflation is equal to zero in steady state. We follow McKay et al. (2016) and set the elasticity of substitution ϵ to 6. For price adjustment costs Ψ we choose a value consistent with a Calvo (1983) probability of maintaining a fixed price equal to 0.86. In comparison, Thomas and Zanetti (2009) estimate a value of 0.88 in a model with labor market frictions for Europe. This estimate is on the high side of the values used in the business cycle literature but it ensures a plausible slope of the Phillips curve.³⁰ The Taylor weight on inflation ψ_π and the value for relative risk aversion σ are both set to 1.5.

The labor market block Regarding the labor market, we set steady-state targets in line with Christoffel et al. (2009). We use these standard values instead of the rates from our survey data (see Section 2.2), as our data underestimates the number of unemployed. Specifically, the targets for the worker finding rate and separation rate are 0.7 and 0.03 respectively. Out of all separations, we assume that one-third are endogenous, while two-thirds are exogenous. Further, the targeted unemployment rate of 9% implies a

³⁰Harding et al. (2022) show that a relatively minor modification of a New Keynesian model with a Kimball aggregator and a non-linear solution is able to produce a flat Phillips curve, while being consistent with more realistic price adjustment at the micro level. However, the latter is not the focus of our paper.

quarterly job-finding rate of 31%. Consistent with these targets are a matching efficiency $\mu = 0.43$, vacancy posting costs $\kappa = 0.58$ and a scale parameter of the profitability shock distribution $s = 0.68$.³¹

It is well known that, in search models, smaller flow profits imply higher volatility of labor market variables (Shimer, 2005a, Hagedorn and Manovskii, 2008). We make use of this to discipline fluctuations in the unemployment rate. Specifically, we set the workers' bargaining power in wage bargaining to $\gamma = 0.88$. Given this, we match a standard deviation of the unemployment rate (in ppt.) relative to output of 0.36. This number corresponds to the unemployment volatility in quarterly German data between 1993 and 2019. The elasticity of matching with respect to unemployment α is set to 0.6 and firing costs f are set to 60% of annual productivity, both parameters follow Balleer et al. (2016). We set the duration in short-term unemployment to on average 5 quarters implying a transition probability to long-term unemployment ω_l of 0.2.³²

Consumption difference and consumption drop To compare the consumption difference between employed and unemployed workers in the model to the data, we proceed as follows. We take the steady state distribution of consumption and compute the means across all full-time workers and across all unemployed (short-term and long-term) agents. We then compute the difference between the two values in percent. Since we compute the average consumption of households in employment and unemployment *at a given point in time*, the numbers can be compared between data and model despite the different measurement periods (month vs quarter), as long as households do not change employment status *within* the measurement period, which would be the cause of attenuation error. In the data, transition rates are low enough that switches within the month of observation are rare. In the model, transitions do not occur within a quarter by assumption.

We target a consumption difference of -34%, the lower bound of our estimates in Table 2. We choose a conservative value here because there might be some dimensions of heterogeneity in the data that we cannot perfectly control for in the empirical estimation.

Relative firm productivities To calibrate the productivity difference between z_h and z_l , we simulate a panel of firms in the model and replicate the linear fixed effects regression of Balleer et al. (2016), Table 1, p. 104. We proceed as follows. We simulate 100,000 firms for 120 quarters using the model transition probabilities and holding all aggregate variables at their steady state values.³³ If a firm exits, it is replaced by a new firm. Firms are indexed by subscript i .

We then aggregate the quarterly simulated data to yearly frequency and define the following variables in line with Balleer et al. (2016) for $\tilde{t} = \frac{t}{4}$ and $t \in \{4, 8, 12, \dots\}$:

- Expected revenue y_{it}^E : mean over the expected productivity z_{it+j} for j between -3 and 0 , given z_{it-3} . That is, given productivity at the beginning of a year z_{it-3} ,

³¹The parameter s is positively related to endogenous separations as these are tail events in the shock distribution.

³²In Germany, entitlement to the highest level of unemployment benefits (Arbeitslosengeld I, ALG 1) is based on age and duration of employment, and can vary between 6 to 24 months. 5 quarters is close to the duration of the average worker.

³³Simulating the panel with aggregate shocks would be very similar, as we would then include time-fixed effects in the regression, taking out aggregate variation. In our panel simulation all periods are identical, so no time-fixed effects are needed.

we compute the expectation over the mean of productivity in that year using the model transition rates. We only use the persistent productivity state here, not the *i.i.d.* profitability shock. As by Balleer et al. (2016), expected revenue is used rather than realized revenue in the period to address endogeneity concerns.

- Short-time work STW_{it}^a : mean over the STW indicator variable in the *last two* quarters of the year, i.e. STW_{it} and STW_{it-1} .

In the establishment survey data used by Balleer et al. (2016) firms are observed on June 30 and information on STW is only available for the first two quarters. Our simulated data reflects this. In our simulation, years thus start July 1 and expected revenue is computed on June 30. If we do not observe a firm in all quarters of a given year due to entry or exit, we drop the observations.

We then regress short-time work on the log-change in expected revenues and a firm-fixed effect:

$$STW_{it}^a \sim \beta \log \left(\frac{z_{it}}{z_{it-1}} \right) + FE_i \quad (43)$$

Our calibration target is $\beta = 0.04$, i.e., a semi-elasticity of STW with respect to expected revenue of 4.

Eligibility and cost of STW As stated in the main text, there are two conditions for the use of STW in a firm. The firm must be distressed and its *i.i.d.* shock must exceed the eligibility criterion. We choose this setup to match observed STW dynamics.

Allowing non-distressed firms to use STW is possible, but would complicate the model with little quantitative consequences. The reason is that the STW rate must be very close to zero in high-productivity firms to generate plausible persistence of STW spells.

