Does Short-Time Work Save Jobs? A Business Cycle Analysis[†]

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Abstract

In the Great Recession most OECD countries used short-time work (publicly subsidized working time reductions) to counteract a steep increase in unemployment. We show that short-time work can actually save jobs. However, there is an important distinction to be made: While the rule-based component of short-time work is a cost-efficient job saver, the discretionary component is completely ineffective. In a case study for Germany, we use the rich data available to combine micro- and macroeconomic evidence with macroeconomic modeling in order to identify, quantify and interpret these two components of short-time work.

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1 Introduction

*"Germany came into the Great Recession with strong employment protection legislation. This has been supplemented with a "**short-time work scheme**," which provides subsidies to employers who reduce workers' hours rather than laying them off. These measures didn't prevent a nasty recession, but Germany got through the recession with remarkably few job losses." (Paul Krugman, 2009)*

In the Great Recession 25 out of 33 OECD countries used short-time work as a fiscal stabilizer. In countries such as Germany, Italy and Japan, more than 2% of the workforce were on short-time work in 2009, leading to fiscal expenditures of more than 5 billion Euro in each of those countries (see, e.g., Cahuc and Carcillo, 2011 and Figure 8 in the Appendix or Boeri and Bruecker, 2011). Yet, our knowledge about the business cycle effects of short-time work (STW henceforth) is limited so far. The purpose of this paper is to use German microeconomic and macroeconomic data as well as a macroeconomic model of the labor market in order to study the role of STW as a fiscal stabilizer.[1]

Germany has had a long tradition of STW and has used STW also outside of recessions.[2] Furthermore, Germany offers rich microeconomic data on the use of STW in establishments. In Germany, firms can use STW at any time subject to a set of rules. In order to be eligible, a firm has to convince the Federal Employment Agency ("Bundesagentur für Arbeit") that the expected demand for the firm's products is lower than its production potential and that it thus has to reduce its labor input.[3] If the Federal Employment Agency approves the STW application, it partly compensates workers for their lost income. The purpose of this instrument is to encourage firms to adjust labor input along the intensive margin (hours reduction) rather than the extensive margin (firings). Typically, more firms are eligible to use STW during a recession than during a boom. Thus, similar to the tax system, the institution STW as such can have automatic stabilization effects. We call this the rule-based component of STW. Beyond this, the German government frequently changes specific features of this rule such as the eligibility to use STW, i.e., there is also a discretionary component of this policy.

From the perspective of employers and forward-looking employment relationships, one might expect that the discretionary and rule-based components of STW have rather different effects on the economy. An important goal of this paper is to disentangle the potentially different effects of these two features of STW. The availability of both microeconomic panel data and macroeconomic time-series data from Germany makes this possible. In contrast with existing studies, which do not discuss

[1] Recent empirical cross country studies on STW (Cahuc and Carcillo, 2011, Arpaia et al., 2010, Hijzen and Venn, 2011, IMF, 2010 and OECD, 2010) found positive employment effects but were restricted to the Great Recession and miss the time-series perspective. For microeconomic studies with German data see Bellmann et al. (2010), Bellmann and Gerner (2011) and Speckesser (2010). The macroeconomic fiscal policy literature has so far almost exclusively focused on fiscal multipliers of traditional government tax and spending instruments. Blanchard and Perotti (2002), Mountford and Uhlig (2009), and Brückner and Pappa (2012) use structural VARs for this purpose and Cogan et al. (2010) or Christiano et al. (2011) use dynamic stochastic general equilibrium (DSGE) models. See Braun and Brügemann (2014) for a recent normative, non-dynamic study, comparing the effects of STW to unemployment insurance.

[2] See Figure 1 (solid line) for post-unification Germany and Figure 9 in the Appendix for STW usage in Germany back to 1975.

[3] See Burda and Hunt (2011, p. 297) or Brenke et al. (2013) for an excellent description of German "Kurzarbeit".

the possible confounding of the two features of STW, we find that whereas the rule-based component does work as an automatic stabilizer, unexpected discretionary STW appears to have no effect on unemployment. Given that many attribute much of the relatively favorable German unemployment experience during the last recession to the extra efforts at providing short-time work, this is arguably a surprising finding. It suggests more generally that the benefits of having a discretionary component of STW as a standard part of the labor-market policy toolkit are limited.[4]

How can these findings be interpreted? We attempt at an answer by formulating a model of a frictional labor market with STW. This setup allows us to study the relationship between STW and unemployment explicitly. In particular, it highlights the importance of future expectations about political institutions as an important determinant of hiring and firing on the labor market. As a matter of modeling, to our knowledge our paper is the first to integrate STW with both a rule-based and a discretionary component into a frictional labor-market model amenable to quantitative assessment.[5]

Our research strategy consists of three interrelated steps, namely the estimation of an elasticity from microeconomic data, a structural vectorautoregression (SVAR) and the simulation of a macroeconomic model of the labor market. We use establishment level data to estimate the automatic reaction of STW with respect to changes in output. Since all firms are subject to the same rules, we can use the cross-sectional dispersion of STW usage and a measure of output over time in order to estimate this elasticity. This elasticity is required for two purposes: First, we use it as a short-run restriction on the contemporaneous variation between STW usage and output for the identification of a SVAR in the spirit of Blanchard and Perotti (2002). Second, it imposes discipline on the parametrization of our macroeconomic model. We further simulate artificial data from the model and show that our SVAR can replicate the true model responses.

While the SVAR allows us to estimate the effects of unexpected discretionary STW policy interventions, the macroeconomic model allows us to run a counterfactual analysis of an economy with and without STW and hence, to quantify the automatic stabilization effects. Our SVAR results show that the effect of unexpected discretionary STW policy interventions on employment and unemployment is not statistically significant. Our counterfactual model analysis shows that STW acts as a fairly strong automatic stabilizer. In our baseline scenario, unemployment fluctuations are reduced by 21% and output fluctuations are reduced by 4% (compared to the economy without STW).[6]

[4]Burda and Hunt (2011) and Boysen-Hogrefe and Groll (2010) argue that STW has played only a limited role for the favorable development of unemployment in the Great Recession. Our evidence contains the Great Recession, but covers a much larger period. We do support a causal link between STW and unemployment, but only for the rule-based component.

[5]Faia et al. (2013) use a labor selection model and analyze STW as one of several fiscal instruments to stimulate the economy. Krause and Uhlig (2012) use a search and matching model along the lines of Ljungqvist and Sargent (2007) to analyze the effects of the German Hartz labor market reforms. They do not model STW explicitly but introduce labor market subsidies for the Great Recession to match the small increase in the unemployment rate during this period. Both studies do not distinguish between the discretionary and the rule-based component, while we show that this distinction is crucial for the evaluation of STW. Furthermore, our model describes the actual institutional features of STW in more detail than these existing studies. This allows us to match the stylized facts of STW that we document in the data. See Section 5 for more details.

[6]As laid out in more detail in Section 5, the tax system that stabilizes employment and unemployment fluctuations to a similar degree represents a much larger share of GDP than STW. Thus, we consider the stabilizing effect of STW as very strong relative to its costs.

The model provides an explanation for the differences between automatic stabilization and the effects of discretionary policy changes. The model consists of a standard search and matching framework with endogenous separations and firing costs. We assume that STW is the only possibility of labor adjustment along the intensive margin. This assumption can be justified on two grounds. First, it reflects the fact that, in Germany, labor adjustment along the intensive margin mainly happens through institutional channels such as STW (see Section 2 for a discussion). Second, we calibrate the model such that it yields an elasticity of STW with respect to changes in output that is in line with our empirical estimates. Thus, we are confident that allowing for other possibilities of adjustment along the intensive margin would not change our results significantly (for more details see Section 5).

In our model, workers are subject to idiosyncratic profitability shocks each period. Whenever the profitability of a worker is low enough such that the worker would otherwise have been fired, the government allows firms to use STW for this particular worker. The firm will decide to send her on STW whenever it is more profitable to keep her at reduced working hours rather than to fire her. By reducing the losses generated by unprofitable workers, STW directly reduces firing. By increasing the value of a job, STW indirectly increases hiring. During a recession more workers become automatically eligible for STW. This implies that more of the labor adjustment can be accomplished through the intensive margin relative to the extensive margin, as intended by the policy. This way, STW automatically stabilizes employment and, with it, output. In contrast, under the existence of a rule-based STW-system, discretionary changes in the eligibility criterion of STW do not affect unemployment in an economically and statistically significant way. An expansionary policy subsidizes extra workers that would not have been fired anyway.

Our baseline model encompasses institutional features such as firing costs and collective wage bargaining that describe a typical central European economy with relatively low labor market flow rates like the German one. Our analysis shows that these institutions matter for the effects of STW. In an economy with flexible labor markets (low firing costs, high flow rates, individual bargaining), the stabilizing effects of STW are much lower than in an economy with rigid labor markets. This result corresponds neatly to the empirical fact that mainly countries with rigid labor markets make extensive use of STW (see Figure 8 in the Appendix).

The rest of the paper is organized as follows. Section 2 documents some stylized facts on STW in Germany. Section 3 presents the microeconometric evidence on STW. Section 4 discusses the evidence from the structural VAR. Section 5 describes the model. Section 6 shows the simulation results. Section 7 concludes.

2 Short-time work facts

2.1 Short-time work over the business cycle

Germany has had a very long tradition of STW institutions. This allows us to assess the movements of STW over the business cycle. The year 1975 marks the beginning of the systematic use of STW

schemes in Germany, although STW has been used even before. Due to the oil price shocks and the subsequent recession, the German legislature passed a law inscribing the future use of STW schemes to be targeted explicitly to support employment, not to insure workers against wage cuts. In 1975, the legislature also established the reimbursement of workers covered by STW schemes to be 60% of the current wage. This law is still in place today.[7]

The solid line in Figure 1 shows the quarterly fraction of workers that are covered by STW schemes relative to total employment in Germany from 1993 to 2010.[8] We refer to this series as STW usage or the extensive margin of STW in the following. We show the series in logs for easier inspection and since this is the transformation used in the empirical exercises. The dashed line in Figure 1 depicts the intensive margin of STW, measured by the average hours reduction (relative to full time) of workers covered by STW programs. We use the post-reunification period as our baseline sample for two reasons. First, this excludes the usage of STW related to the transition period after reunification as well as the use of STW compensation in lockouts until 1986. This ensures that the VAR attributes movements in STW usage to discretionary policy changes that were implemented to stabilize employment in response to the business cycle ("konjunkturelle Kurzarbeit"). Second, we have information about the cyclical behavior of the intensive margin of STW in the shorter sample. We use this additional information to check the validity of our model.[9]

On average, 0.69% percent of the workforce were working short-time in the post-reunification period (0.83% in the long sample starting in 1975). Two large peaks indicate heavy use of STW institutions and, possibly, active discretionary policy favoring the use of STW: the post-unification period of the early 1990's and the recent Great Recession (in addition, the mid 1970's and early 1980's in the long sample, i.e., the two oil price shocks). About 1.5 million or 3.8% of workers in Germany were on STW at the peak of the Great Recession in May 2009. But also outside the severe recessions, the graph documents substantial variation in the series. STW usage both inside and outside severe recessions is negatively correlated with growth in GDP and employment and hence the business cycle (see Figure 10 in the Appendix). These contemporaneous correlations are potentially driven by two effects that are of interest to us: the rule-based and the discretionary component of STW. In our model in Section 5, STW automatically increases in a recession because more firm-worker pairs are unprofitable and thus eligible to use STW. Beyond this, policy makers may facilitate the access to STW in a discretionary way. In Section 3 and 4, we estimate the rule-based and discretionary component of STW in the data.

[7] See Flechsenhar (1979), Will (2010) and Brenke et al. (2013).

[8] Compare Table 5 in the Appendix for the data sources of all time series used in the analysis.

[9] We have information on the extensive margin of STW since 1975, compare Figure 9 in the Appendix. The long series consists of numbers for West Germany before and West and East Germany after the reunification in 1991. The data for West Germany and total Germany perfectly co-move except for a short period after the reunification in which STW was heavily used in East Germany to alleviate the transition from a planned to a market economy. We use the long time series to check the robustness of our results in Section 4.

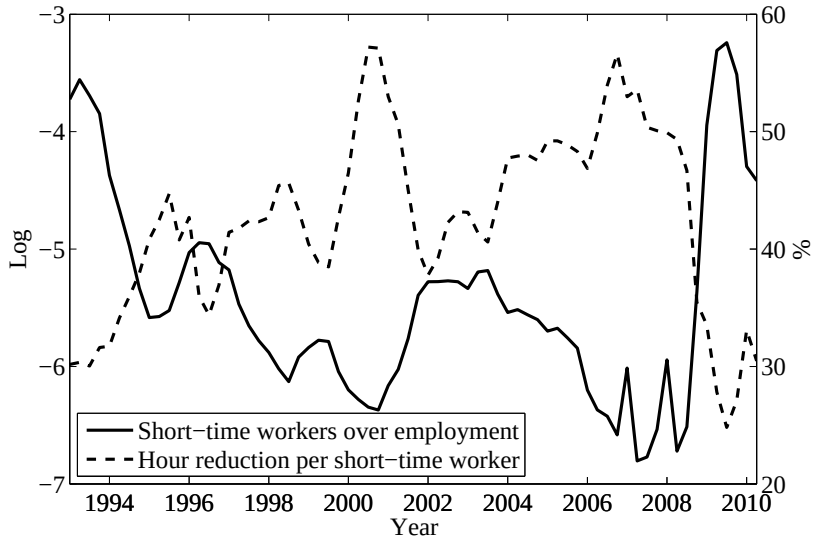

Figure 1: The extensive and the intensive margin of STW 1993-2010. The extensive margin of STW is measured by the log number of short-time workers as a fraction of total employment (left scale). The intensive margin of STW depicts the average hours reduction by those on STW as a fraction of hours worked when full-time employed (right scale).

2.2 Adjustment of labor input via STW

For the cyclical adjustment of labor input (total hours worked) in Germany, the extensive margin of labor input (number of workers) is generally more important than the intensive margin (hours per worker).[10] In contrast to the US, the importance of adjustment along the intensive margin increases in recessions in Germany. This was the case in particular in the Great Recession (10% adjustment along the extensive margin versus 90% adjustment along the intensive margin), as also documented in Burda and Hunt (2011). Our model reflects the fact that labor adjustment along the intensive margin becomes more important in recessions.

The intensive margin of labor input, given by hours worked per worker, can vary because the number of workers covered by STW programs (extensive margin of STW) changes since these workers work fewer hours than the regular full-time employed. Hours per worker can also vary when those on STW programs work more or less within these programs (intensive margin of STW). Figure 1 shows that these two STW margins are negatively correlated (with a correlation of $-.90$). This means that when more workers are covered by STW programs, hours worked of these workers increase, i.e., the more workers are on STW, the lower is the reduction in hours worked due to STW. At first this seems

[10]Between 1970Q1 and 2012Q2, 57% of labor input in Germany is adjusted along the extensive margin. Outside the large recessions, the extensive margin accounts for about 63% of the overall adjustment of labor input. We measure this as in Fujita and Ramey (2009) using the cyclical components (filtered with the HP filter with $\lambda = 1,600$) of total hours t, hours per worker h and employment n. The proportion of the intensive margin is given by $\frac{cov(t,h)}{var(t)}$, the proportion of the extensive margin is given by $\frac{cov(t,n)}{var(t)}$. Similar to the case of Germany, Reicher (2012) shows that the extensive margin is most important for labor adjustment in most of the continental European countries.