The eligibility criterion ζ determines the minimal hours reduction among short-time workers. As shown by Stiepelmann (2024), an eligibility criterion is part of an optimal implementation of STW, as it can partially prevent inefficient hours reductions. In our setting, $\zeta = -f$ would be optimal in the sense that only firms which would otherwise separate from their workers use STW. We do not assume that the policymaker is able to identify these firms perfectly and instead set the eligibility criterion to match the average hours reduction among short-time workers to the data. A tighter eligibility criterion implies a larger minimal hours reduction, which is positively related to the average hours reduction. The resulting $\zeta = -1.53$ is significantly smaller in absolute value than the firing cost. This implies that many firms which use STW would not separate in absence of STW. Eliminating the eligibility criterion entirely and allowing all firms who would find it optimal to use STW results in counterfactually small hours reductions.

Our calibration of the cost parameter c_k implies equal separation rates among full-time and short-time workers. This is in line with our evidence from Section 2 that separations are rare for short-time workers, both directly out of STW and also after returning to full-time work. In fact, we observe no such separations, but our sample size is limited. One downside of this calibration strategy is that endogenous separations at high-productivity firms occur purely due to the *i.i.d.* profitability shock. These shocks must therefore have a relatively large variance.³⁴ As a robustness check we present results

³⁴Our model shares this feature with a large majority of models with endogenous separations.

from an alternative model calibration, where separations are concentrated in distressed firms in Appendix G.

Monthly probability to remain in STW To compare the quarterly transition rates in the model to the monthly rates in the data, we proceed as follows. We take the full steady-state model transition matrix for all labor market states. We then aggregate across states to get a three-by-three transition matrix, for only full-time employment, STW and unemployment which we observe in the data. Next we approximate the quarterly Markov chain by a continuous time Markov process following Davies (2010) and back to a Markov chain with monthly frequency.³⁵ This procedure accurately allows for multiple transitions in and out of each state within a quarter. We find that the result is very similar to the simple calculation of taking the cubic root of the quarterly probability, which is also common practice.³⁶

We target a monthly probability to remain in STW of 40% which is at the lower end of the numbers in the third row of Table 1, with an implied quarterly probability of remaining in STW of 0.064. We choose a conservative number, as our sample stems from a time when STW was elevated, which might bias the probability of staying in STW upwards relative to the average quarter. Our target implies a probability of remaining in the distress state to 0.53, given that around 12% of distressed firms use STW.³⁷

Countercyclical income risk Income risk is countercyclical in this economy because of fluctuations in separations and job-finding rates. This implies that precautionary savings motives increase in recessions, because the unemployment probability increases. The assumption of countercyclical income risk is supported empirically. Storesletten et al. (2004) study PSID household income data and find that individual income processes exhibit countercyclical variance. Guvenen et al. (2014) find that countercyclical fluctuations in earnings risk may derive from countercyclical left-skewness of shocks, i.e., an increasing likelihood of large income losses rather than large income gains in recessions. This concept is distinct from a countercyclical variance but similar predictions arise, namely that precautionary savings rise in recessions. Ravn and Sterk (2021) provide a detailed discussion on the countercyclicity of income risk.

E Demand shocks

Here, we investigate whether STW stabilization works differently under demand shocks. To do so, we shock the discount factor β in the worker's Euler equation. The stabilization results are displayed in columns (5) and (6) of Table 4 (in the main text). Figure 14 and 15 show the impulse responses. A negative shock to the discount factor triggers a fall in demand and is deflationary. Both effects are amplified by unemployment risk. Overall, the STW stabilization is qualitatively similar to that of productivity shocks. However, in face of demand shocks, STW stabilizes output and hours more than unemployment (with the productivity shock, the main stabilization was in unemployment). Unemployment

³⁵We cannot directly transform the quarterly Markov chain to monthly frequency because the cubic root of the transition matrix contains negative entries and is therefore not a transition matrix itself.

³⁶In particular, $0.064^{(1/3)} = 0.401$.

³⁷The probability of remaining in STW is approximately equal to the probability of remaining in the distress state multiplied by the share of STW firms among distressed firms.

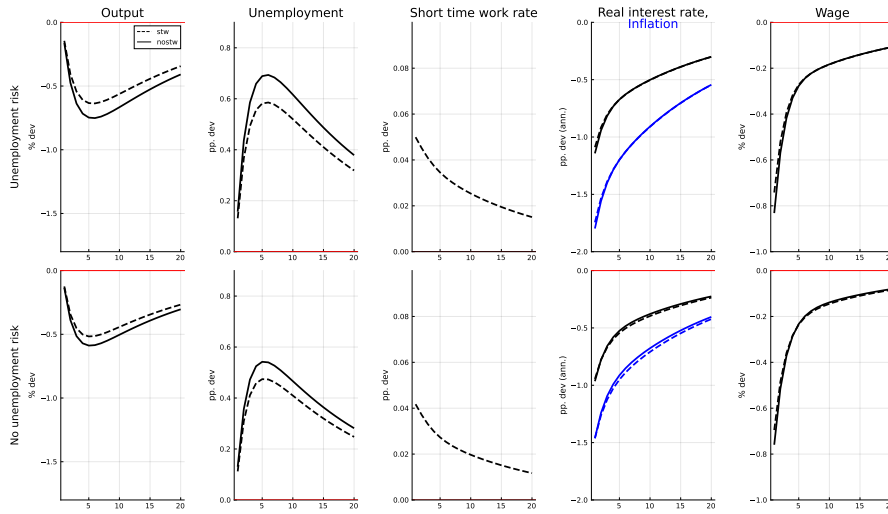


Figure 14: Impulse responses to a negative shock to the discount factor with autocorrelation 0.95. The shock is scaled to yield the same peak response of unemployment as for the productivity shock. First and second row show IRFs under unemployment risk and without unemployment risk. Dashed lines indicate IRFs when firms can use STW, solid lines indicate IRFs when firms have no such option.

risk increases the stabilizing role of STW. The similarity of employment dynamics in response to supply and demand shocks is a feature of search and matching models. By contrast, the textbook New Keynesian model predicts an increase in hours worked in response to negative productivity shocks and a decrease in response to negative demand shocks for standard calibrations (see e.g., Galí, 2008). Broer et al. (2021) derive the same similarity result as in our model analytically in a tractable HANK model with search and matching frictions.

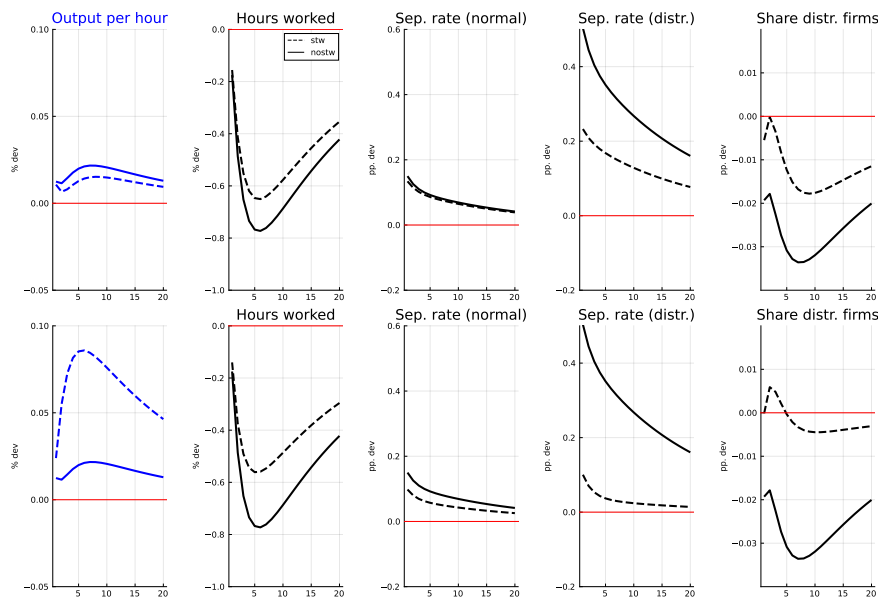


Figure 15: Impulse responses to a negative shock to the discount factor with auto-correlation 0.95. The shock is scaled to yield the same peak response of unemployment as for the productivity shock. Models with unemployment risk only. Blue lines show the exogenous productivity process. First row shows the IRFs with a fixed eligibility criterion, second row shows the IRFs with a rule-based criterion adjustment.

	Baseline	LT replacement rate δ_l/w (0.3)	Wage rigidity γ_w (0.69)	Price rigidity Ψ (207)	Deficit rule γ_B (-0.2)				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Stabilization (%)		0.25	0.35	1.0	0.54	300	150	-0.0	-0.4
Output	-5.91	-7.14	-5.46	-9.55	-4.25	-5.93	-5.88	-6.02	-3.28
Unemployment	-15.73	-17.34	-15.22	-16.82	-15.10	-15.75	-15.72	-15.92	-9.37
Total hours	-6.06	-7.29	-5.61	-9.73	-4.39	-6.08	-6.03	-6.17	-3.42

Table 13: This table compares the stabilization of STW across different calibrations in response to productivity shocks.

F Sensitivity analysis

The strength of the risk channel may vary depending on the choice of parameters. In particular, we have argued that the unemployment insurance and the degree of wage rigidity drive the cyclical nature of income risk and are therefore relevant for the precautionary savings channel. We illustrate this by changing those parameters. Column 1 in Table 13 repeats the baseline results from Column 1 in Table 4 for comparison.

Replacement rate in long-term unemployment The replacement rate for the long-term unemployed δ_l/w represents the relative income difference between the long-term unemployment and the full-time employment state. In our baseline scenario, we set the replacement rate of long-term unemployed workers fixed at 0.3, chosen to fit the difference in consumption between the employed and unemployed as in Section 2. The degree of income risk associated with long-term unemployment and unemployment in general, depends both on the separation probability ϕ_t and the size of the relative income difference δ_l/w . A lower long-term replacement rate δ_l/w implies a stronger increase in income risk for a given increase in the separation probability, and therefore a stronger increase in precautionary savings in response to shocks. Accordingly, the demand channel outlined in Section 4.4.1 becomes stronger, leading to a deeper recession, especially so in the model without STW. By contrast, in the model with STW, the smaller increase in separation rates in response to shocks lowers this risk, and dampens the demand channel (see Section 4.4.2). Generally, when the demand channel is amplified, STW stabilizes more (see also Section 5.2 on the ZLB). This implies that a lower long-term replacement rate yields more automatic stabilization, and a higher long-term replacement rate implies less automatic stabilization, which is reflected in column 2 and 3 of Table 13.

Wage rigidity and price rigidity Columns 4 and 5 of Table 13 show the stabilization results for different levels of real wage rigidity. Perfectly rigid wages ($d \ln w/a = 0$) imply larger fluctuations of firm profits, and consequently, a stronger decline in the job-finding and separation rate in response to productivity shocks. Hence, the stabilization of unemployment risk coming from STW is increased. By contrast, when wages are more flexible as in the baseline case (column 5), it is reduced but remains substantial. For different degrees of price rigidity in column 6 and 7, the intuition is similar. More rigid price setting increases the volatility in the labor market and the stabilization of STW. The opposite is true with more flexible prices.

Financing In models with incomplete markets, fiscal policy can play a large role in theory (see e.g. Kaplan et al., 2018). Therefore we test how a different specification of the fiscal rule affects our results. For robustness, we show what happens when bonds are held constant ($\gamma_B = 0$), and higher unemployment or STW benefits are purely financed by a higher tax rate (column 8 of Table 13). This increases the stabilization slightly compared to the baseline. By contrast, when we allow debt to react more flexibly by lowering γ_B , the stabilization decreases. Ceteris paribus, more supply of government debt in recessions has a stabilizing effect on the business cycle because it provides more insurance possibilities (see e.g. Aiyagari and McGrattan, 1998), thereby increasing workers' consumption. Since employment declines more in the model without STW, government debt increases more according to the deficit rule (38). This reduces the stabilization that STW provides.

G Alternative calibration

G.1 Alternative calibration strategy

In the main text, we calibrate our model based on the observation that the separation rate among short-time workers is low and identical to that of full-time workers. A consequence of this assumption is that endogenous separations must occur at both normal and distressed firms to reach the calibration target for the aggregate separation rate. Since normal firms generate positive expected surplus over many future periods, endogenous separations in normal firms require large *i.i.d* cost shocks. In our baseline calibration, their standard deviation is 60% of normal firm productivity. In this appendix, we present a substantially different calibration of the model, which does not involve similarly large *i.i.d* shocks. We show that the results on STW are nevertheless similar. Further, the alternative calibration reveals some interesting additional insights into the effects of STW.