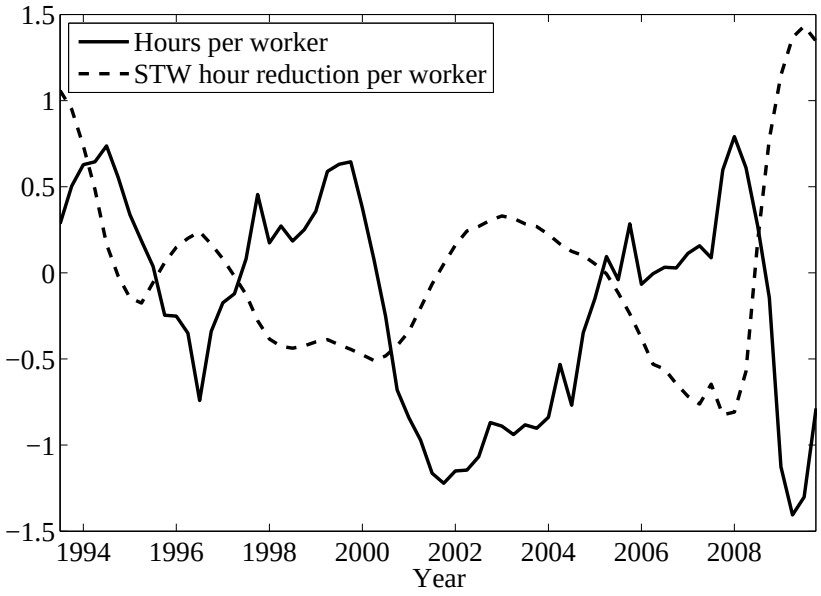

Figure 2: Hours per worker (solid line) are measured by total hours worked divided by employment. The hours reduction per worker due to STW (dashed line) multiplies the hour reduction per STW worker with the fraction of short-time workers in employment. The sample shows annual averages from 1993 to 2010. Both series are HP filtered with $\lambda = 1,600$, the hours per worker cycle is multiplied with 100 for expositional purposes.

surprising, but our model provides a plausible intuition: Workers whose profitability is too low to be kept full-time employed, but too high to be fired, will work reduced hours under the STW scheme. The less profitable a worker is, the shorter she will work. During a recession more workers are fired. This cleansing effect increases the average quality of short-time workers (in terms of idiosyncratic profitability), and hence lowers the optimal average hours reduction in recessions.

Figure 2 (dashed line) shows a measure of the reduction of hours worked per worker due to STW as the product of the hours reduction per STW worker and the fraction of short-time workers in employment. This measure strongly comoves with hours worked per employee (solid line) in the economy (with a correlation of $-.69$ measured using cyclical deviations from an HP-trend). Although this simple correlation does not provide a formal test, it suggests that STW is an important determinant of labor adjustment along the intensive margin. Complementing our findings, Abraham and Houseman (1994) find in a study for the 1970's and 1980's that the existence of STW schemes renders the hours adjustment in Germany equally flexible as the US adjustment.

Burda and Hunt (2011) decompose the hours reduction in the Great Recession into various different sources of adjustment. Their results emphasize the notion that labor market frictions in Germany are such that adjustment along the intensive margin is relatively costly due to rigid institutional constraints, e.g., heavy working time regulation. Given these constraints, adjustment along the intensive margin mainly happens through institutions, such as STW, but also working time accounts, overtime

or regular part-time work.[11] Our establishment survey data described below documents that firms that operate working time accounts tend to use more STW than other firms. This indicates that working time accounts and STW are complements rather than substitutes when adjusting hours. Taking annual averages at a quarterly basis in Figure 2 helps us to (at least partly) wash out the influence of overtime or working time accounts. Complementary, Burda and Hunt (2011) identify STW as the most important source of labor adjustment along the intensive margin. In our analysis, we focus exclusively on one possibility to adjust the intensive margin of labor input, namely through STW. Hence, we provide a lower bound of stabilization effects taking into account all possible ways of institutional adjustment of hours. Consistent with this assumption, we do not target the overall changes in the intensive margin to changes in output in our model, but use the results from our microeconometric analysis to calibrate the elasticity of STW with respect to changes in output.

3 Estimating the short-time work elasticity using microeconomic data

3.1 Specification

In the time-series data presented in the previous section, it is not possible to distinguish whether STW usage fluctuates because of changes in the business cycle (rule-based component) or because of changes in policy (discretionary component). We estimate the automatic stabilization effects of the rule-based component of STW from microeconomic data and use it for two purposes: First, in order to disentangle the two components of STW in the structural VAR. Second, as the key calibration target of our model and the corresponding stabilization exercise. In our model, the rule-based component of STW describes the elasticity of STW usage to changes in output when STW rules remain unchanged. When output drops, more worker-firm pairs become unprofitable and thus eligible to use STW. Firm output can change because of idiosyncratic shocks or because of aggregate shocks. Without changes in output, STW usage can only change when policy changes. We use this insight from the model in order to estimate the rule-based component from a firm panel for recent years.

The time and cross-sectional dimension of the panel data allows us to identify the rule-based component of STW. STW policy in Germany is implemented at the federal level providing the same rules for all firms. Hence, the cross-sectional variation of firm output and STW usage at a given point in time provides information about the rule-based component. However, firms that use STW (or a lot of STW) may systematically differ from firms that do not use STW (or very little STW). Consequently, we use within-firm variation over time rather than between-firm variation in output and STW usage in order to estimate the rule-based component. The following relationship describes the

[11] With working time accounts, the total annual working time is kept constant, but hours can be adjusted within the year. In contrast to STW, working time via accounts, overtime or part-time work can change, but is fully compensated by the firm. STW programs subsidize wages and, hence, constitute a regulatory framework which loosens working-time regulations for worker-firm pairs with bad idiosyncratic shocks, particularly in recessions.

effect of output x_{it} on the fraction of short-time workers in employment y_{it} in firm i and year t:

$$y_{it} = x_{it}\beta_1 + \alpha_i + \gamma_t + \mathbf{z}_{it}\beta_2 + u_{it}.$$

Here, α_i controls for time-invariant firm-specific effects in our estimation, i.e., systematic differences between firms in our sample. In order to rule out that we pick up discretionary policy changes in our estimation, we further include year-specific effects γ_t. Since STW policy applies at a federal level to all firms identically at the same point in time and firm data applies to the same point in time in a given year (June 30), the combination of firm and time fixed effects controls for the effect of discretionary policy changes on the estimated elasticities. The error term u_{it} is white noise, $\mathbf{z}_{it}$ denotes the vector of additional control variables that will be specified below. We estimate the elasticity of STW usage to output changes using three different specifications: A linear specification and two non-linear models (a Tobit and a Heckman model) that will be described in detail in the next section.

We employ the Institute for Employment Research (IAB) Establishment Panel, a representative German establishment level panel data set that surveys information from almost 16,000 personal interviews with high ranked managers. The IAB panel contains information on the number of employees in STW in each firm in four waves: 2003, 2006, 2009, and 2010.[12] The number of short-time workers in each firm is measured in the first half of year t. In order to abstract from firm-size, we denote short-time workers relative to the total number of employees within a firm. This is also consistent with our time-series measure and the definition of STW usage in the model. Note that the fraction of short-time workers in employment can be zero for a given firm. We use firms expected revenue as our measure for firm-level output in period t. This variable reflects the notion that firms have to show their need for STW, i.e., a danger of a reduction in labor input due to a fall in revenue, already in their application to the employment agency.[13] Moreover, for a given firm-specific demand, using this variable addresses a potential endogeneity problem stemming from potential reverse causality between STW usage and output. In fact, the use of STW affects current production more directly than expected revenue, because expected revenue is largely driven by demand. Note that we will use the estimated elasticity as an input into the SVAR and as a calibration target for the model. For both of these applications, it is sufficient to provide an estimate of the relationship between output and STW changes, i.e., their correlation, not necessarily their causal relationship. As additional controls in the estimation, we use the number of employees in the previous year as a measure of time-varying firm size.

[12] This dataset is widely used in a number of different studies, see for example Dustmann et al. (2009). Data access was provided via on-site use at the Research Data Centre (FDZ) of the German Federal Employment Agency (BA) at the Institute for Employment Research (IAB) and subsequently through remote data access. Table 6 in the Appendix provides descriptive statistics of the IAB establishment panel with respect to STW.

[13] See http://www.arbeitsagentur.de/zentraler-Content/Vordrucke/A06-Schaffung/Publikation/V-Kug-101-Anzeige-Arbeitsausfall-ab-01-2012.pdf

3.2 Results

Table 1 documents the estimation results. Across linear specifications (1 to 3), the effect of changes in expected revenue on STW usage is precisely estimated to range between -2.80 and -3.13 depending on whether we add year fixed effects or the size of the firm. These estimates measure the semi-elasticity of STW usage (in levels) to changes in expected revenue (in logs) and imply that in response to a one percent drop in expected revenue, firms have on average about 0.03 percentage points more workers on short-time. Year fixed effects are negative in 2006 and positive in 2009 and 2010 indicating that it is important to control for discretionary policy changes. Further, the larger the firm the more STW per employee is used in our sample.[14]

The linear specification ignores an important feature in the data. The firm makes two decisions with respect to STW: First, whether to use STW or not (participation decision) and, second, how much STW to use. In fact, across our sample, only 6.5% of all firms use STW on average, while for the others the number of short-time workers is zero. For our applications, the estimate of the overall elasticity needs to incorporate both the participation decision and the quantity decision with respect to STW. We therefore estimate two further models, a Tobit model and a Heckman selection model that take these non-linearities in the data into account.

The difference between these two models is that the participation decision of firms is taken into account, but not directly estimated in the Tobit model, while the Heckman model seeks to directly estimate the participation decision

Following Wooldridge (2010, p. 835), we estimate a Tobit model with fixed effects using pooled Tobit and Mundlak terms.[15] We report censored marginal effects which means that our estimates summarize the aggregate effect of a one percent change in expected revenue on the STW usage of all firms. Due to the nonlinear structure of the model, marginal effects are computed for each value of the right-hand side variables and are then averaged. Our estimate ranges from -2.32 to -2.61 (specifications 5 to 6) which corresponds to a response of STW of about $.025$ percentage points to a one percent reduction in revenue. Again, our results are significant at the 1% level.

Different from the Tobit model, the Heckman selection model explicitly estimates what determines whether a firm uses STW or not. Estimating these aspects may change the estimates of the overall elasticity, but is not essential for our later use of the elasticity as an input into the SVAR and as a

[14] We look at various additional specifications for robustness of our results. First, for a subsample of those firms that operate working time accounts, the STW reaction is stronger. Hence, more STW is used in firms with working time accounts than in those without. Second, as the usage of STW is likely to differ across industries, we also include industry fixed effects in the estimation as a robustness check. We can identify these effects, since some firms in our sample switch industries over time. Our estimates are robust towards this modification. We further add an interaction term of changes in expected revenue and year-specific effects, allowing for the possibility that firms react differently to output changes in different states of the business cycle. When including interaction terms, we calculate the elasticity based on β_1 and the average of the coefficients of the interaction terms over all years. Including interaction terms hardly changes the estimated elasticity. Our results show that STW is used more heavily in 2009 and 2010 than in 2003 and 2006. Excluding these last two years from the sample reduces the estimated elasticity to -1.5. Detailed results for all robustness checks are available upon request.

[15] As introduced by Mundlak (1978), we include firm-specific means of explanatory variables to capture permanent level effects in our estimation.

	log exp. revenue	derived elasticity	year fixed effects	employees in firm	observations
Linear fixed effects					
(1)	-2.802^{***} [0.306]	-4.003			$39,545$
(2)	-2.968^{***} [0.299]	-4.240	yes		$39,545$
(3)	-3.131^{***} [0.342]	-4.473	yes	yes	$31,824$
Fixed effects tobit					
(5)	-2.319^{***} [0.286]	-3.313	yes		$31,824$
(6)	-2.614^{***} [0.311]	-3.734	yes	yes	$31,824$
Fixed effects heckman					
(7)	-4.972^{**} [2.57]	-7.103	yes		$31,824$
(8)	-4.87^{*} [2.75]	-6.957	yes	yes	$35,264$

Table 1: Elasticity estimates. Dependent variable is the number of workers in STW over total employees in the firm. *** denotes 1% significance, ** denotes 5% significance, * denotes 10% significance.

calibration target of our model. To estimate selection, we need to argue why and how the decision of a firm of whether to use STW or not is determined differently from the decision on how many short-time workers to use. A panel version accounting for individual fixed effects is derived in Wooldridge (1995).[16] We use the fraction of firms using STW in the firm-specific industry sector as the exclusion restriction to identify our Heckman model. We argue that a large fraction of direct competitors using STW increases the individual firm-specific probability of using STW (as the stigma of admitting the need of STW is gone), while it does not drive the firm-specific number of workers in STW. Indeed, substantial variation in this variable exists across industries and we find significant effects on the STW decision in our estimation. In analogy to above, we want to measure the marginal effect of changes in expected revenue on STW over the whole sample of firms, and not only on those that use STW. In the Heckman approach, this is equivalent to the coefficients from the pooled OLS estimation controlling for selection into STW. Across Heckman specifications (7 to 8), our estimates range from -4.87 to -4.97 which means that a one percent drop in expected revenue generates an increase of about 0.05 percentage points in STW. Our estimates are significant, at least at the 10% level. Standard errors of the inverse Mill's ratios indicate that selection is present in our model specification.

[16]Estimation is pursued by first estimating a probit for the selection in STW separately for each year t. In a second step, we run a pooled OLS regression on the selected sample accounting for the inverse Mills ratios from step one and time fixed effects. We correct for firm fixed effects by including Mundlak terms and obtain standard errors using a panel bootstrap. See Wooldridge (2010, p. 835).

Since we have estimated the automatic feedback effects of changes in expected revenue on the use of STW in levels (a semi-elasticity), but use elasticities in the structural VAR and calibration of the model, we transform this estimate into an elasticity by dividing it by the average STW use in the sample of interest. For our baseline sample of 1993Q1-2010Q4 this corresponds to dividing by an average STW use of 0.69%. We report the derived elasticity estimates in the second column of Table 1. Our most conservative estimate of the STW elasticity across specifications is -3.31, while we obtain -7.10 at maximum.

4 SVAR evidence

4.1 Identifying short-time work shocks in a structural VAR

In the SVAR exercise we estimate the effects of discretionary STW policy on macroeconomic variables such as output and unemployment. The challenge when estimating these effects is that we do not explicitly observe exogenous discretionary changes in STW policy. The reason is that STW policy is effective along many dimensions, e.g., with respect to the eligibility criteria of firms (which are loosely defined and can potentially be interpreted very differently[17]), the legal allowances of the duration of workers in STW, or the degree to which the government can additionally reduce the firms' cost that is related to the use of STW (such as covering social security contributions of workers in STW[18]). Instead of using a direct measure of STW policy, we use a SVAR in the tradition of Blanchard and Perotti (2002)[19] to estimate the effects of discretionary STW policy shocks based on a simple assumption: Policy reacts with a one period implementation lag to changes in output. This seems to be a reasonable assumption in quarterly data.

The general VAR setup is based on a reduced-form estimation of

$$Y_t = B(L)Y_{t-1} + e_t, \qquad t = 1, ..., T,$$

where Y_t is a $N \times 1$ vector of endogenous variables, and the lag polynomial $B(L)$ represents $N \times N$ coefficient matrices for each lag up to the maximum lag length k. The reduced-form innovations are denoted by the $N \times 1$ vector e_t, which are assumed to be independent and identically distributed with mean zero and covariance Σ_e. We seek to identify the underlying structural shocks ω_t from transforming the reduced-form innovations e_t using a transformation matrix A such that

$$Ae_t = \omega_t.$$

In order to correspond to a model in which economic shocks are independent from each other, the structural innovations ω_t are assumed to be orthogonal (i.e., Σ_ω is diagonal). From orthogonality and

[17] See the discussion in Burda and Hunt (2011).

[18] See Bundesministerium für Arbeit und Soziales (2011).

[19] Blanchard and Perotti (2002) seek to identify the effects of a shock in fiscal policy on output, hence the output multiplier. We apply their framework in order to identify STW policy shocks.

normalization, we obtain $N(N+1)/2$ restrictions to identify the N^2 elements of the transformation matrix A. In order to exactly identify this matrix, we need $N(N-1)/2$ additional restrictions in order to obtain the underlying structural shocks. In a simple bivariate VAR, we need one additional restriction in order to find A.[20]

Two variables are important for identification in the VAR: output and STW usage. Key to the VAR exercise is to decompose the negative correlation between these two variables into an output (or business cycle) shock and a discretionary STW policy shock. Note that the assumption about the implementation lag of policy implies that all contemporaneous covariation of the STW usage and output is described by the rule-based component of STW. Put differently, output (or business cycle) shocks are defined through their automatic effects on STW usage in the short-run. This does not mean that policy shocks are unrelated to the business cycle. In fact, our results below show that large STW policy shocks occur during strong economic expansions and contractions.

We impose the value estimated from the microeconomic data in the previous section as the additional restriction on A as described above. Given that we have identified business cycle shocks via the rule-based component of STW, all remaining variation of STW usage and output is then attributed to discretionary changes in STW policy. Clearly, if the imposed automatic feedback effects from the business cycle onto STW are negative and large, the effect of the policy shock on output is small. In fact, if the negative automatic feedback effect is larger in absolute value than the negative covariation between STW and output, the effect of policy shocks on output becomes positive on impact. Hence, the value of the elasticity potentially plays a crucial role for the estimated effects of the discretionary policy shocks.[21] We look at robustness of the results to different values of this elasticity below and find that, within a reasonable range, the elasticity only matters for the impact effect.

Note that we identify the VAR with an elasticity describing how STW usage reacts to output changes on the firm level. This elasticity is not necessarily equal to a macroeconomic measure of the output elasticity of STW usage that would take into account all possible general equilibrium effects. Informing the VAR with this elasticity means that we assume that the two are the same (or very similar). In our model below, we argue that this is the case when labor market tightness does not play an important role in the wage bargaining. This result naturally arises in a model of collective wage bargaining, because the threat-point of the firm bargaining with a union cannot be to dismiss the whole workforce. Collective wage bargaining is a realistic description of European labor markets like the German one. If wages were allowed to adjust to changes in labor market conditions, our model predicts the macroeconomic elasticity to be smaller than the estimated one. Intuitively, wages that react more to business cycle conditions stabilize the value of a worker and thus rely less on STW. This suggests that we might use a value too low for our identification. Our robustness checks below show that smaller elasticities generate the same qualitative results.

[20] The identification in the bivariate VAR can be extended in a straightforward way to include more shocks and variables. The restrictions to identify output and policy shocks remains unchanged in this case and it is assumed that additional shocks have no effect on output and the policy variable on impact. See Blanchard and Perotti (2002) or Caldara and Kamps (2012) for a detailed description of the implementation.

[21] Caldara and Kamps (2012) has pointed this out with respect to the estimation of government spending and tax shocks.

4.2 Results

In our baseline estimation of the effects of business cycle shocks and exogenous STW policy changes, we specify a VAR with three variables: the fraction of short-time workers in employment (in logs), GDP growth and the log unemployment rate. We specify GDP in growth rates, since unit root tests suggest that this variable has a unit root.[22] In addition, we use GDP growth as measuring the business cycle component of this variable, since we can compare this to the output of a model with a constant steady state as the one presented below. We estimate the reduced form VAR as described above with four lags in the specification. We then use the formal relationship between the output elasticity of STW and the coefficients in the matrix A (as derived by Caldara and Kamps (2012) in the case of government spending or tax shocks) in order to implement the short-run restrictions. Here we use our lowest elasticity estimate of -3.3 as our baseline. We estimate the VAR for our baseline sample 1993Q1-2010Q4.

To see whether our estimated STW policy and output shocks are plausible, we consider the historical time series of the two shocks (shown in Figure 11 in the Appendix). Since these shocks are calculated from the reduced form residuals in the VAR, they occur every period, but differ in sign and magnitude. We do not literally interpret each of these small shocks as an actual output shock or discretionary policy shift. Instead, a moving average of the two shocks indicates economically meaningful output and STW shocks. Note that, except for the same quarter, we do not assume whether or how strong policy shocks are related to output shocks. Our identifying assumption merely states that output shocks and policy shocks cannot exactly coincide. Our results show that economic contractions and discretionary policy expansions generally have a (lagged) positive correlation, i.e., discretionary policy changes are related to the business cycle. The graph shows that policy expansions (contractions) sightly lag the economic contractions (expansions), e.g., in the contraction in the late 90's, the expansion around 2008 and in the Great Recession. The graph also shows that discretionary policy was not implemented in the economic contraction in the mid-2000's. These relationships reflect the usage of STW that was documented in Figure 1. Generally, STW policy works along many dimensions most of which we cannot directly observe. One exception is the legal maximum period of eligibility which is shown in Figure 12 in the Appendix. The Great Recession episode illustrates that our estimated policy shocks coincide with periods in which this aspect of discretionary policy is changed such as the reduction of the eligibility period in the second half of 2007 and in 2010 and its expansion in 2009.[23] The increase in the estimated policy shock in 2009 also reflects a cost reduction in STW usage due to increased reimbursement of social security contribution of STW workers.

Figure 3 shows the quarterly responses of output, STW usage and unemployment to positive one-

[22] In the case of unemployment, unit root tests give ambiguous results. If unemployment was integrated, it is clearly not cointegrated with GDP. In line with the model and the literature, we treat unemployment as a stationary variable.

[23] As a direct narrative measure one particular type of STW policy shocks, we can use the short time series of the eligibility period changes. The results are very similar to the SVAR results. However, they are insignificant, which is the result of very little variation in the series. Hence, the conclusion that discretionary STW policy is ineffective remains. The results are available upon request.

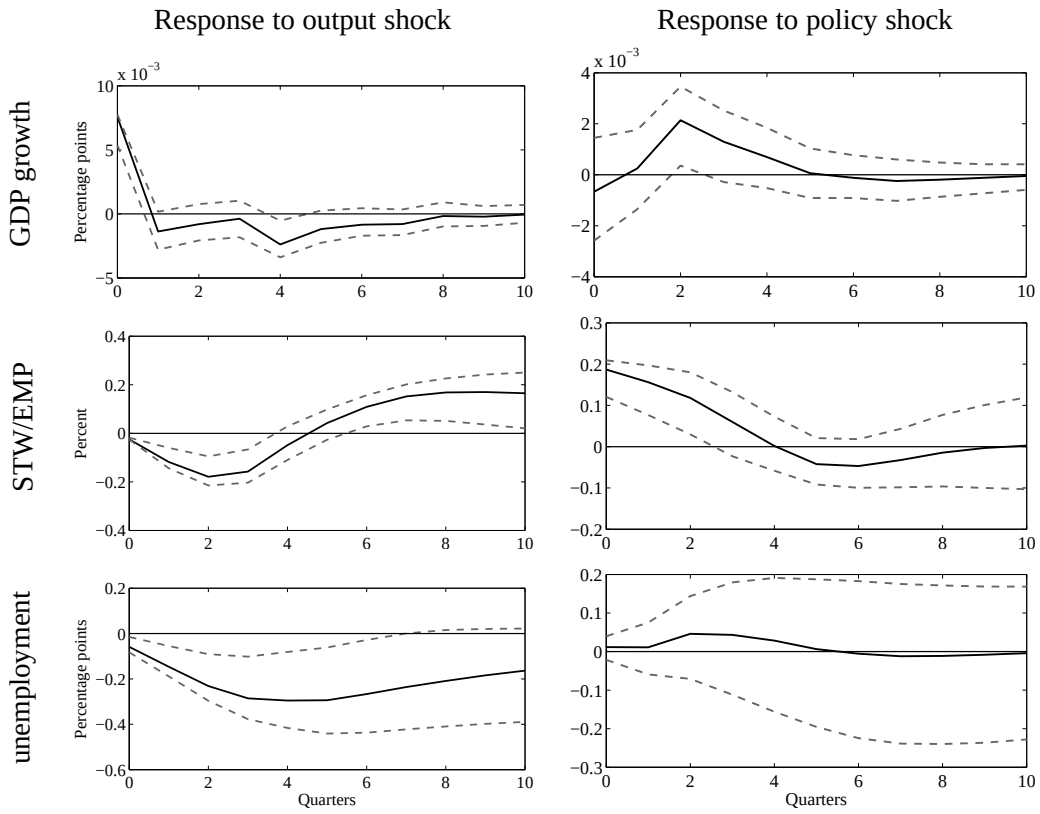

Figure 3: Impulse responses to output and STW policy shocks. SVAR estimated with log STW per employed workers, GDP growth and the log unemployment rate for 1993Q1 to 2010Q4. Quarterly responses to a positive one-standard deviation shock. Confidence intervals are 90% bootstrapped bands with 10,000 draws.

standard-deviation shocks in output and policy. To be comparable to the model output in Section 5, we show the response of output as deviations from a linear trend, i.e., in growth rates not in levels, and the responses of the unemployment rate in percentage points. The confidence intervals depict 90% bootstrapped bands that were calculated in line with Kilian (1998). The left column of Figure 3 shows the responses to a positive business cycle shock. After this shock, output increases, while STW falls reflecting the imposed short-run restriction of the automatic feedback effects along the business cycle. Unemployment falls in a boom. The right column of Figure 3 depicts the responses to a positive discretionary STW policy shock. After a positive policy shock, STW is used more. Since we have not imposed any restriction on this response, it is reassuring that it is in fact positive. Output does not show any significant impact response to a STW policy shock, except for a marginally statistically significant increase after two quarters. Strikingly, the unemployment rate does not significantly react to a STW policy shock. This is a surprising result, as STW schemes were initially designed to support employment. Our model will provide an interpretation of this result.

4.3 Robustness

We address the robustness of our results along various dimensions. Here, we distinguish three groups of robustness checks: First, robustness to the value of the estimated micro elasticity that is used for the identification of STW policy shocks. Second, robustness with respect to time variation in output (large recessions) and the policy variable (using additional direct evidence). Third, robustness regarding the specification of the SVAR. Table 7 in the Appendix documents the results of our robustness checks.[24]

4.3.1 Identification using the estimated elasticity

Above, we have discussed the importance of the imposed short-run restriction for the output elasticity of the policy variable. Given this, we assess how different assumptions about this elasticity affect the the estimated responses of output and unemployment after a policy shock. Figure 13 in the Appendix compares these responses for various values of the elasticity. Varying the elasticity does affect the impact response of GDP to the policy shock.[25] In line with our intuition from above, the more of the negative correlation between output and STW usage is explained by the automatic feedback effects, the larger are the effects of the policy shocks on output. If they are large enough, policy shocks can have positive effects on output. In fact, if the automatic feedback effects are relatively large, output significantly increases on impact. If they are zero or positive, output falls, significantly in the latter case. Note, however, that the estimates for later periods hardly change when different elasticities are used.

The effect of policy shocks on unemployment behaves similarly when varying the elasticity. Unemployment falls for relatively large negative elasticities and increases for zero or positive elasticities. However, except for positive elasticities of unplausibly high values, these effects are all insignificant. If we consider variation of the elasticity between -2.90 (corresponding to our most conservative Tobit estimate in column one of Table 1 plus the estimated standard deviation), -4.56 (corresponding to our largest Tobit estimate minus the respective standard deviation) and -11.90 (corresponding to our largest Heckman estimate minus the respective standard deviation), the responses of output and unemployment to policy shocks change very little.[26]

4.3.2 Time variation: Direct evidence and large recessions

As argued above, direct identification of STW policy shocks is difficult, as STW policy potentially works along many dimensions. We do not directly observe all aspects of these policy changes. One exception is the legal maximum period of eligibility for a particular worker in STW. We have information on this policy dimension for our baseline sample (see Figure 12 in the Appendix). One may

[24] See Table 5 in the Appendix for the data sources of all time series used in the analysis. More detailed results are available upon request.

[25] This is similar to what Caldara and Kamps (2012) has shown in the case of tax shocks.

[26] The same is true when we consider an elasticity of -1.5 that we have estimated based on data for 2003 and 2006 only.

associate periods with legal changes to this maximum period as episodes of particular political focus on STW schemes, e.g., the Great Recession. In order to exclude the possibility that STW policy was conducted in a systematically different way together with these legal changes, we incorporate a dummy controlling for these changes into our VAR. This is similar to Blanchard and Perotti (2002) who incorporate a dummy for large tax reforms into their fiscal VAR.

In Section 5, we apply our SVAR identification to data simulated with the model for two different types of STW policy shocks: A shock to the eligibility of STW and a shock to the cost of STW. We show that our SVAR is able to recover the true underlying policy responses.

In analogy to the argument above, one may associate recessions generally as periods with particular focus on STW policy. In other words, the relationship between output and STW may be different over time, which could potentially affect our identification. To control for these possible nonlinearities, we estimate our baseline specification including recession dummies for 1991Q1-1993Q1 and 2008Q1-2009Q2[27] and show that the results are not affected in any significant way. Table 7 and Figure 14 in the Appendix shows that our results are robust to controlling for legal changes in STW policy and recession periods this way.

4.3.3 Different SVAR specifications

In our model, business cycle shocks are measured by changes in output or labor productivity. Table 7 shows that our results are robust to replacing GDP with GDP per employed worker. This result may reflect the fact that relatively unproductive workers work short-time, while relatively productive workers continue to work full time or even increase their labor input. Hence their weight in aggregate productivity increases. Next, we use the GDP deflator instead of the CPI to deflate output. This does not change our results substantially. To assess the robustness of the unemployment response to policy shocks, we replace the unemployment rate by employment and total hours worked, respectively. As with unemployment, both variables show an insignificant response to the policy shock. Clearly, policy shocks do not have a significantly positive effect on hours or employment. Policy shocks do also not have a significantly positive effect on output in this setup.

One may wonder whether our identified shocks pick up the effects of other important macroeconomic shocks. Shocks that cover future information about the business cycle, so-called news shocks, are one candidate. To control for the presence of news shocks or any type of anticipation effects, we include a business confidence indicator (the ifo business climate index) into our specification. With this indicator, both unemployment and output do not react significantly to policy shocks. To control for monetary policy shocks, we include the interest rate as measured by the 3-months money market rate into the SVAR. Table 7 shows that including the interest rate does not change our baseline results. Likewise, we control for movements in aggregate consumption and investment in two further SVAR specifications. Again, this does not change our results.

Finally, we consider the long time series which cover the period 1975 to 2010. This data then

[27] We measure recessions as peak to trough of the GDP series that is HP-filtered with smoothing parameter $\lambda = 1,600$.

captures important economic events such as the oil price crises. However, we face a severe structural break due to the German reunification in 1991. To eliminate the level effect in the data, we regress the growth rates of GDP and unemployment on a reunification dummy. We further account for a general structural break in the VAR using a broken constant before 1991 and afterwards. To circumvent potential problems with the heavy use of STW in East Germany directly after reunification for reasons not related to the business cycle, we only use STW data for West Germany.[28] Since the mean STW usage in the long sample is higher than in the short sample (0.83%), we reduce our elasticity estimate to -2.79. Note that our elasticity estimate stems from microeconomic survey data for the years 2003, 2006, 2009 and 2010. Thus, our estimate possibly deviates from the true elasticity estimate in the long sample. This is less of a concern in the short sample. In addition to estimating our baseline specification in the long sample, we also add recession dummies (1973Q1-1975Q2, 1980Q1-1982Q2, 1991Q1-1993Q1 and 2008Q1-2009Q2). Table 7 shows that the results are overall similar to the ones from the short sample. In contrast to the short sample, output does not show any significant increase anymore. Unemployment increases, though insignificantly. This documents that even when taking into account early recessions, discretionary STW policy changes have on average not been very successful in stabilizing employment or output in recessions.

5 A labor market model with short-time work

5.1 Model description

Our paper quantifies the effects of the rule-based and the discretionary component of STW. While the SVAR has shown the non-effects of discretionary policy changes on unemployment, it is silent about the underlying economic rationale. In addition, we analyze the automatic stabilization of the rule-based component of STW for which we need to model the counterfactual economy without STW. Thus, we need a model that integrates important institutional features of the German economy to deliver credible results and that is rich enough for quantitative analysis. We use the search and matching framework of Diamond (1982) and Mortensen and Pissarides (1994) to model job findings and endogenous job separations assuming that worker-firm pairs are subject to idiosyncratic shocks. We then incorporate STW in this model. The key equations are shown in the main part. More details can be found in Appendix B.

A few words on specific assumptions of the model are in order: First, we assume that STW is the only way to use the intensive margin of labor adjustment. This assumption can be justified on the grounds that in normal times the extensive margin is far more important than the intensive margin, while in deep recessions, STW plays a very important role in rendering the intensive margin more flexible (see Section 2). Hence, we do not consider the role of instruments other than STW that may make the intensive margin more flexible such as working time accounts. Note, however, that we

[28] As mentioned above, the series for the number of short-time workers in total and West Germany excluding the reunification period have a strong correlation of 0.99.

calibrate the model in such a way that the model-elasticity of STW with respect to changes in output corresponds to its empirical counterpart (for more details see Section 6.1). Thus, if we included other means of adjustment along the intensive margin in our model and did not change the parameters of the model, the effects of STW would be diminished (as firms could use the other means of adjustment as substitutes[29]) However, as a consequence the elasticity of STW with respect to changes in output would not correspond to the empirical elasticity any more. Then we would have to recalibrate the model to match the empirical elasticity. This would re-establish the importance of STW. As a result, we are confident that the quantitative results would remain similar if we included other means of adjustment along the intensive margin.