The alternative calibration differs from the baseline in three ways. First and most importantly, we do not assume that separation rates of workers in STW and full-time employment are equal. We replace this assumption by introducing a new target, namely the average consumption difference between full-time and short-time employed agents. This difference is estimated at 6%, see the second line of Table 2.³⁸ Similar to the average consumption difference between full-time employed and unemployed, it contains information about the consumption risk that each group is exposed to. Therefore it can pin down the difference in separation rates between short-time and full-time employed workers. An important consequence is that *i.i.d* cost shocks are then not necessarily needed to generate a substantial rate of endogenous separations in normal firms, if separations are concentrated at distressed firms. Second, we reduce the firing costs by a factor of 4, to 15% of annual productivity at normal firms. Lower firing costs directly reduce the size of adverse shocks necessary to bring a firm to fire a worker, which further helps to reduce the calibrated standard deviation of *i.i.d* shocks. Third, we choose a target for the average hours reduction of 30% instead of 40% as in the baseline, which is still within the range of values in German data. This change is necessary because of the lower firing costs. Firms fire workers rather than reducing hours by a large amount, so the model does not generate much higher average hours reductions.

³⁸This difference is untargeted and slightly understated in the baseline calibration.

The resulting parameters in comparison to the baseline calibration are shown in Table 14, all other parameters are identical. Most importantly, the standard deviation of *i.i.d.* shocks is reduced by a factor of three in the alternative calibration.³⁹ Also notably, the quadratic cost parameter of hours reduction and the eligibility threshold for accessing STW are lower, both by factors between 2 and 3. The relative productivity of distressed firms is closer to normal firms, while their chance of recovering to the normal state is lower in the alternative calibration. The fit of the model to target the moments in the alternative calibration is shown in Table 15 and is comparable to the baseline.

As expected, the alternative calibration implies a higher separation rate for distressed firms, which translates to short-time workers. In particular, endogenous separations *only* occur among distressed firms, which separate with rate of 13%. Because of the eligibility criterion, a worker who is currently on STW must be employed at a distressed firm, which remains in distress with a probability of more than 80%. Thus, the average short-time worker faces a probability of more than 10% to become unemployed in the next quarter. In contrast, the separation rate for normal firms is identical to the exogenous separation rate at 2% (i.e. the share of normal firms which separate endogenously is numerically equal to zero). Since most full-time workers are employed at normal firms,⁴⁰ their average probability to become unemployed is only slightly larger than 2%. Thus, in the alternative calibration, workers on STW have substantially worse employment prospects than the average full-time worker. It is important to point out that this is strongly counterfactual based on our data and hence this alternative is not our preferred calibration. In our data, we observe that separations are rare for short-time workers, both directly out of STW and also after returning to full-time work (see Section 2). In fact, we observe no such separations. Even if our data were to understate separations among short-time workers, we consider a 10% separation rate outside of the plausible range.⁴¹ We interpret this exercise more as an illustration of an extreme case when the unemployment risk of STW would be very high. Next, we analyze the steady state properties of this extreme calibration.

G.2 Effects of short-time work in the alternative calibration

The high separation rate among short-time workers implies that they are not as well insured as in the baseline and the consequences can be seen in Figure 16, which is the counterpart to Figure 4. Workers on STW have more need for self-insurance than in the baseline calibration. As a result, they cut consumption more and reduce savings less compared to full-time workers (top right and lower left panel of Figure 16).

The effect of STW on aggregates in the steady state is shown in Figure 17. The results are qualitatively similar to the baseline (cf. Figure 5). By insuring workers and reducing overall unemployment, STW reduces demand for precautionary savings which leads to a higher real interest rate. Introducing STW raises the real interest rate by 0.5 percentage points in both calibrations, suggesting similar effects on the demand for precautionary savings. This might appear surprising, since we have just argued that that short-time workers are not as well insured relative to full-time workers in the alternative

³⁹In particular, this implies that the mass of operating firms, for which *i.i.d.* costs exceed output within a period is numerically zero.

⁴⁰The employment share of distressed firms among full-time workers is around 7%.

⁴¹In a recent study, Schäper and Wrohlich (2024) find that short-time workers during Covid-19 in Germany did not have a higher chance of unemployment compared to normally employed workers one year later.

Parameter	Baseline	Alternative
f/z_h	2	0.5
μ	0.43	0.43
κ	0.57	1.04
s/z_h	0.60	0.19
z_l/z_h	0.38	0.51
β	0.987	0.985
c_k	6.17	2.46
γ	0.876	0.77
γ_w	0.69	0.60
δ_l/w	0.30	0.24
$\mathcal{P}(z_2 z_1)$	0.030	0.028
$\mathcal{P}(z_1 z_2)$	0.467	0.181
$\zeta(z_l)$	-1.340	-0.497

Table 14: Parameter comparison, baseline vs alternative calibration.

calibration. The reason is that insurance *relative to the relevant alternative* in the economy without STW determines the change in the demand for precautionary savings. For workers at distressed firms, the relevant alternative is not full-time employment at the average firm, but employment at a distressed firm, which has no access to STW. In the economy without STW, employment at distressed firms exposes workers to high risk, as their separation rate is 22% compared to 13% with STW. Thus STW provides a lot of insurance, explaining the strong effect on precautionary savings demand. Because employment risk at a distressed firm is far higher than at normal firms overall, a sizable risk remains even with STW. We thus conclude that the demand side effect of STW is similar, despite the large differences between the two calibrations.