This issue would only be worrisome if we calibrated our model such that STW is responsible for the adjustment of the entire intensive margin in deep recessions. Instead, we calibrate our model to the elasticity of STW with respect to output that we have estimated in Section 3.

Second, firms in our model would reduce the working time of unprofitable workers to zero unless they are subject to some form of adjustment cost. The data shows that a 100% working time reduction rarely happens. Only for 8% of workers on STW the working time is reduced to zero. On average the working time for workers on STW is reduced by approximately one third.[30] To allow for a working time reduction of less than 100% and to keep our model tractable, we assume that firms are subject to convex costs of reducing working time. Below we provide some institutional underpinnings, but we do not provide deep microfoundations for the observed firm behavior.

Third, we assume that wages are determined on the collective level (which is true for the majority of contracts in Germany) and that the wage for a full-time worker is unaffected by the STW decision of the firm (although a working time reduction obviously reduces the paid-out wage for a worker on short-time). We also check for the robustness of our results by simulating a US style economy with individual bargaining.

For normative work, it is crucial to provide a deep microfoundation as well as a constrained efficient benchmark for the interaction between the firm and the worker with STW. For our purposes, i.e., the quantification of the rule-based component and an interpretation of the SVAR results, these limitations are only of second order. Most importantly, the model does a very good job in replicating the business cycle features of the extensive and intensive margin of STW and offers a plausible explanation for the SVAR results. We further check the robustness of our results with respect to some of the above mentioned assumptions, such as changing the bargaining rule or varying the level of firing costs.

The timing in the model is as follows: First, agents in the economy learn about the level of aggregate productivity. Second, unemployed workers search for a job and firms post vacancies. Third, the matching function establishes contacts between workers and firms. Fourth, new contacts and

[29] However, evidence from the German establishment data in Section 3 suggests that firms that use working time accounts are also more likely to use STW.

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

incumbent workers are hit by an idiosyncratic shock. Fifth, the wage is determined. Finally, firms make their endogenous separation and STW decisions, based on the idiosyncratic shock realization.

5.2 Separation and short-time work decisions

Since STW is targeted at reducing separations, we start by deriving the separation decision and show how it is affected by STW. As is standard in the literature we endogenize separations by assuming that the profits generated by a worker depend on the realization of an idiosyncratic shock, ε_t. We assume that the idiosyncratic component is additive and has the interpretation of a profitability shock. With additivity, worker-firm pairs may generate negative contemporaneous value added, even with zero fixed costs.[31] The shock ε_t is drawn from the random distribution $g(\varepsilon_t)$ and is i.i.d. across workers and time. We will first describe the STW decision and then the firing decision because the latter depends on the former.

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

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

where a_t is aggregate productivity, w_t is the wage of the worker, c_f is a fixed cost of production, β is the discount factor and J_{t+1} the expected value of the worker next period (see equation (11) for the definition). The fixed cost of production c_f was introduced by Christoffel and Kuester (2008) to generate the large volatility of unemployment over the business cycle found in the data, without resorting to wage rigidity or using a large value of unemployment benefits/home production.[32]

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

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

We interpret D as an instrument to conduct discretionary STW policy. By lowering D_t, the government makes the eligibility criterion more stringent and directly reduces the number of workers on STW. In our benchmark calibration, we assume $D_t = -f$, where f is the cost of firing a worker. This implies that the STW-threshold in equation (2) coincides with the firing condition of an equivalent matching model without STW. This assures that only those workers are allowed to be sent on STW that would otherwise have been fired. With this modeling choice we replicate the German rule that says that any firm that is in difficulties such that it would otherwise have to fire a substantial part of

[31] Interestingly, negative contemporaneous value added allows us to provide an interpretation for the SVAR results, i.e., why discretionary short-time work may have a positive effect on output. Note, however, that our result that discretionary STW leaves employment unaffected does not depend on the additivity of the shock.

[32] It is well known from the literature that the search and matching model has trouble to replicate the labor market amplification effects over the business cycle from the aggregate data (Shimer, 2005). See Costain and Reiter (2008) for a discussion. We choose fixed costs as proposed by Christoffel and Kuester (2008) to solve this problem because it seems the most innocuous assumption in the context of our approach (the alternative of larger unemployment benefits would, for example, show up in the government budget constraint and thereby distort the cost and benefit analysis of STW).

its workforce, can apply for STW. When quantifying and simulating the model in Section 6, we show the effects of loosening the eligibility criterion, i.e., of increasing D_t.

Based on equation (2) we can define a threshold-level v_t^k for the idiosyncratic component ε_t

$$v_t^k = a_t - w_t + \beta E_t J_{t+1} - c_f - D_t, \tag{3}$$

such that workers with $\varepsilon_t < v_t^k$ work full-time, while workers with $\varepsilon_t > v_t^k$ are allowed to be sent on STW, i.e., the least profitable workers will use STW.[33]

When a worker is eligible for STW, the firm has the option to adjust along the hours margin. Without any further restrictions, firms would choose 100% STW for unprofitable workers in our model. However, as described above, the average working time reduction in the data is only about one third. Assuming a linear cost function would not solve this problem because it would imply corner solutions such that workers either work full time or their working time is reduced by 100%. Therefore, we assume that the optimal working time reduction K is subject to convex STW costs $C\left(K\left(\varepsilon_t\right)\right)$, with $\frac{\partial C(K(\varepsilon_t))}{\partial K(\varepsilon_t)} > 0$ and $\frac{\partial C(K(\varepsilon_t))^2}{\partial^2 K(\varepsilon_t)} > 0$, which assures interior solutions. There are many institutional reasons in Germany for such a convexity. First, although the employer reduces the labor costs with STW, the reduction is not necessarily proportional to the working hours reduction because the employer has to pay the social security contributions for the full time equivalent.[34] Second, the implementation of STW must be approved by the workers' council.[35] As long as there is no approval, workers have the right to obtain their full wage. Workers' councils are generally more willing to approve small working time reductions than larger working time reductions because employees only receive a partial compensation for their wage loss. Our convex adjustment function is a short-cut for the interaction of many factors (besides the institutional features, the shape of the production function or variable capital utilization may matter in reality). We defend our short-cut based on its empirical performance. We will show in the simulations that our model replicates the cyclical movement of the number of workers on STW and the average hours reduction due to STW very well.

The firm chooses the optimal level of the working time reduction K by maximizing the contemporaneous profit of a worker on STW:[36]

$$\max_{K(\varepsilon_t)} \pi_t = \left(a_t - w_t - \varepsilon_t\right)\left(1 - K\left(\varepsilon_t\right)\right) - c_f - C\big(K\left(\varepsilon_t\right)\big). \tag{4}$$

[33] In contrast to Faia et al. (2013), this defines the rule-based component of STW. Worker-firm pairs with a lower profitability level can automatically use STW and choose an optimal hours reduction. This allows us to calibrate our model with the estimated elasticity and to quantify the automatic stabilization effects of STW.

[34] See Boeri and Bruecker (2011) who argue that these institutional features generate a convexity in the cost of STW.

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

[36] This is an important difference to the earlier models in Faia et al. (2013) and Krause and Uhlig (2012). In contrast to these, firms in our model decide optimally about the working time reduction of workers on STW, while in Krause and Uhlig (2012) hours are not reduced at all and in Faia et al. (2013) the hours reduction is exogenous and the same for all firms. Endogenous hours reduction is not only realistic but allows us to distinguish between the extensive margin and the intensive margin of STW and base them both on optimal firm decisions. As demonstrated further below our model replicates well the empirical movements of both margins.

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

$$C\big(K\left(\varepsilon_t\right)\big) = c_K \frac{1}{2} K\left(\varepsilon_t\right)^2. \tag{5}$$

This implies that the optimal hours reduction of STW for a given ε_t is

$$K^*\left(\varepsilon_t\right) = -\frac{a_t - w_t - \varepsilon_t}{c_K}. \tag{6}$$

Naturally, the lower the profitability of a worker, i.e., the higher the realization of ε_t, the higher the working time reduction ($\frac{\partial K^*(\varepsilon_t)}{\partial \varepsilon_t} > 0$). We can now describe the firing decision of the firm, which depends on the working time reduction K. Workers are fired if the losses they generate are higher than the firing cost:

$$\left(a_t - w_t - \varepsilon_t\right)\big(1 - K\left(\varepsilon_t\right)\big) - C\left(K\left(\varepsilon_t\right)\right) - c_f + \beta E_t J_{t+1} < -f. \tag{7}$$

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

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

Thus, the endogenous separation rate is

$$\phi_t^e = \int_{v_t^f}^{\infty} g\left(\varepsilon_t\right) d\varepsilon_t, \tag{9}$$

and the rate of workers on STW is

$$\chi_t = \int_{v_t^k}^{v_t^f} g\left(\varepsilon_t\right) d\varepsilon_t. \tag{10}$$

Figure 4 illustrates the distribution of the idiosyncratic shock and both threshold values. All workers with a profitability shock realization above the STW threshold v_t^k are eligible for STW, but workers above the firing threshold v_t^f are so unprofitable that they are fired despite the possibility to send them on STW. Note that STW exists in this economy if $v_t^f > v_t^k$. This is the case as long as STW costs are not prohibitively high. If the scale parameter or the STW cost function c_K approaches infinity, then $K = 0$ from equation (6), i.e., firms do not use STW. In this case the STW threshold and the firing threshold are identical: $v_t^f = v_t^k$. This limiting case will be used for the counterfactual analysis in the numerical part. If c_K is smaller than $a_t - w_t - \varepsilon_t$, the firm optimally reduces hours worked for those on STW to zero. In that case, no firing occurs. For the value of c_K that we calibrate, the working time reduction for those on STW will be strictly between zero and 100%.

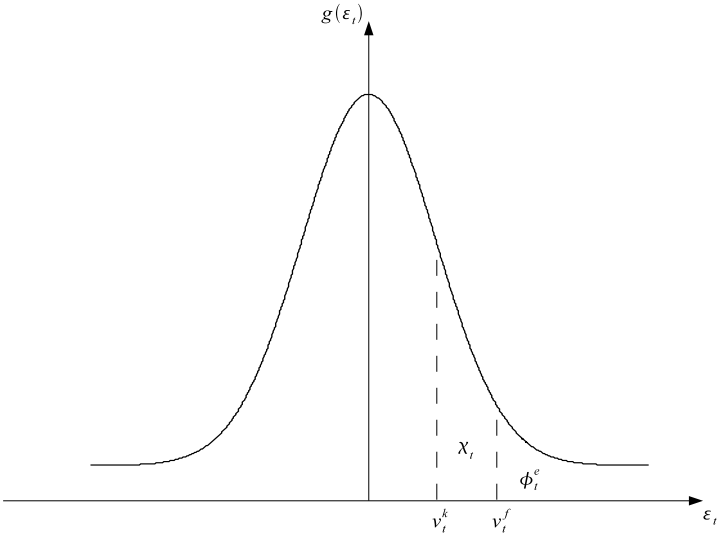

Figure 4: Illustration of the distribution of idiosyncratic shocks to the worker-firm pair and firing threshold v^f and STW threshold v^k.

From equation (8) it follows that positive values of the working time reduction K affect the firing threshold v_t^f positively due to a direct effect and a reinforcing indirect effect. The working time reduction directly reduces the losses generated by a worker and thereby makes the firm more reluctant to fire a worker. At the same time, the possibility to reduce the future losses generated by a worker increases the expected value of a worker, which indirectly lowers the incentives to fire. Both effects shift the threshold v_t^f upwards relative to v_t^k and imply both a positive range of workers on STW and a smaller range of workers being fired compared to the situation without STW in which $v_t^f = v_t^k$.[37]

Note that the existence of STW in our model does not depend on the exact bargaining regime, nor on the assumption of positive fixed costs and/or firing costs. We need the fixed costs of production to calibrate our model to the estimated elasticity of STW with respect to output. And we add firing costs and collective bargaining to replicate realistic European institutions. But even if $f = c_f = 0$ and under individual bargaining, some workers exist who would generate contemporaneous losses, but who would not be fired. The reason is that costly hiring due to search and matching frictions (see the next section) implies that the future value of a worker is always positive. So even in this setup, some firms have an incentive to use STW.

It should further be noted that it is both in the interest of the firm and the worker to use STW rather than to separate the match. The firm is free to choose the optimal working time reduction. It will only use a positive level of STW if this increases profits. Although the worker has no choice in our model,

[37]Note that the increase in J_{t+1} also indirectly shifts the STW threshold. However, the described direct effect is absent and therefore v^f shifts by more than v^k.

her participation constraint will not be violated. Even though STW reduces her income relative to full employment, the worker is even worse off if she quits. In that case the income in the current period would be just the unemployment benefit b, while it is $bK + (1 - K)w$ if the worker stays employed and on STW (as usual under German STW rules). Thus, since $w > b$, a quit would imply a loss in contemporaneous income. Furthermore, quitting the job implies a lower chance of having a job in the next period and, thus, reduces the continuation value of the worker.

We are now in a position to define the expected value of a worker, before the realization of the idiosyncratic shock ε_{t+1} is known:

$$\begin{aligned} J_{t+1} = {} & (1-\phi^x) \int_{-\infty}^{v^k_{t+1}} (a_{t+1} - w_{t+1} - \varepsilon_{t+1})\, g(\varepsilon_{t+1}) d\varepsilon_{t+1} \\ & + (1-\phi^x) \int_{v^k_{t+1}}^{v^f_{t+1}} \left[(a_{t+1} - w_{t+1} - \varepsilon_{t+1}) \left(1 - K\left(\varepsilon_{t+1}\right)\right) - C\left(K\left(\varepsilon_{t+1}\right)\right) \right] g\left(\varepsilon_{t+1}\right) d\varepsilon_{t+1} \\ & - (1-\phi_{t+1})\, c_f - (1-\phi^x)\, \phi^e_{t+1} f + (1-\phi_{t+1})\, E_{t+1} \beta J_{t+2}. \end{aligned} \tag{11}$$

Here,

$$\phi_{t+1} = \phi^x + (1-\phi^x)\, \phi^e_{t+1}, \tag{12}$$

is the overall rate of job destruction, which depends on the endogenous rate of job destruction defined in (9) and on the exogenous rate of job destruction ϕ^x. The first integral in equation (11) is the expected revenue of workers who work full-time. The second integral is the expected revenue of workers on STW. Here, we need to take into account that these workers have reduced working time, but that the firm has to incur the cost of STW. The fixed cost has to be paid for all employed workers. The firing cost has to be paid only for endogenous, not for exogenous separations.

5.3 Matching on the labor market

While we have focused on the firing and STW decision of the firm so far, we now formulate the rest of the labor market. Matches m_t are determined by a Cobb-Douglas matching function

$$m_t = \mu u_t^{\alpha} v_t^{1-\alpha}, \tag{13}$$

where u_t is unemployment, v_t are vacancies and α is the matching elasticity with respect to unemployment. The parameter $\mu > 0$ is the matching efficiency. We assume free entry of vacancies. The worker finding rate q_t (i.e., the probability of a firm to fill a vacancy) is

$$q_t = \mu \theta_t^{-\alpha}, \tag{14}$$

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

$$\eta_t = \mu\theta_t^{1-\alpha}. \tag{15}$$

The present value of a vacancy is defined as[38]

$$V_t = -\kappa + \beta E_t q_t J_{t+1} + E_t \beta\,(1 - q_t)\, V_{t+1}, \tag{16}$$

where J_{t+1} is the value of a job and κ are the vacancy posting costs. Free entry implies that in equilibrium $V_t = 0 \,\forall\, t$ which simplifies the above equation to

$$\kappa = \beta E_t q_t J_{t+1}. \tag{17}$$

In equilibrium the vacancy posting cost has to equal the expected payoff of the vacancy, which consists of the probability to find a worker and the value of a successful match.

5.4 Employment evolution

The evolution of the employment rate $n_t = 1 - u_t$ in this economy is described by

$$n_t = (1 - \phi_t)\, n_{t-1} + (1 - \phi_t)\, \eta_{t-1}\, (1 - n_{t-1})\,. \tag{18}$$

The employment rate in the current period includes workers of the previous period who were not fired and unemployed workers who got newly matched. As stated above, this law of motion reflects that both existing and new matches are subject to the separation risk. Workers on STW are treated as employed, corresponding to the official German employment statistics (although they do not work full time).

5.5 Wage bargaining

Finally, we specify wage formation. Collective wage bargaining is the predominant regime in continental Europe and especially in Germany.[39] Therefore, we use a simple model of collective wage bargaining for our baseline simulation. We assume that the wage is bargained between the representative firm and the incumbent worker for whom the realization of the profitability shock equals its expectation of zero. Every worker who is working full time earns this wage. Every worker who is on STW gets a share of this wage, according to her working time (plus some reimbursement for the lost

[38] Note that we have assumed that new matches are also subject to separation risk. This is taken into account in the definition of J_{t+1} in equation (11).

[39] According to OECD (2012a), the collective bargaining coverage (share of contracts covered by collective bargaining) in Germany was 72% in 1990 and 62% in 2009.

wage income). Hence, the wage does not depend on the idiosyncratic profitability of a worker, which implies inefficient separations. However, we will also show the results for individual wage bargaining.

The profit of the median worker-firm pair (with idiosyncratic profitability shock zero) of a match is[40]

$$F_t = a_t - w_t - c_f + \beta E_t J_{t+1}. \tag{19}$$

In case of disagreement, production will come to a halt (e.g., due to a strike), and bargaining will resume in the next period. Hence, the match stays intact in the case of disagreement. This particular feature of the bargaining setup is described in more detail in Hall and Milgrom (2007) and used in Lechthaler et al. (2010) or Christiano et al. (2012). It is especially plausible under collective bargaining since it is unlikely that all workers become unemployed in case of a disagreement. Thus, the fall-back option of the firm is

$$\tilde{F}_t = -c_f + \beta E_t J_{t+1}. \tag{20}$$

The median workers' surplus W_t from a match is

$$W_t = w_t + \beta E_t \left(1 - \phi_{t+1}\right) W_{t+1} + \beta E_t \phi_{t+1} U_{t+1}, \tag{21}$$

where U_t is the value of unemployment, defined as $U_t = b + \eta_t \left(1 - \phi_{t+1}\right) W_{t+1} + \left(1 - \eta_t \left(1 - \phi_{t+1}\right)\right) U_{t+1}$. The workers' fall-back option under disagreement is then

$$\tilde{W}_t = b + \beta E_t \left(1 - \phi_{t+1}\right) W_{t+1} + \beta E_t \phi_{t+1} U_{t+1}. \tag{22}$$

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

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

$$w_t = \gamma a_t + \left(1 - \gamma\right) b. \tag{23}$$

In Section 6, we will check for the robustness of our results by using individually bargained wages (including the profitability shock and the market tightness).

5.6 Government budget constraint

The government has a balanced budget and finances STW expenses and unemployment benefits through a lump-sum tax

$$b \frac{n_t}{1 - \phi_t^e} \int_{v_t^k}^{v_t^f} K\left(\varepsilon_t\right) g(\varepsilon) d\varepsilon_t + b u_t = T_t. \tag{24}$$

[40] Note that the median worker-firm pair does not use STW (empirically, on average only 0.69% of German employees are in STW programs).

We explore the robustness of our results to the possibility to finance STW through (distortionary) income taxation instead of lump-sum taxes below.

5.7 Equilibrium and aggregation

The labor market equilibrium is defined by equations (3), (7), (8), (9), (10), (18) and (23). Aggregate output (Y) in our model is defined as

$$Y_t = \frac{n_t}{1-\phi_t^e}\int_{-\infty}^{v_t^k}(a_t-\varepsilon_t)\,g(\varepsilon_t)\,d\varepsilon + \frac{n_t}{1-\phi_t^e}\int_{v_t^k}^{v_t^f}(1-K(\varepsilon_t))\,(a_t-\varepsilon_t)\,g(\varepsilon_t)\,d\varepsilon$$
$$- n_t c_f - \frac{n_t}{1-\phi_t^e}\phi_t^e f - v_t\kappa. \tag{25}$$

Aggregate output equals production (first line) minus resource costs (second line). Note, that n_t is the number of all workers employed in period t, i.e., after taking into account the separation risk. Therefore, we need to divide n_t by $(1-\phi_t^e)$ to get the number of available workers before endogenous separations. When determining production we need to take into account the idiosyncratic profitabilities of all relevant workers, i.e., those that work full time and those that work reduced hours on STW. The resource costs include vacancy posting costs, firing costs and fixed costs of production. Since our model does not contain any other aggregate demand components, aggregate output equals aggregate consumption in our model.

6 Numerical simulation

This section first describes our calibration strategy. Then we present the results of numerical simulations. Our model allows for two types of shocks: discretionary changes in STW policy and business cycle shocks. We first analyze the effects of policy shocks and compare them to our SVAR results. Then we analyze how large the automatic stabilizing effects of STW are in response to business cycle shocks.

6.1 Calibration

We calibrate the baseline model to the German economy. Table 2 summarizes our parameters and our calibration targets. The quarterly discount factor β is 0.99, which matches an annual real interest rate of 4.1%. Following Christoffel et al. (2009), we target a steady state value for the quarterly worker finding rate q of 70% and a separation rate of 3%. As in Krause and Lubik (2007) one third of separations is endogenous, whereas two thirds are exogenously determined. We target the quarterly job finding rate η to 31.2% to obtain a steady state unemployment rate of 9% (Christoffel et al., 2009). The matching elasticity α is set to 0.6. We calibrate unemployment benefits b to 65% of the wage and set the bargaining power to an intermediate value of $\gamma = 0.5$.

Parameter		Value
β	discount factor	0.99
κ	cost of posting a vacancy	1.21
α	matching elasticity w.r.t unemployment	0.60
μ	matching efficiency	0.43
b/w	replacement rate	0.65
f	linear firing costs	2.40
s	scale parameter of the profitability distribution	1.03
c_K	shift parameter in STW cost function	20.22
a	productivity	1
c_f	fixed cost of production	0.23
Steady state targets		**Value**
q	worker finding rate	0.70
ϕ	overall job destruction rate endogenous 1/3, exogenous 2/3	0.03
η	job finding rate	0.31
u	unemployment rate	0.09
χ	short-time work rate	0.007

Table 2: Calibration.

We have to set several parameters to obtain the steady state values of the labor market flow rates. We assume that the idiosyncratic profitability shock follows a logistic distribution,[41] which we normalize to have an unconditional mean of zero. To achieve our calibration target, we set the scale parameter s of the distribution to 1.03. The costs of posting a vacancy κ is set to 1.21 and the efficiency of matching μ is set to 0.43. In line with Bentolila and Bertola (1990), we set firing costs to 60% of annual productivity. In the numerical section, we will check the robustness of our results by reducing this value to 30% and 0%.

The steady state short-time work rate χ is targeted to 0.69%, which is in line with German data. Note that this implies a value for c_K of 20.22. This value appears to be large, but in the aggregate the convex STW costs amount to only 0.3% of output.

We set the fixed costs of production c_f to 0.23 in order to target the contemporaneous elasticity of the extensive margin of STW with respect output changes of -3.3. This estimate corresponds to our lower bound.[42]

As discussed above, our estimated elasticity may not take into account the general equilibrium effects of changing labor market tightness on wages and hence other aggregate variables. However, these effects are absent in our baseline model due to the assumed bargaining game. Thus, the calibra-

[41] A logistic distribution is very close to a normal distribution, but allows for closed form solutions.

[42] When we calibrate the model to larger elasticities (by using larger fixed costs), the automatic stabilization of unemployment remains similar and the stabilization of output increases. With a larger elasticity, more unprofitable workers are sent on short-time work in a recession and thus output drops by less than with a lower elasticity. Thus, our calibration constitutes a lower bound for output stabilization.

tion strategy is consistent with our model.

6.2 Policy shock

To demonstrate the effects of discretionary policy, we assume that the government changes the eligibility criterion for STW, i.e., it increases the level of D. The effects of this change in the eligibility criterion depend on the persistence of the policy. For illustration purposes we start with a temporary policy shock, i.e., the government increases the level of D for only one period and returns to the old rules one period later (further below we also consider a more persistent policy change). The shock size is normalized to 1.

Figure 5 shows the results. As can be seen from equation (3), D has a direct impact on the STW threshold. Weakening the eligibility criterion shifts the STW threshold and allows workers with a smaller ε to use STW (in Figure 4 this means that v^k is shifted to the left). These workers are more profitable than the workers who are on STW without the policy change, but they are less profitable than the workers who work full time. It is important to note that, due to firing costs and collective wage bargaining, these workers still generate losses to the firm and thus it is profitable to use STW. Although surprising at first, the working time reduction then leads to a positive effect in the resource constraint and, hence, output. This is in line with the results from the SVAR, albeit with a somewhat different timing.

Looking at equation (8), it can be seen that the firing threshold is not directly affected by changes in D. This is intuitive because it is the least profitable workers who are first sent on STW. Put differently, the workers at the firing threshold do already use STW due to the rule-based component, irrespective of any policy change that affects the eligibility criterion. Therefore, increasing D for one period does not change the firing threshold and neither does it change the unemployment rate.

In a second step, we show that the effects of change in the eligibility criterion are different when the policy change is persistent. We set the policy shock such that we obtain the same first period STW response and the same autocorrelation for the STW time series as after a one-standard deviation policy shock in the SVAR (see Figure 3). The solid lines in the right column of Figure 6 show the impulse response functions for this shock. The increase in D (with an autocorrelation coefficient of 0.81) now has an effect on hiring, firing and unemployment.

To understand this remember that, due to firing costs and collective wage bargaining, even some full-time workers generate losses to the firm (those close to the STW threshold). Increasing D persistently allows firms to send some of these workers on STW, reduces the losses generated by these workers and thereby raises the expected value of a job J (i.e., the value of a job prior to the realization of ε, see equation (11)). The increase in the expected value of a job reduces the incentives to fire (see equation (8), v^f in Figure 4 shifts to the right). It also increases the incentives to post vacancies (see equation (16)). Consequently, unemployment goes down.

In Section 4, we have argued that our assumptions used to identify output and policy shocks in the SVAR are consistent with the model presented here. Conversely, we can also show that the SVAR

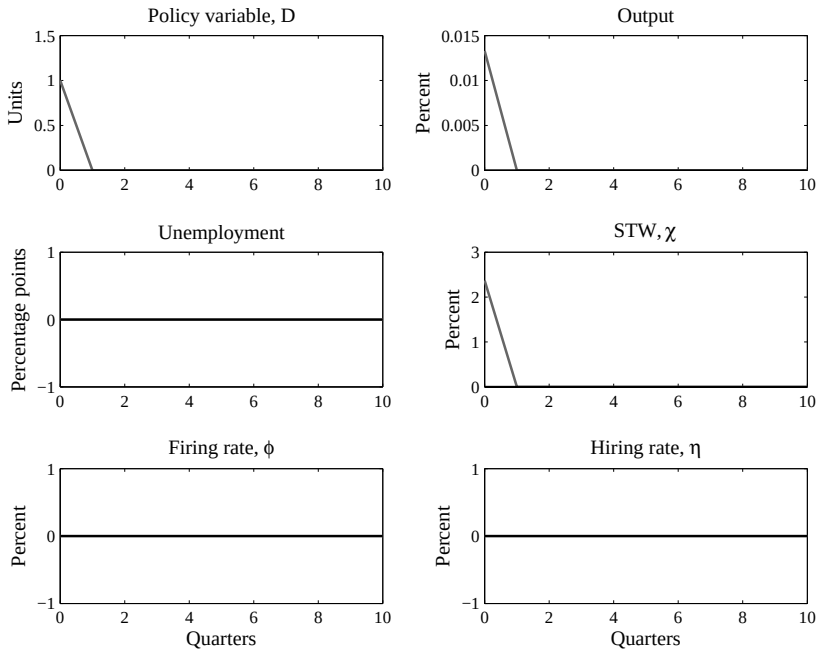

Figure 5: Impulse responses of a positive one unit shock to D. Impulse responses are given as deviations from the steady state. The shock is implemented as a temporary, one-period loosening of the STW eligibility criterion.

can replicate the theoretical responses when applied to artificial data simulated from the model. We simulate 1,000 time series of 68 periods corresponding to the length of our baseline sample.[43] In addition to the policy shock discussed above, we simulate a productivity shock with an autocorrelation of 0.95 and a standard deviation of 0.01. We further add normally distributed noise to all variables in our 3-variable baseline SVAR to simulate a potential third shock in the data.

Figure 6 shows the impulse response functions estimated from the simulated data together with the theoretical responses from the model. Two things are worth pointing out: First, the IRFs estimated from simulated data are very similar to the true ones from the model (the true responses are well within the error bands). Second, the true unemployment and output responses in reaction to STW policy shocks are replicated by the estimated ones, but are too small to be statistically significant. This mirrors the corresponding insignificant results using the actual data.

So far, we have assumed that discretionary STW policy facilitates the access to STW. However, alternatively it could also affect the convexity of STW costs. As a robustness check, we impose a shock to the cost parameter c_K instead of to the eligibility criterion D in the model. When we calibrate the shock similar to above, i.e., to match the standard deviation of the STW time series that is driven by the policy shock only, the SVAR reports a statistically significant reaction of unemployment (see Figure 15 in the Appendix). Intuitively, a shock to the cost parameter c_K shifts the convex cost function of short-time work and thereby makes the use of STW more attractive, also for marginal workers, and thereby exerts a stronger effect on unemployment. Our exercise shows two things. First,

[43] In order to prevent any dependence on the starting values, we simulate 1,068 periods and discard the first 1,000 periods.

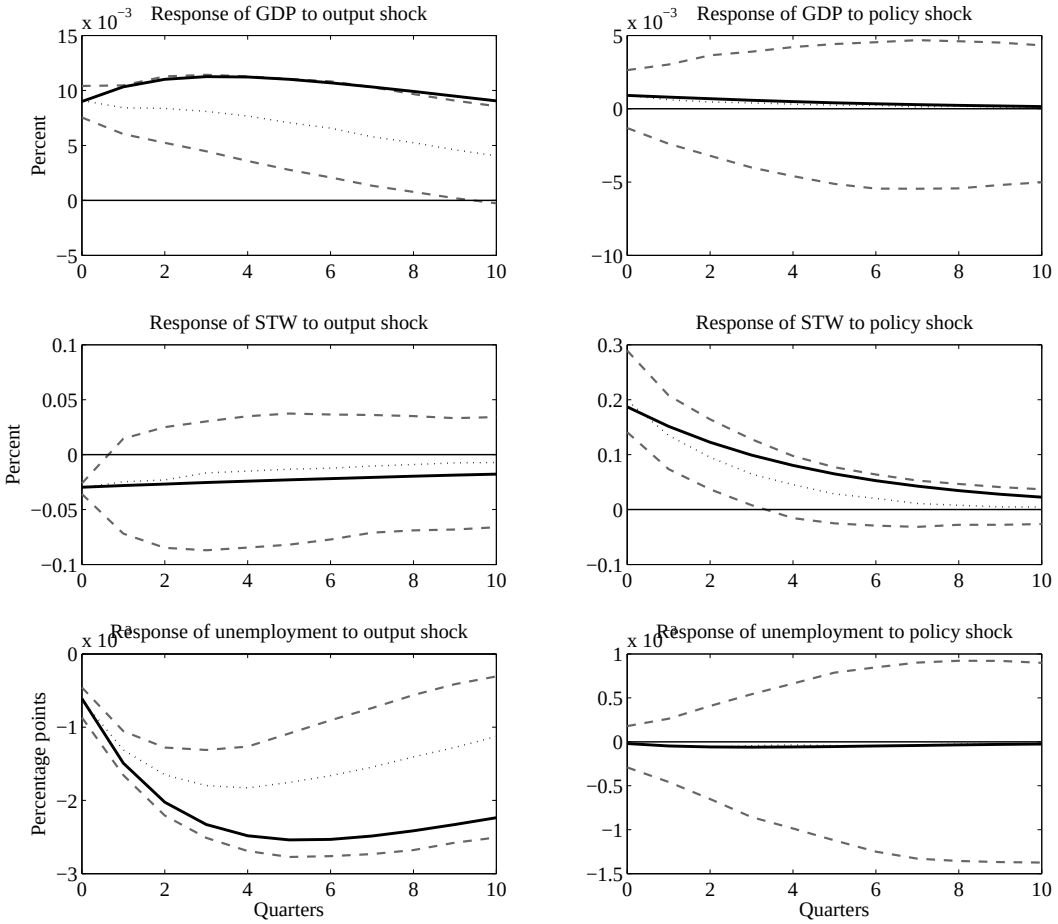

Figure 6: Impulse responses of a positive autocorrelated shock to a (left column) and to D (right column). Impulse responses are given as deviations from the steady state. The solid lines show the theoretical impulse responses. The dotted lines show the mean and the dashed lines the 90% error bands of the responses estimated from the SVAR applied to 1,000 simulations of artificial data from the model.

our SVAR methodology is able to detect statistically significant effects of discretionary STW if they are sufficiently powerful. Second, the discretionary STW shocks in the data resemble more eligibility (D) shocks in the model than cost shocks (c_K).