On the supply side, STW reduces unemployment and the separation rate at distressed firms, raising hours worked and output, while lowering hourly productivity. Quantitatively, the effects of STW on unemployment and hours are similar to the baseline. However, there are large differences in the remaining variables. In particular, in the alternative calibration, the share of distressed firms is 8% with and 6% without STW. The differences of 2 percentage points exceeds the fall in unemployment (1.2 percentage points), indicating that STW raises employment at distressed firms at the cost of *reducing* employment at normal firms. Hourly productivity is then 1% lower and output only 0.2% higher in the steady state with STW. In the baseline calibration STW raises the share of distressed firms by only 0.5 percentage points and lowers unemployment by 1.2 percentage points, thus increasing employment *both* at distressed and normal firms. The result is a much smaller negative effect on hourly productivity (-0.2 ppt) and an increase in output by almost 1%.

Why does the trade-off between employment at the two types of firms only exist in the alternative calibration? The answer is that STW affects employment at normal firms through multiple channels in both directions, and their importance differs across the calibrations. First, by preventing separations at distressed firms, STW reduces turnover, raises labor market tightness and thus makes it harder for normal firms to hire. This channel always lowers employment at normal firms. Second, distressed firms,

Moment	Symbol	Target Value	Model Value
Unemployment rate	u_{stst}	0.09	0.09
Worker finding rate	q_{stst}	0.7	0.7
Overall job-destruction rate	ϕ_{stst}	0.03	0.03
STW rate	χ_{stst}	0.007	0.007
Avg. STW hours reduction	K_{stst}^{av}	0.3	0.3
Volatility of unemployment	$\frac{sd(u)}{sd(y)}$	0.36	0.37
Real interest rate	r_{stst}	2.00	2.04
Elasticity of wages w.r.t productivity	see text	0.55	0.51
STW semi elasticity w.r.t. exp. firm output	see text	-0.040	-0.040
Flow prob. STW-STW (monthly)	see text	0.40	0.39
Consumption difference unemployment	see text	0.35	0.36
Consumption difference STW	see text	0.06	0.06

Table 15: Calibration fit of internally calibrated parameters, alternative calibration.

which do not separate due to STW, have a chance to recover, which raises employment at normal firms. This channel is stronger in the baseline than in the alternative calibration, because (i) the calibrated transition probability from the distress to the normal state is more than twice as high (47% vs 18%) and (ii) distressed firms are less likely to separate in subsequent periods, giving them more time to recover. Third, in the baseline calibration STW reduces endogenous separations not only at distressed firms, but also at normal firms, because access to STW raises their value in case they become distressed in the future. In the alternative calibration normal firms do not endogenously separate, so this channel is absent. Overall the first channel dominates in the alternative calibration, while the second and third channel dominate in the baseline.⁴²

H Wage determination, equilibrium definition, solution method, and summary of model equations

H.1 Wage determination

For wages, we assume collective bargaining to capture labor market institutions in continental Europe. The wage in Equation 29 in the main text can be rationalized from the following Nash bargaining game between a firm with median productivity \bar{z} and a realization of the profitability shock ϵ_t equal to zero, and a worker representative. For computational ease, we assume that the worker representative does not internalize the worker's asset holdings and the degree of risk aversion. Instead, we consider a risk-neutral representative. In that sense, our wage setting is in between that of Krusell et al. (2010) where workers' assets affect wages and studies that treat the wage as a constant share of output (e.g., Díaz Rodríguez et al., 2024).

On the side of the worker, every worker who is working full-time earns this wage. Workers on STW also receive a collective wage, according to the average working time

⁴²To save space, we only give this narrative explanation and do not perform a full, clean decomposition. The list of channels might not be exhaustive. For example, STW also stimulated vacancy posting by raising the value of a filled job.

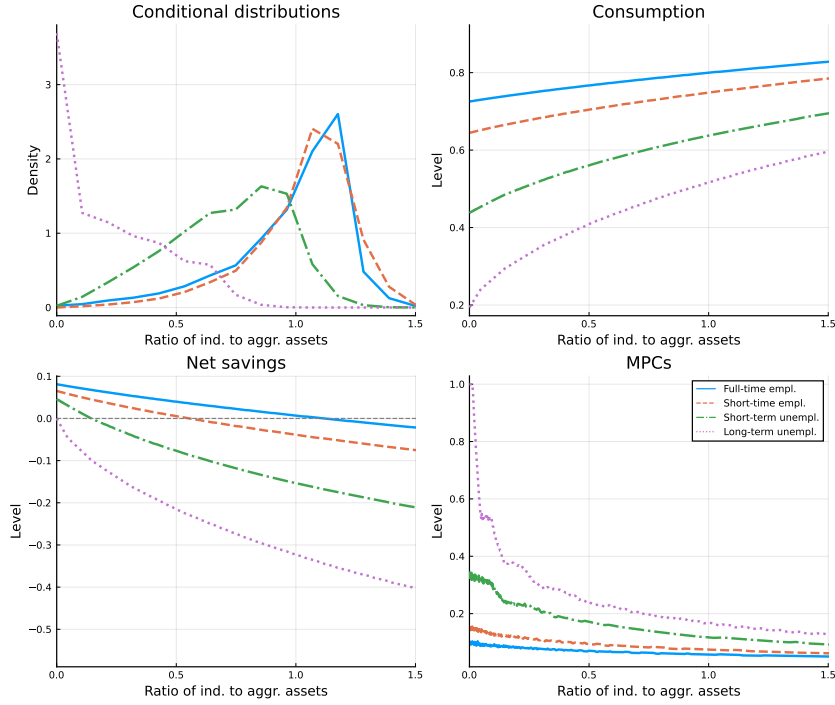


Figure 16: Model properties in steady state (alternative calibration). The figure shows the steady state asset distribution, policy rules for consumption and net savings and marginal propensities to consume (MPCs) under the alternative calibration.

of short-time workers, plus a reimbursement for the lost wage income. This type of bargaining makes the model easier to solve but implies inefficient separations.⁴³ The value of the median worker to the firm is therefore

$$F_t(\bar{z}) = \pi_t(\bar{z}, 0) + \beta^e \mathbb{E}_t \sum_{z' \in \bar{z}} \mathcal{P}(z' | \bar{z}) J_{t+1}(z') \quad (44)$$

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

$$\tilde{F}_t(\bar{z}) = \beta^e \mathbb{E}_t \sum_{z' \in Z} \mathcal{P}(z' | \bar{z}) J_{t+1}(z') \quad (45)$$

The worker representative's value W_t from a match is

$$W_t = w_t + \beta \mathbb{E}_t W_{t+1} \quad (46)$$

Lastly, the worker representative's fall-back option under disagreement is

$$\tilde{W}_t = \delta_{su,t} + \beta \mathbb{E}_t W_{t+1}. \quad (47)$$

⁴³The median worker is not affected by STW. Further, STW does not affect the outside option in the bargaining game as it is not a relevant outside option in case of wage disagreement. In practice, STW is only allowed in case of a temporary lack of demand and financial difficulties.