Our SVAR identification is based on a long time series. We know that the discretionary shocks were larger in the Great Recession. In addition, they may have been of different nature. However, we have no signs that these issues would change our result (i.e., the ineffectiveness of discretionary STW in Germany) in a meaningful way. First, simply doubling the D-shock (as corresponding to the shock size in the Great Recession) would not yield any statistically significant results either. Second, including dummies for the Great Recession or controlling for the maximum duration of STW in robustness checks for the SVAR in section 4.3 leaves our main results unaffected. Our methodology comes to the conclusion that discretionary short-time work shocks in Germany, both in and outside the Great Recession, were ineffective (or the effects were too small to be measurable in a statistical sense). However, our structural model simulation and the SVAR estimations based on simulated data shows that discretionary STW shocks can be designed in a way such that they have an effect on unemployment. First, they should make sure that STW becomes more attractive for marginal workers. Second, they should be implemented in a persistent fashion to also affect expectations of firms which are not in financial difficulties yet.

6.3 Automatic stabilization

6.3.1 Baseline scenario

Figure 7 shows the impulse responses to a negative, one standard deviation shock (normalized to 1%) to aggregate productivity a, with autocorrelation 0.95 (see solid lines for IRFs in the economy with STW). A drop in productivity reduces the value of a filled job J, which implies that firms post less vacancies. Consequently, the labor market tightness θ and the hiring rate η decrease. The decrease in productivity also has a negative effect on the firing threshold v_t^f, i.e., the endogenous firing rate ϕ_t^e goes up. The increase in firing and the reduction in hiring lead to a fall in employment and output and an increase in unemployment. Due to our assumption of fixed costs of production, our model replicates two important stylized facts of the business cycle. First, our model shows a Beveridge curve, i.e., a negative correlation between unemployment and vacancies. Second, the labor market variables are more volatile than productivity and output. The standard deviation of unemployment in our simulation is 3 times larger than the standard deviation of the underlying productivity shock.

What happens to STW in a recession? With a negative aggregate productivity shock, more worker-firm pairs are automatically eligible for STW and the share of workers on STW increases. However, the average quality of workers on STW increases in a recession, because more low-quality workers are fired. It follows that the average reduction of working hours due to STW decreases. Overall, hours per worker in the economy fall.

Remember that this is well in line with the stylized facts presented in Section 2: the extensive margin of STW (the share of workers on STW) moves countercyclically while the intensive margin

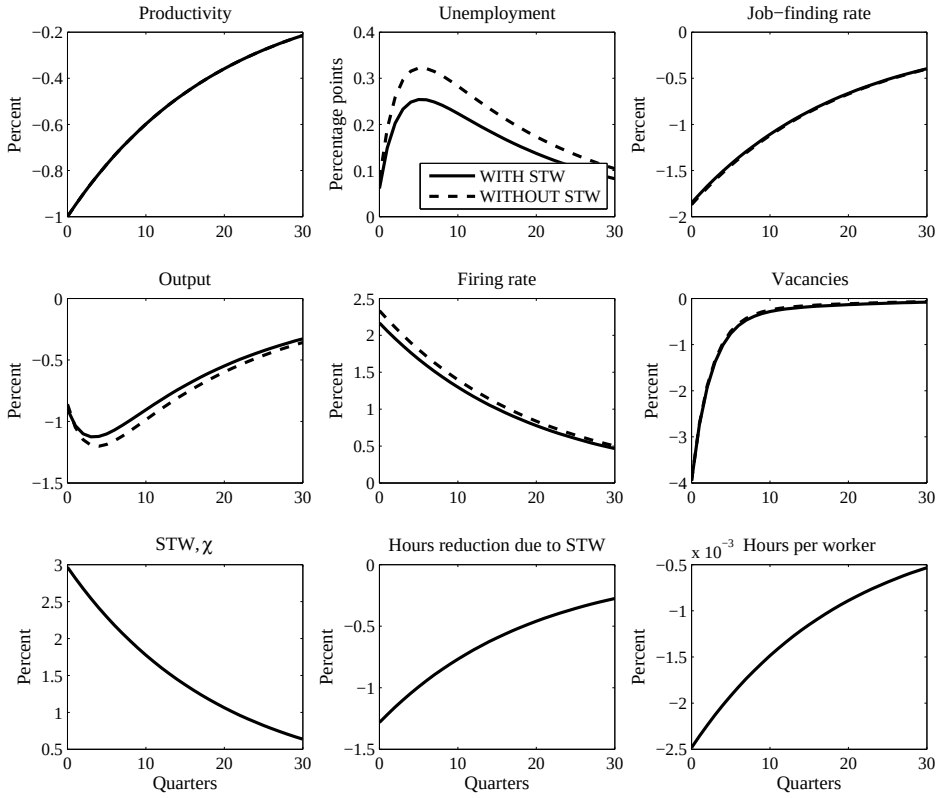

Figure 7: Impulse responses of a positive shock to aggregate productivity. Impulse responses are given as deviations from the steady state. The shock is implemented as a temporary autoregressive reduction in aggregate productivity.

of STW (the average hours-reduction of a worker on STW) is procyclical. Overall, hours per worker fall in recessions. Our model replicates all those facts very well. In the dynamic simulation, output and the share of workers on STW have a correlation of -0.96. Output and the average reduction of working hours have a correlation of 0.96. The respective values in the German data are -0.74 and 0.49.[44]

In order to assess the role of STW as an automatic stabilizer of the labor market and the macroeconomy, we compare an economy with and without STW. We keep all parameters the same in both scenarios. This assures that our stabilization results are not driven by parameter changes, but has the drawback that the steady states differ between the two scenarios. In Section 6.3.2 below we recalibrate the model without STW so that both models yield the same steady state and show that the differing steady states are not responsible for our results.

The second column in Table 3 shows the difference in the volatility of output and unemployment for our baseline scenario with constant parameters. The presence of STW reduces the standard deviation of the cyclical component of output by roughly 4% and reduces unemployment fluctuations measured by the absolute deviation of the cyclical component by roughly 21%. With a negative ag-

[44]The coefficients of autocorrelation of the model also correspond neatly to their empirical counterparts. In the model the coefficients of autocorrelation for both margins are 0.71, while they are 0.83 and 0.81 in the German data.

Stabilization in %	baseline	lower firing costs		distortionary taxation	fixed steady states
		$f = 1.2$	$f = 0$		
Output y	3.8	3.5	2.7	3.8	6.3
Unemployment u	21.2	13.1	6.5	21.2	14.9

Table 3: Reduction of the standard deviation in the model with STW compared to the model without STW. We use HP filtered deviations from steady state (smoothing parameter $\lambda = 1,600$). For output, we use log-deviations, for unemployment level deviations, since this variable is already denoted as a percentage.

gregate productivity shock, more firms are automatically eligible to use this instrument. Thus, in contrast to the economy without STW, some firms reduce the working time instead of firing workers and, therefore, reduce unemployment fluctuations.

The stabilization of unemployment comes at the cost that STW induces firms to keep unprofitable workers employed, who would otherwise have been fired. With and without STW, the average quality of the workforce increases in a recession because relatively more unprofitable workers are fired. This effect tends to counteract the decrease in aggregate productivity and thus reduces fluctuations in aggregate output. Since less workers are fired, the average quality of the workforce increases by less in recessions in the economy with STW compared to the economy without STW. Put differently, we have two counteracting effects: On the one hand, STW reduces unemployment fluctuations and thus output fluctuations via the production function. On the other hand, STW reduces the stabilizing effect of adjustments in the quality of the workforce (smaller cleansing effect of recessions). Naturally, the first effect dominates, but the second effect implies that STW stabilizes output by less than unemployment.

Is a stabilization of 4% of GDP fluctuations and 21% of unemployment fluctuations a lot? To evaluate the cost-effectiveness of the automatic stabilization, we have to relate the stabilization effects to the expenditures. Between 1998 and 2011 on average 0.7% of all workers are on STW. The average costs of STW accounted for just 0.01% of GDP in our model. In the data, the cost of STW in terms of GDP was 0.03%.[45] How does this compare to other automatic stabilizers such as the tax system? The estimated size of the automatic stabilization of the income tax system depends on the employed methodology and the analyzed country. The existing literature predicts an automatic output stabilization between 8% and 30% (see Table 2 in in't Veld et al., 2012). Given that the income tax system accounts for roughly 10% of GDP in the OECD average (see OECD Statistics, OECD, 2012b), the stabilization through STW appears to be large relative to the costs.[46]

[45] To calculate this number, we have used the gross transfers to workers due to STW according to the balance sheet of the Federal Employment Agency. At the peak in 2009 the costs were 0.13% of GDP.

[46] Note that we compare the income tax system to STW based on GDP-shares and stabilization effects only, not taking into account other potentially important aspects such as the effect on governmental revenue or the reduction of income inequality.

6.3.2 Robustness

In a first robustness check, we reduce firing costs from 240% of quarterly productivity (i.e. 60% of the annual productivity) to 120% and 0%, respectively. All the other parameters remain the same. Two results are worthwhile to be pointed out. First, lower firing costs lead to a smaller automatic stabilization effect of STW. In this case, frictional costs fluctuate less and, hence, the possibility of STW to dampen these fluctuations is reduced. Second, STW also stabilizes an economy without firing costs. This certainly does not correspond to German institutions, but it illustrates that firms have an incentive to use STW even when firing is costless. This is the case, because finding new workers is costly in a labor market with search and matching and, thus, some labor hoarding is optimal.

Next we assume that additional expenses due to the cyclical variation in STW are financed by an immediate increase in a distortionary proportional income tax.[47] Given that we assume a balanced budget, the bargaining outcome is directly affected by tax increases. As expected, a distortionary financing of STW reduces the unemployment stabilization effects (although only in the second digit, i.e., this is not visible in Table 3). The reduction is surprisingly small. The reason is that the STW in our model is very cost-efficient and thus the extra costs in a recession due to the automatic reaction of STW are small.

In order to exclude that our results are driven by steady state shifts, we adjust the standard deviation of the idiosyncratic profitability shocks and the vacancy posting costs to obtain the same steady states for the labor market flows in all versions of the model.[48] Interestingly, with fixed steady states all results are very similar compared to the scenario with fixed parameters. In our baseline scenario, output fluctuations drop by 6% and employment fluctuations by 15%. Lower firing costs lead to somewhat less stabilization and distortionary taxes leave the results almost unchanged.

6.3.3 Simulation for the US economy

So far, we have performed our simulations based on German labor market flows (which are roughly three times smaller than in the United States), collective bargaining and substantial firing costs. Lowering firing costs has indicated that labor market institutions are important for the quantitative results. To obtain an idea about the potential effects of STW in an anglosaxon country, we repeat our exercise under standard individual Nash bargaining, where the threat point of worker and firm is the termination of the match, and recalibrate the model to match the US economy. This is of course only a rough quantification of the potential stabilizing effects of STW in the US, since, in contrast to our earlier analysis, it is not based on an empirically estimated elasticity of STW. However, this scenario demonstrates that STW is likely to be less stabilizing in more flexible labor markets.

[47] The bargaining equation changes to $w_t = \gamma a_t + (1-\gamma)\, b/(1-\tau_t)$, where τ_t is the proportional income tax.

[48] Note, however, that we do not adjust the fixed costs of production, which are the driving force for the amplification and the elasticity of STW with respect to output.

The wage is then given by

$$w_t(\varepsilon_t) = \gamma(a_t - \varepsilon_t - c_f + \kappa\theta_t) + (1-\gamma)b. \tag{26}$$

Note that in contrast to our baseline with collectively bargained wages, the wage now depends on the tightness of the labor market θ and the idiosyncratic profitability of a worker ε. The latter implies that the risk stemming from idiosyncratic shocks is shared between worker and firm. Note, however, that there is still scope for STW. Due to costly hiring (vacancies are associated with costs and are only filled with a certain probability), the future value of a worker is positive. This implies that some workers are retained even though they generate contemporaneous losses. Putting these workers on STW reduces the losses they generate and is therefore beneficial for the firm.

In our parametrization, we target US labor market flows, namely a job destruction rate of 0.1, a job finding rate of 0.81 and a worker finding rate of 0.7 (Krause and Lubik, 2007). The efficiency of the matching function, the costs of posting a vacancy and the scale parameter of the idiosyncratic profitability distribution are used to match these targets. In line with US institutions, we set firing costs to zero and the replacement rate to 0.4. All other parameters remain the same (and are summarized in Table 8 in the Appendix). We run two STW scenarios: one with the German parameter c_K and one with the German steady STW rate χ, which necessitates a recalibration of c_K (values in parentheses in Table 8 in the Appendix).

Using the same parameter value for STW costs c_K as in our baseline calibration leads to a much lower STW take up than in our previous simulations. The share of workers on STW, χ, in the steady state drops from 0.7% to 0.1%. This is not surprising. Lower firing costs and larger labor market flows imply that adjustments via the extensive margin are much easier and less costly than in our baseline scenario. Additionally, the flexibility of individually bargained wages allows easier adjustments in response to idiosyncratic shocks. Thus, the possibility to adjust via the intensive margin appears much less attractive. This is, in fact, well in line with Figure 8 in the Appendix, showing that STW is not much used in the United States. Naturally, this leads to much lower stabilization (see Table 4). Output fluctuations are reduced by only 0.1% and unemployment fluctuations are reduced by 0.7% compared to an economy without STW.

Stabilization in $\%$	German case	US case	
	baseline	German c_K	German STW share
Output y	3.8	0.1	0.5
Unemployment u	21.2	0.7	4.0

Table 4: Reduction of the standard deviation in the model with STW compared to the model without STW. We use HP filtered deviations from steady state (smoothing parameter $\lambda = 1,600$). For output, we use log-deviations, for unemployment level deviations, since this variable is already denoted as a percentage.

Suppose next that the US government promotes the use of STW with the goal of achieving a similar steady state proportion of workers on STW as observed in Germany. To analyze this scenario, we

recalibrate the STW costs c_K to 3.5, which implies that the STW rate χ rises to 0.7%. Nevertheless, the stabilization through STW over the business cycle is still much lower than in our baseline scenario for Germany. Table 4 shows that unemployment fluctuations are reduced by 4% and output fluctuations by 0.5%. Based on the most optimistic stabilization results, a back-of-the envelope calculation suggests that STW would have buffered the increase in US unemployment from 5 to 10% in October 2009 by only 0.2 percentage points, i.e., to 9.8%. Again, this is due to the higher flexibility of the US economy. Making STW cheaper, implies of course that more firms use it in steady state, but still the other margins of adjustment appear more attractive in response to business cycle shocks. Overall, our analysis suggests that STW can be an important margin of adjustment for otherwise rigid labor markets, but the additional benefit for labor markets which are already flexible is rather limited.

7 Lessons and outlook

"... it's time to try something different." (Paul Krugman, 2009)

Does our analysis suggest that Paul Krugman (2009) is right that STW was an important job saver in the Great Recession? We argue that STW can act as a powerful automatic stabilizer, but that the empirical evidence concerning discretionary policy changes shows no effects. According to our SVAR evidence a discretionary change in STW policy has no effect on unemployment. Our theoretical model provides a plausible explanation for this puzzling result. A discretionary loosening of the STW eligibility criterion only subsidizes worker-firm pairs that would not have been destroyed even in absence of the intervention. If the discretionary intervention is used in a transitory way, firms' future expectations remain unaffected and no additional jobs are saved. In contrast, rules both have a direct effect on unemployment through a reduction of the firing threshold and indirectly affect firm's hiring and firing decisions via future expectations.

These results suggest that it is crucial to disentangle those two components. One additional worker on STW due to a discretionary intervention may have no effect, while one additional worker on STW due to automatic adjustments may stabilize the economy. Not differentiating these two different cases may lead to biases when estimating the effects of STW on the macroeconomic level.

Our empirical results for the discretionary component of STW are derived from a SVAR for the post-reunification period (note that it is impossible to run a SVAR just for the crisis). Since the results remain largely unchanged when we include dummies for deep recessions (Great Recession, unification and oil price crises), we infer that the discretionary interventions in Germany in the Great Recession did not save jobs.