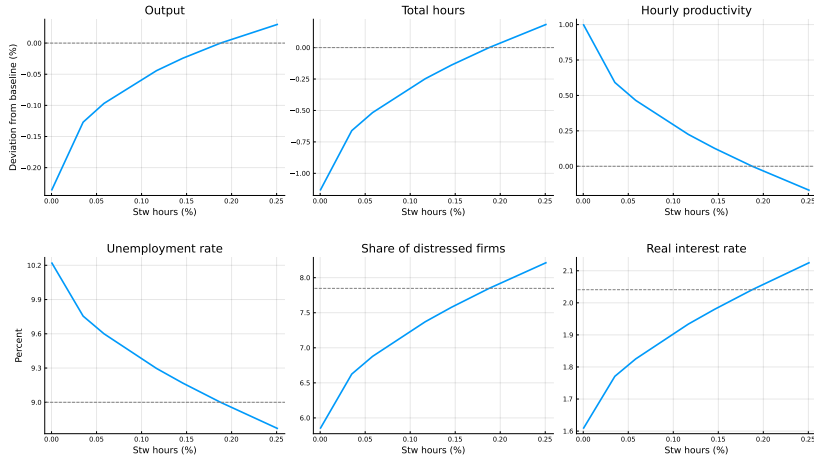


Figure 17: Illustration of the steady state trade-off associated with STW (alternative calibration). STW hours are in percent of the total labor endowment in the economy. Different values for STW hours are achieved by varying the cost parameter c_K . The point at zero on the horizontal axis is the limit $c_k \rightarrow \infty$. The grey dashed lines indicate the steady state under the alternative calibration.

In case of disagreement, the worker representative receives unemployment benefits $\delta_{su,t} < w_t$. The wage follows from

$$w_t^N = \arg \max (W_t - \tilde{W}_t)^\gamma (F_t - \tilde{F}_t)^{1-\gamma}, \quad (48)$$

where $\gamma \in (0,1)$ represents the bargaining power of the worker representative. The outcome of the wage bargain is shown in Equation 29.

H.2 Equilibrium definition and solution method

To define the equilibrium of the model, it remains to specify the joint distribution of workers over labor market states x and asset holdings. We define $\mathcal{Q}_t(b, x)$ as the mass of workers in labor market state x with asset holdings smaller or equal to b .⁴⁴ Summing up over all labor market states x , gives the marginal cumulative distribution over assets $\mathcal{A}_t(b) = \sum_{x \in X} \mathcal{Q}_t(b, x)$. Evaluating $\mathcal{Q}_t(b, x)$ at some maximal asset level \bar{B} such that $\mathcal{A}_t(\bar{B}) = 1$, gives the mass of agents in state x , $Q_t(x) = \mathcal{Q}_t(\bar{B}, x)$.

$\mathcal{Q}_t(b, x)$ evolves according to

$$\mathcal{Q}_t(b, x) = \sum_{x^l \in X} \mathcal{T}_t(x | x^l) \mathcal{Q}_{t-1}(\bar{b}_{t-1}^l(b, x^l), x^l) \quad (49)$$

where $\bar{b}_{t-1}^l(b, x^l) = \arg \max_{b^l} b_{t-1}^*(b^l, x^l) \leq b$. In words, $\bar{b}_{t-1}^l(b, x^l)$ is the largest value of last period asset holdings, for which the worker optimally chooses savings less or equal to

⁴⁴Because of the no-borrowing constraint, there are mass points in the asset distribution. No density function exists and we rely on cumulative distributions. Technically, we use the distribution *before* labor market transitions as the state variable in the numerical solution of the model instead of \mathcal{Q}_t which depends on the equilibrium transition probabilities \mathcal{T}_t in this period. See Reiter (2009), footnote 3. We omit this distinction for readability, but our numerical solution takes it into account correctly.

b conditional on x^l . Using $\bar{b}_{t-1}(b, x^l)$ relies on the weak monotonicity and continuity of the policy function, which are guaranteed as workers face a standard income fluctuation problem.

An equilibrium of the model then consists of

- a worker value function $U_t(b, x)$ which satisfies (2) and the associated policy function $b_t^*(b, x)$,
- a set of aggregate quantities, transition probabilities, and prices, which satisfy equations (4) - (41),
- and a distribution $Q_t(b, x)$ which obeys the law of motion (A-48),

given initial conditions and stochastic processes for the exogenous aggregate states a_t and β_t . We solve the household problem globally and non-linearly in the steady state with a value function iteration algorithm. For aggregate fluctuations we use first-order perturbation, i.e., we compute a first-order Taylor expansion around the steady state following the method developed by Reiter (2009).

H.3 Summary of model equations

$$\begin{aligned}
 U_t(b, x) &= \max_{b'} u(c) + \beta_t \mathbb{E}_t \sum_{x' \in X} \mathcal{T}_{t+1}(x' | x) U_{t+1}(b', x') \\
 \text{s.t. } c &= b(1 + r_{t-1}) + (1 - \tau_t) E_t(x) - b', \\
 b' &\geq 0,
 \end{aligned} \tag{A-1}$$

where $b_t^*(b, x)$ solves the optimization problem.

$$E_t(x) = \begin{cases} w_t & \text{if } x = (fe, z) \\ w_{stw,t} & \text{if } x = (stw, z) \\ \delta_{su,t} & \text{if } x = (su, 0) \\ \delta_{lu,t} & \text{if } x = (lu, 0) \end{cases}, \tag{A-2}$$

$$m_t = \mu u_t^\alpha v_t^{1-\alpha} \quad (\text{A-3})$$

$$u_{su,t} = (1 - \omega_l)(1 - \eta_{t-1})u_{su,t-1} + \sum_{z \in Z} \phi_t(z) \left(\sum_{z' \in Z} \mathcal{P}(z | z') n_{t-1}(z') + \mathcal{P}^n(z) m_{t-1} \right) \quad (\text{A-4})$$

$$u_{lu,t} = (1 - \eta_{t-1})(\omega_l u_{su,t-1} + u_{lu,t-1}) \quad (\text{A-5})$$

$$u_t = u_{su,t} + u_{lu,t} \quad (\text{A-6})$$

$$\theta_t = v_t / u_t \quad (\text{A-7})$$

$$\eta_t = \mu \theta_t^{1-\alpha} \quad (\text{A-8})$$

$$q_t = \mu \theta_t^{-\alpha} \quad (\text{A-9})$$

$$\phi_t^e(z) = \int_{v_t^f(z)}^{\infty} g(\epsilon) d\epsilon \quad (\text{A-10})$$

$$\chi_t(z) = \frac{1}{1 - \phi_t^e(z)} \int_{v_t^k(z)}^{v_t^f(z)} g(\epsilon) d\epsilon, \quad (\text{A-11})$$

$$\phi_t = \frac{\sum_{z \in Z} \phi_t(z) \frac{n_t(z)}{1 - \phi_t(z)}}{\sum_{z \in Z} \frac{n_t(z)}{1 - \phi_t(z)}} \quad (\text{A-12})$$

$$\chi_t = \frac{\sum_{z \in Z} \chi_t(z) n_t(z)}{n_t} \quad (\text{A-13})$$

$$n_t(z) = (1 - \phi_t(z)) \left(\sum_{z' \in Z} \mathcal{P}(z | z') n_{t-1}(z') + \mathcal{P}^n(z) m_{t-1} \right) \quad (\text{A-14})$$

$$n_t = (1 - \phi_t)(n_{t-1} + m_{t-1}) \quad (\text{A-15})$$

$$\frac{\kappa}{q_t} = \beta^e \mathbb{E}_t \sum_{z' \in Z} \mathcal{P}^n(z') J_{t+1}(z') \quad (\text{A-16})$$

$$\pi_t(z, \epsilon) = a_t z p_{I,t} - w_t - \epsilon, \quad (\text{A-17})$$

$$J_t(z, \epsilon) = \pi_t(z, \epsilon) + \beta^e \mathbb{E}_t \sum_{z' \in Z} \mathcal{P}(z' | z) J_{t+1}(z') \quad \text{if } \epsilon < v_t^k(z), \quad (\text{A-18})$$

$$J_t(z, \epsilon) = \pi_{stw,t}(z, \epsilon) + \beta^e \mathbb{E}_t \sum_{z' \in Z} \mathcal{P}(z' | z) J_{t+1}(z') \quad \text{if } \epsilon \geq v_t^k(z) \quad (\text{A-19})$$

$$J_t(z) = (1 - \phi^x) \int_{-\infty}^{v_{t+1}^f(z)} J_{t+1}(z, \epsilon) g(\epsilon) d\epsilon, \quad (\text{A-20})$$

$$v_t^f(z) = \pi_t(z, 0) + f + \beta^e \mathbb{E}_t \sum_{z' \in Z} \mathcal{P}(z' | z) J_{t+1}(z') \quad \text{if } v_t^f(z) < v_t^k(z), \quad (\text{A-21})$$

$$v_t^f(z) = \pi_t(z, 0) + \frac{f + \beta^e \mathbb{E}_t \sum_{z' \in Z} \mathcal{P}(z' | z) J_{t+1}(z')}{1 - K_t^*(z, v_t^f(z))} - \frac{C(K_t^*(z, v_t^f(z)))}{1 - K_t^*(z, v_t^f(z))} \quad \text{if } v_t^f(z) \geq v_t^k(z) \quad (\text{A-22})$$

$$v_t^k(z) = \pi_t(z, 0) + \beta \mathbb{E}_t J_{t+1}(z) - \zeta(z) \quad (\text{A-23})$$

$$K_t^*(z, \epsilon) = -\frac{\pi_t(z, \epsilon)}{c_k}, \quad (\text{A-24})$$

$$K_t^{av} = \frac{\sum_{z \in Z} n_t(z) \int_{v_t^k(z)}^{v_t^f(z)} K^*(z, \epsilon) g(\epsilon) d\epsilon}{n_t \chi_t} \quad (\text{A-25})$$

$$C(K) = c_k \frac{1}{2} K^2 \quad (\text{A-26})$$

$$d_t^I = \sum_{z \in Z} \frac{n_t(z)}{1 - \phi_t^e(z)} \left(\int_{-\infty}^{v_t^k} \pi_t(z, \epsilon) g(\epsilon) d\epsilon + \int_{v_{H,t}^k}^{v_t^f} \pi_{sw,t}(z, \epsilon) g(\epsilon) d\epsilon - \phi_t^e(z) f \right), \quad (\text{A-27})$$

$$d_t^W = (1 - p_{I,t}) y_t - \frac{\Psi}{2} (\Pi_t - 1)^2 y_t, \quad (\text{A-28})$$

$$d_t = d_t^W + d_t^I \quad (\text{A-29})$$

$$c_{e,t} = d_t - \kappa v_t, \quad (\text{A-30})$$

$$w_{N,t} = \gamma a_t \bar{z} p_{I,t} + (1 - \gamma) \delta_{su,t}, \quad (\text{A-31})$$

$$w_t = (w_{N,t})^{1-\gamma w} (w_{ss})^{\gamma w}, \quad (\text{A-32})$$

$$w_{stw,t} = \frac{\sum_{z \in Z} n_t(z) \int_{v_t^k(z)}^{v_t^f(z)} (1 - K_t^*(z, \epsilon)) w_t + \delta_{su,t} K_t^*(z, \epsilon) g(\epsilon) d\epsilon}{n_t \chi_t}, \quad (\text{A-33})$$