However, the automatic stabilization effects of STW were also at work in the Great Recession. When we feed a GDP shock into our SVAR that leads to a 6.6% decline of GDP, equivalent to the German peak-to-trough movement in the Great Recession (Burda and Hunt, 2011), this shock generates an increase of unemployment of 4.82 percentage points within a year according to the SVAR. To quantify the automatic stabilization effects of STW in the Great Recession, we feed an aggregate

shock into our model with STW that also leads to a peak increase of unemployment of 4.82 percentage points. In the model without STW the same aggregate shock leads to an increase of unemployment of 6.11 percentage points. Thus, our counterfactual analysis predicts that the automatic component of STW has prevented an increase in German unemployment of 1.29 percentage points, i.e., it saved roughly $466,000$ German jobs in the Great Recession.

Our calculation suggests that STW saved many jobs but STW alone cannot explain the non-response of unemployment in Germany in the Great Recession. Additional forces must have been at work. Möller (2010) and Burda and Hunt (2011) point towards the role of working time accounts, which gained importance in the recent years and have contributed to make the intensive margin more flexible in the Great Recession. Boysen-Hogrefe and Groll (2010) show that unit labor costs (wages normalized by productivity) fell a lot before the recession. This may have had an impact on firms' labor demand. Burda and Hunt (2011) argue that firms were overly pessimistic in the 2005-2007 economic upturn, did not hire enough workers and thus had to reduce the employment stock by less in the Great Recession. Clearly, some or all of these aspects could be incorporated into our model-based analysis. We leave this to future research and focus on a more detailed investigation of STW instead.

Thus, Krugman is right that STW has indeed contributed to the German labor market miracle. But our analysis also shows that the institutional setup is crucial for the automatic stabilization effects of STW. According to the model simulations, economies with larger firing costs and collective wage bargaining can expect stronger stabilization effects from STW. Individually bargained wages allow the adjustment of wages in response to idiosyncratic shock. Under collective bargaining this adjustment is precluded, implying that idiosyncratic shocks are more costly to the firm. STW partly reduces the inflexibility imposed by collective bargaining and thereby stabilizes employment.

Large firing costs make it costly to adjust along the extensive margin. In such an environment STW increases the flexibility of the intensive margin of labor adjustment and hence prevents firings that constitute resource costs to the firm and the economy. Cahuc and Carcillo (2011) show that there is indeed a positive cross-country correlation between the average level of firing costs (measured by the OECD employment protection legislation index) and the STW take-up rate in the Great Recession. Policy makers seem to understand well that the largest benefits of STW can be reaped in economies with large firing costs.

Although the purpose of this paper is of pure positive nature (i.e., quantifying the effects of the discretionary and rule-based component of STW), some words on the normative dimension are in order. Does STW improve welfare and is it therefore desirable for policy makers? Typically, general equilibrium search and matching models assume a large family with consumption pooling and risk-averse agents. Under these assumptions, less volatile consumption improves welfare. Given that we have modeled a closed economy without government spending (except for STW expenses), output is equal to consumption in our framework. We have shown in Table 3 that STW stabilizes consumption fluctuations and thereby increases welfare. Interestingly, the results are of similar size with proportional income taxes, i.e., they continue to hold when STW has to be financed in a distortionary way.

However, we would like to emphasize that our analysis lacks some dimensions that may be desirable in the context of a fully-fledged welfare analysis. Two important motives for STW are the prevention of loss of human capital and the stabilization of consumption for those who would have otherwise lost their job. The first aspect is only contained in an indirect way in our analysis. Firing generates resource costs that can be prevented in the presence of STW. However, human capital losses would have a different timing. The second effect could only be incorporated in a model with heterogeneous savings decisions. Thus, we conclude that our analysis is suggestive that STW is clearly desirable. However, we leave a more detailed analysis and a precise quantification of welfare gains for future analysis.

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Appendix

A Supplementary tables and figures

Variable	Source
Short-time workers	German Federal Employment Agency
Employment	German Federal Employment Agency
Unemployment rate	German Federal Employment Agency
Hours worked	Institute for Employment Research
GDP	Deutsche Bundesbank
GDP deflator	German Federal Statistical Office
CPI	German Federal Statistical Office
ifo business climate index	ifo Institute for Economic Research
3-month money market rate	Deutsche Bundesbank
Consumption	German Federal Statistical Office
Gross investment	German Federal Statistical Office

Table 5: Data sources. We take quarterly averages of all monthly series, since not all data is available at monthly frequency. All series are seasonally adjusted using Census' X12-ARIMA procedure.

	All	2003	2006	2009	2010
Observations	64,056	16,067	15,912	15,909	16,168
Firms using STW	4202	622	231	1648	1701
Mean of STW/EMP, in %	3.34	2.03	0.74	5.63	4.93
Mean of STW/EMP, in %, only STW firms	50.90	52.41	51.55	54.37	46.90

Table 6: Descriptives on STW data in IAB establishment panel

	Response in output			Response in unemployment		
	Sign	(qrt.)	Significant in qrt.	Sign	(qrt.)	Significant in qrt.
Baseline (1993-2010)						
baseline	-	(1)	none	+		none
	+	(2-)	2			
with recession dummies	-	(0)	none	+		none
	+	(1-)	2			
with legal change dummies	-	(0-1)	none	+		none
	+	(2-)	2			
with labor productivity instead of output	-	(0)	none	+		none
	+	(1-)	2			
with GDP deflator	-	(0-1)	none	-	(0-5)	none
	+	(2-)	2	+	(6-)	none
with employment instead of unemployment	-	(0-1)	none	+	(0-1)	none
	+	(2-)	none	-	(2-)	none
with total hours instead of unemployment	-	(0-1)	none	-	(0-5)	none
	+	(2-)	none	+	(6-)	none
with ifo index as control	-	(0)	none	+		none
	+	(1-)	none			
with interest rate as control	-	(0)	none	+		none
	+	(1-)	2			
with consumption growth as control	-	(0)	none	+		none
	+	(1-)	none			
with investment growth as control	-	(0)	none	+		none
	+	(1-)	2			
Long sample (1975-2010)						
baseline	-	(0-1)	1	+		none
	+	(2-)	none			
with recession dummies	-	(0-1)	none	+		none
	+	(2-)	none			

Table 7: Summary of robustness checks. The table reports the sign and significance of the responses in output and unemployment to a STW policy shock. Significance is based on 90% bootstrapped confidence bands. Each row reports the sign of the response, the corresponding horizon (in quarters) in which the sign occurs, and whether the response is significant or not. When the sign of the respective impulse-response changes, the next row indicates this change, the corresponding horizon and the significance.

Parameter		Value	
		German type economy	US type economy
β	discount factor	0.99	
κ	cost of posting a vacancy	1.21	0.34
α	matching elasticity w.r.t unemployment	0.60	
μ	matching efficiency	0.43	0.77
b/w	replacement rate	0.65	0.4
f	linear firing costs	2.40	0
s	scale parameter of profitability distribution	1.03	0.32 (0.34)
c_K	shift parameter in STW cost function	20.22	20.22 (3.50)
a	productivity	1	
c_f	fixed cost of production	0.23	
Steady state targets		**Value**	
q	worker finding rate	0.70	
ϕ	overall job destruction rate endogenous 1/3, exogenous 2/3	0.03	0.1
η	job finding rate	0.31	0.81
u	unemployment rate	0.09	0.12
χ	short-time work rate	0.007	not targeted (0.007)

Table 8: Calibration of US type economy.

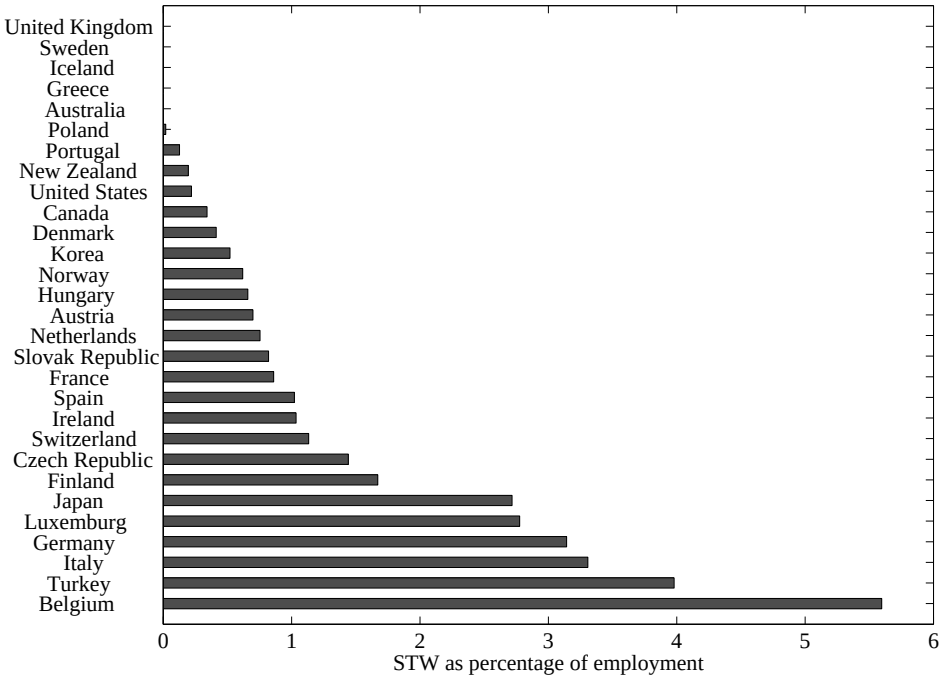

Figure 8: STW as a percentage of total employment across OECD countries in 2009 (Cahuc and Carcillo, 2011). We thank Pierre Cahuc for providing the data set.

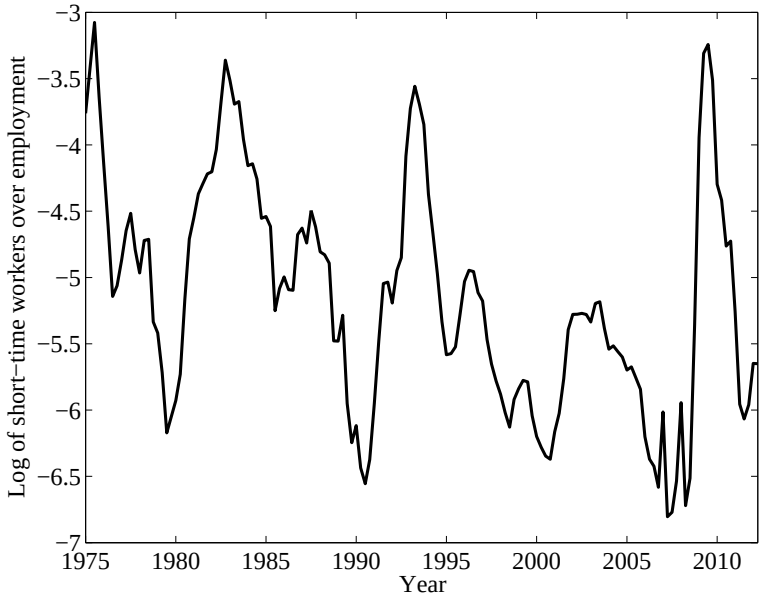

Figure 9: Short-time work in Germany 1975-2012. The series depicts the log of the number of short-time workers as a fraction of total employment.

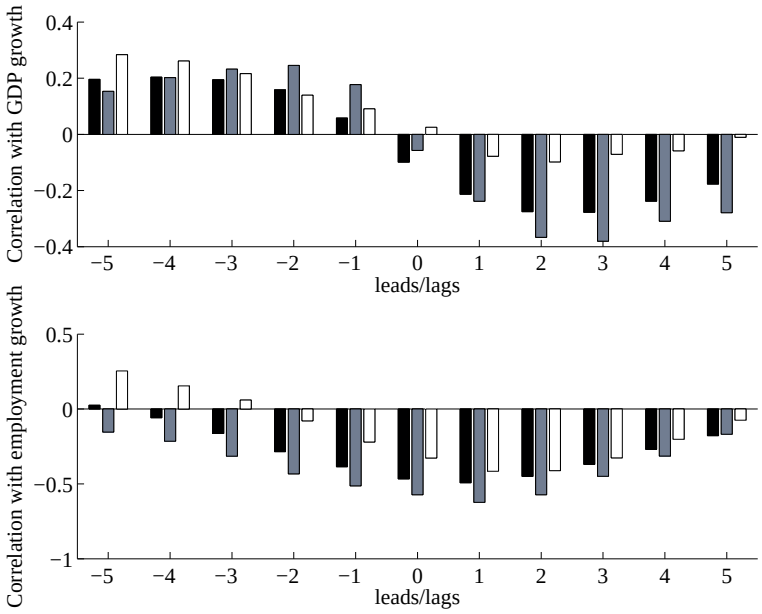

Figure 10: Correlation of number of short-time workers as a fraction of employment with GDP and employment. Leads/lags depict the correlation of STW/EMP in period t with GDP or employment in period $t+i$ / $t-i$. Black bars show correlations over the long sample corresponding to 1975 to 2010, gray bars show the short post-reunification sample corresponding to 1993-2010. White bars show correlations over the long sample without STW peaks in the 4 recessions.

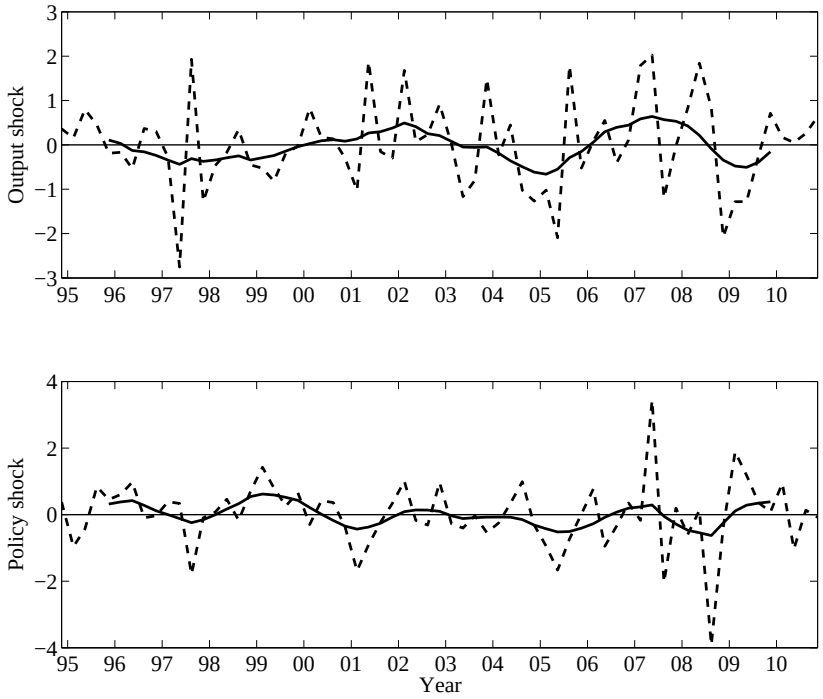

Figure 11: Estimated output and STW shocks from baseline VAR. The dashed series shows the actual shock, the solid series is smoothed with a centered moving average with four leads and lags and triangularly declining weights. SVAR estimated with STW per employed workers, GDP growth and unemployment (all in logs) for 1993Q1 to 2010Q4.

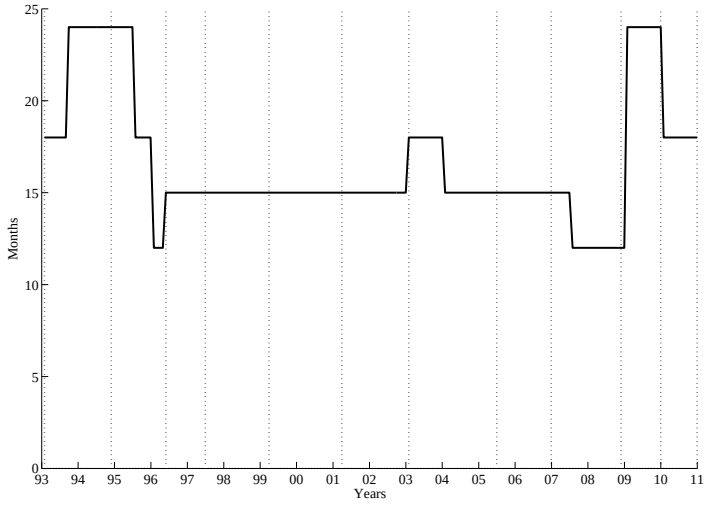

Figure 12: Legal changes in duration of eligibility of short-time work. The series describes legal maximum period of eligibility of a worker under short-time work scheme. Vertical lines show the timing of the corresponding legislation.