$$y_{j,t} = \left(\frac{P_{j,t}}{P_t} \right)^{-\epsilon} y_t, \quad (\text{A-34})$$

$$P_t = \left(\int_j P_{j,t}^{1-\epsilon} dj \right)^{\frac{1}{1-\epsilon}}, \quad (\text{A-35})$$

$$\Pi_t = \frac{P_{j,t}}{P_{j,t-1}}, \quad (\text{A-36})$$

$$0 = (1 - \epsilon) + \epsilon p_{I,t} - \Psi (\Pi_t - 1) \Pi_t + \beta^e \mathbb{E}_t \left\{ \Psi (\Pi_{t+1} - 1) \frac{y_{t+1}}{y_t} \Pi_{t+1} \right\} \quad (\text{A-37})$$

$$\frac{1 + i_t}{1 + r_{ss}} = \Pi_t^{\psi_\pi} \quad (\text{A-38})$$

$$T_t + B_t = (1 + r_{t-1}) B_{t-1} + \delta_t \sum_{z \in Z} n_t(z) \int_{v_t^k(z)}^{v_t^f(z)} K_t^*(z, \epsilon) g(\epsilon) d\epsilon + \delta_t u_{su,t} + \delta_{lu,t} u_{lu,t} \quad (\text{A-39})$$

$$\frac{B_t}{B} = \left(\frac{B_{t-1}}{B} \right)^{\rho_B} \left(\frac{n_t}{n} \right)^{(1-\rho_B)\gamma_B}, \quad (\text{A-40})$$

$$y_t = \sum_{z \in Z} n_t(z) \left[\int_{-\infty}^{v_t^k(z)} a_t z g(\epsilon) d\epsilon + \int_{v_t^k(z)}^{v_t^f(z)} a_t z (1 - K^*(z, \epsilon)) g(\epsilon) d\epsilon \right], \quad (\text{A-41})$$

$$c_{w,t} + c_{e,t} = \sum_{z \in Z} \int_{-\infty}^{v_t^k(z)} (a_t z - \epsilon) g(\epsilon) d\epsilon + \int_{v_t^k(z)}^{v_t^f(z)} (a_t z - \epsilon) (1 - K^*(z, \epsilon)) g(\epsilon) d\epsilon \quad (\text{A-42})$$

$$- \frac{n_t}{1 - \phi_t^e} \phi_t^e f - \kappa v_t - \frac{\Psi}{2} (\Pi_t - 1)^2 y_t,$$

$$B_t = \int_0^\infty (1 - \mathcal{A}_{t+1}(b)) db \quad (\text{A-43})$$

$$Q_t(x) = \begin{cases} (1 - \chi_t(z))n_t(z) & \text{if } x = (fe, z) \\ \chi_t(z)n_t(z) & \text{if } x = (stw, z) \\ u_{su,t} & \text{if } x = (su, 0) \\ u_{lu,t} & \text{if } x = (lu, 0) \end{cases} \quad (\text{A-44})$$

$$\mathcal{T}_{t+1}(x' | (e, z)) = \begin{cases} \mathcal{P}(z' | z)(1 - \phi_{t+1}(z'))(1 - \chi_{t+1}(z')) & \text{if } x' = (fe, z') \\ \mathcal{P}(z' | z)(1 - \phi_{t+1}(z'))\chi_{t+1}(z') & \text{if } x' = (stw, z') \\ \sum_{z' \in Z} \mathcal{P}(z' | z)\phi_{t+1}(z') & \text{if } x' = (su, 0) \\ 0 & \text{if } x' = (lu, 0) \end{cases} \quad (\text{A-45})$$

for $(e, z) \in \{(fe, z), (stw, z)\}$.

$$\mathcal{T}_{t+1}(x' | (su, 0)) = \begin{cases} \eta_t \mathcal{P}^n(z')(1 - \phi_{t+1}(z'))(1 - \chi_{t+1}(z')) & \text{if } x' = (fe, z') \\ \eta_t \mathcal{P}^n(z')(1 - \phi_{t+1}(z'))\chi_{t+1}(z') & \text{if } x' = (stw, z') \\ (1 - \eta_t)(1 - \omega_l) + \sum_{z' \in Z} \mathcal{P}^n(z')\phi_{t+1}(z') & \text{if } x' = (su, 0) \\ (1 - \eta_t)\omega_l & \text{if } x' = (lu, 0) \end{cases} \quad (\text{A-46})$$

$$\mathcal{T}_{t+1}(x' | (lu, 0)) = \begin{cases} \eta_t \mathcal{P}^n(z')(1 - \phi_{t+1}(z'))(1 - \chi_{t+1}(z')) & \text{if } x' = (fe, z') \\ \eta_t \mathcal{P}^n(z')(1 - \phi_{t+1}(z'))\chi_{t+1}(z') & \text{if } x' = (stw, z') \\ \sum_{z' \in Z} \mathcal{P}^n(z')\phi_{t+1}(z') & \text{if } x' = (su, 0) \\ (1 - \eta_t) & \text{if } x' = (lu, 0) \end{cases} \quad (\text{A-47})$$

$$Q_t(b, x) = \sum_{x' \in X} \mathcal{T}_t(x | x') Q_{t-1}(\bar{b}_{t-1}^l(b, x'), x') \quad (\text{A-48})$$

where $\bar{b}_{t-1}^l(b, x') = \operatorname{argmax}_{b'} b_{t-1}^*(b^l, x') \leq b$

$$\mathcal{A}_t(b) = \sum_{x \in X} Q_t(b, x) \quad (\text{A-49})$$

$$Q_t(x) = \begin{cases} (1 - \chi_t(z))n_t(z) & \text{if } x = (fe, z) \\ \chi_t(z)n_t(z) & \text{if } x = (stw, z) \\ u_{su,t} & \text{if } x = (su, 0) \\ u_{lu,t} & \text{if } x = (lu, 0) \end{cases} \quad (\text{A-50})$$

which is identical to

$$Q_t(x) = Q_t(\bar{B}, x)$$

for some maximal asset level \bar{B} .