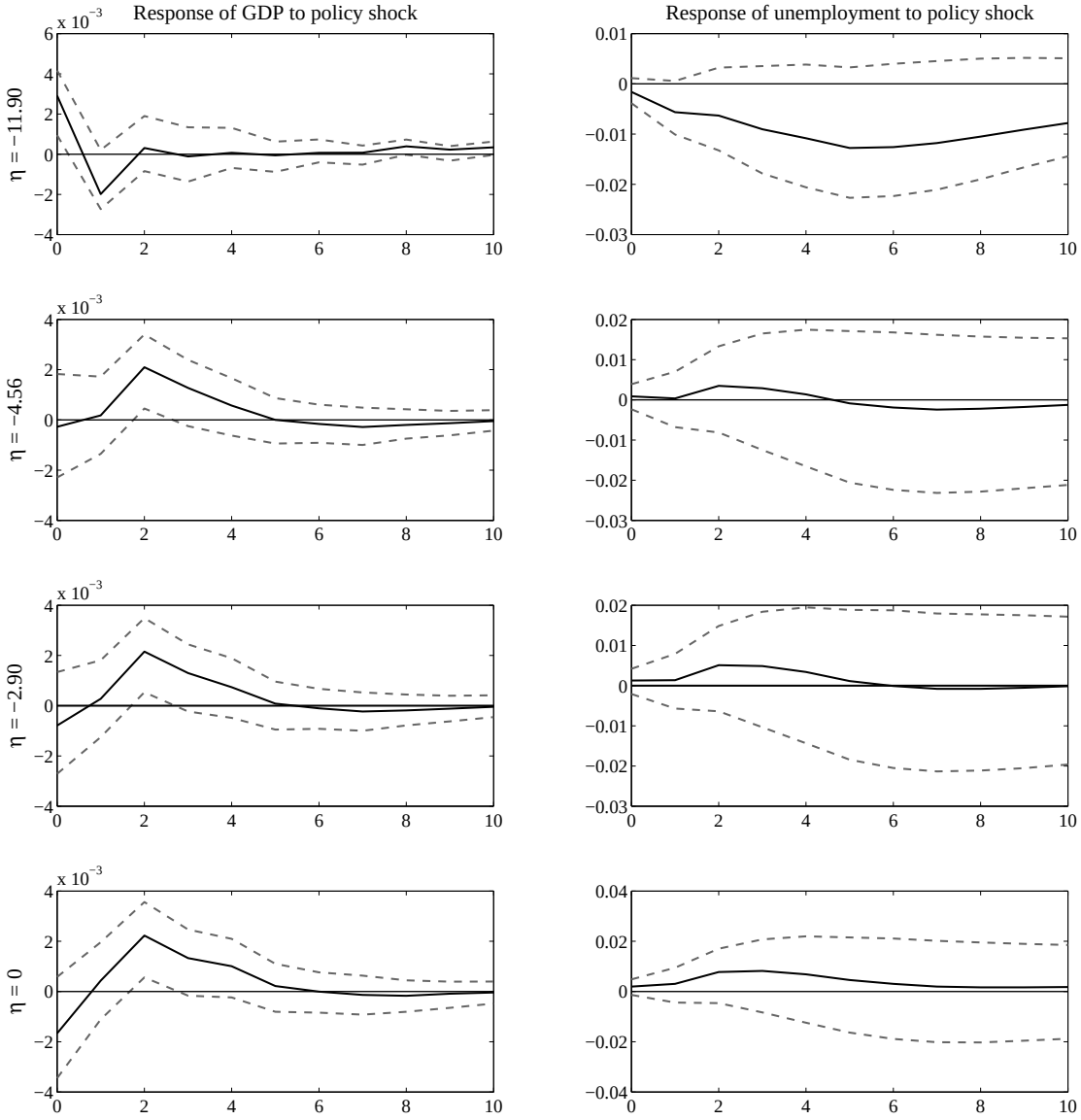

Figure 13: Impulse responses to policy shocks for different output elasticities of STW η. SVAR estimated with STW per employed workers, GDP growth and unemployment (all in logs) for 1993Q1 to 2010Q4. Quarterly responses to a positive one-standard deviation shock. Confidence intervals are 90% bootstrapped bands with 10,000 draws.

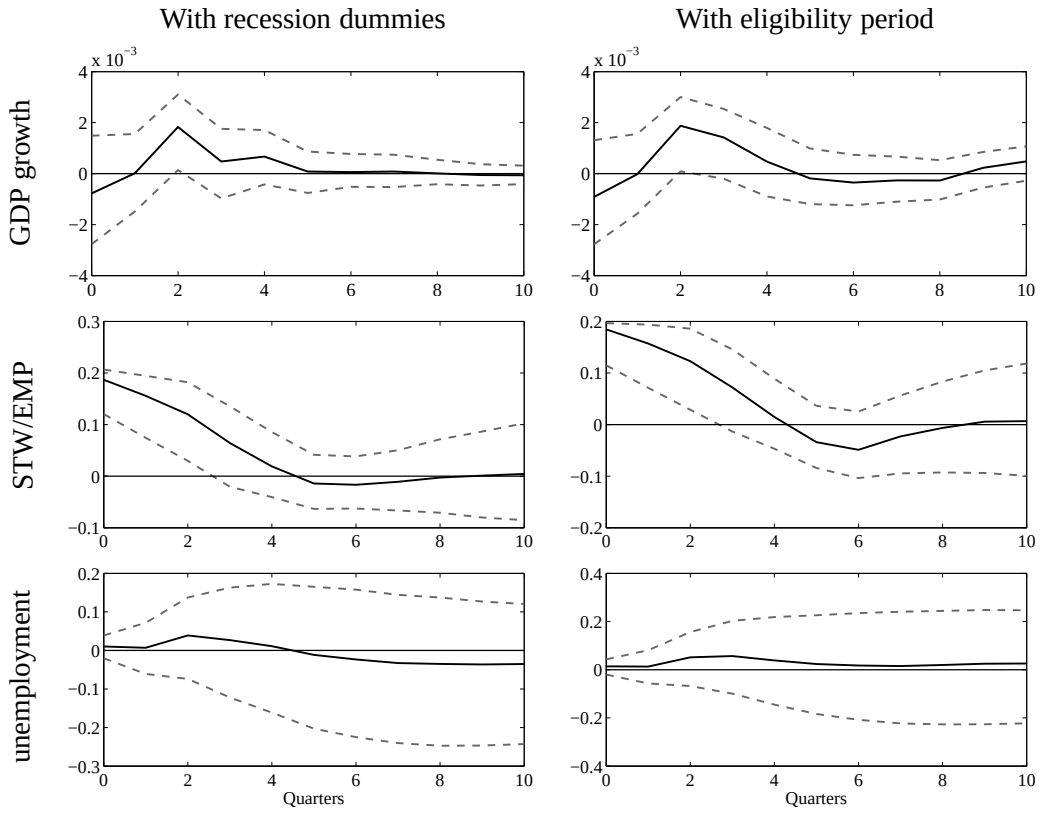

Figure 14: Robustness for impulse responses to STW policy shocks. SVAR estimated with log STW per employed workers, GDP growth and the log unemployment rate for 1993Q1 to 2010Q4. In the left column, we add recession dummies, in the right column, we add a the maximum STW eligibility period as control to the SVAR. Quarterly responses to a positive one-standard deviation shock. Confidence intervals are 90 percent bootstrapped bands with 10,000 draws.

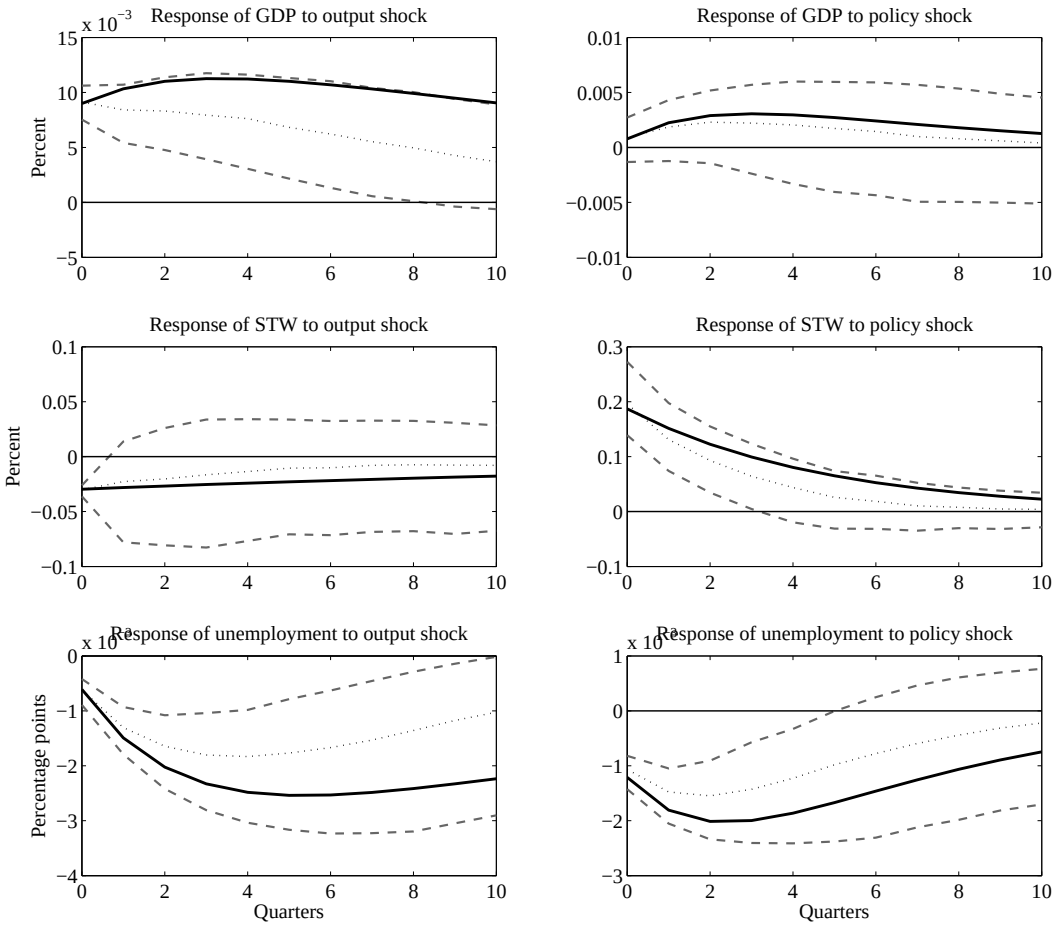

Figure 15: Impulse responses of a positive autocorrelated shock to a (left column) and to c_K (right column). Impulse responses are given as deviations from the steady state. The solid lines show the theoretical impulse responses. The dotted lines show the mean and the dashed lines the 90% error bands of the responses estimated from the SVAR applied to 1000 simulations of artificial data from the model.

B Derivation of the theoretical model

B.1 Matching on the labor market

The labor market is subject to matching frictions. Unemployed workers search for a job and find one with probability $\eta_t \leq 1$. Firms have to pay a per period vacancy posting cost κ to search for a worker. A searching firms finds an unemployed workers with probability $q_t \leq 1$. We assume that a vacancy that is filled today only becomes productive in the next period. The probabilities η_t and q_t depend on the tightness of the labor market $\theta_t = v_t/u_t$, the share of open vacancies to searching workers. The total number of new matches is given by a Cobb-Douglas constant returns matching function

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

where u_t is the number of searching workers, v_t is the number of open vacancies, α is the elasticity of the matching function with respect to unemployment and $\mu > 0$ is the matching efficiency. Consequently, the worker finding rate $q_t = m_t/v_t$ and the job finding rate $\eta_t = m_t/u_t$ are given by

$$\begin{aligned} q_t &= \mu \theta_t^{-\alpha}, \\ \eta_t &= \mu \theta_t^{1-\alpha}. \end{aligned}$$

The present value of a vacancy is defined as

$$V_t = -\kappa + \beta E_t q_t J_{t+1} + E_t \beta \left(1 - q_t\right) V_{t+1}.$$

where J_t is the value of a filled job. We assume free entry of vacancies which implies that in equilibrium $V_t = 0 \; \forall \, t$ which simplifies the above equation to

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

In equilibrium, the vacancy posting cost has to equal the expected payoff of the vacancy, which consists of the probability to find a worker and the expected value of a successful match.

B.2 Production and short-time work

The output of a filled job depends on aggregate productivity a_t and an idiosyncratic component ε_t that is drawn each period from a random distribution $g\left(\varepsilon_t\right)$. This is a standard way of endogenizing separations in the search and matching framework. Workers get fired immediately in case their ε_t is above the firing threshold v_t^f. Different to the standard setup, workers who do not get fired might either work full time or be sent on short-time work (STW). Again this choice is determined by the draw of ε_t so that workers with $\varepsilon_t < v_t^k$ work full time while workers with $v_t^k < \varepsilon_t < v_t^f$ are on STW. The short-time work threshold v_t^k is defined below. Correspondingly, the expected value of job before

the realization of the idiosyncratic shock is known is given by

$$
\begin{aligned}
J_{t+1} = (1-\phi^x) \int_{-\infty}^{v_{t+1}^k} \Big(a_{t+1} - w_{t+1}(\varepsilon_{t+1}) - \varepsilon_{t+1} \Big) g(\varepsilon_{t+1}) d\varepsilon_{t+1} \\
+ (1-\phi^x) \int_{v_{t+1}^k}^{v_{t+1}^f} \Big[\big(a_{t+1} - w_{t+1}(\varepsilon_{t+1}) - \varepsilon_{t+1} \big) \big(1 - K(\varepsilon_{t+1}) \big) - C\big(K(\varepsilon_{t+1}) \big) \Big] g(\varepsilon_{t+1}) d\varepsilon_{t+1} \\
- (1-\phi_{t+1}) c_f - (1-\phi^x) \phi_{t+1}^e f + (1-\phi_{t+1}) E_{t+1} \beta J_{t+2}.
\end{aligned}
$$

The wage $w_t(\varepsilon_t)$ potentially depends on ε_t,[49] ϕ^x is the rate of exogenous separations, $\phi_t^e = \int_{v_t^f}^{\infty} g(\varepsilon_t) d\varepsilon_t$ is the rate of endogenous separations and

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

is the rate of total separations. The first line in the equation above shows the operating profits generated by the workers who work full time, aggregate productivity a_{t+1} minus wages w_{t+1} minus the idiosyncratic component. The second line shows the operating profits generated by the workers on STW. The working time of these workers is reduced by $K(\varepsilon_{t+1})$. This reduces output and wage payments but implies a cost of using STW, $C(K(\varepsilon_{t+1}))$. The third line shows the fixed cost of production, c_f, which accrues for every employed worker, the cost of firing workers, f, and the expected future value of retained workers.

Note that without STW, the above equation for the expected value of the job collapses to

$$
\begin{aligned}
J_{t+1} = (1-\phi^x) \int_{-\infty}^{v_{t+1}^f} \Big(a_{t+1} - w_{t+1}(\varepsilon_{t+1}) - \varepsilon_{t+1} \Big) g(\varepsilon_{t+1}) d\varepsilon_{t+1} \\
- (1-\phi_{t+1}) c_f - (1-\phi^x) \phi_{t+1}^e f + (1-\phi_{t+1}) E_{t+1} \beta J_{t+2},
\end{aligned}
$$

which is the standard equation in search and matching model with endogenous separations.

Next we discuss the determination of the two threshold values v_t^k and v_t^f, and the extent of STW usage. The value of an employed worker with realization ε_t who is not on STW is given by

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

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

$$a_t - w_t(\varepsilon_t) - \varepsilon_t - c_f + \beta E_t J_{t+1} < D_t.$$

[49] For our baseline model, we assume collective wage bargaining implying that the wage does not depend on ε_t. Here, we define the wage more generally and discuss different wages below.

Thus, we can define a threshold level v_t^k for the idiosyncratic component ε

$$v_t^k = a_t - w_t\left(v_t^k\right) + \beta E_t J_{t+1} - c_f - D_t.$$

In case that $D_t = f$, the STW condition is equivalent to the firing condition in a model without STW. In our calibration this condition holds. The government only allows STW usage for worker-firm pairs that would have been destroyed in the absence of STW.

When a worker is eligible for STW, the firm has the option to adjust along the hours margin. STW usage is subject to convex STW costs

$$C\big(K\left(\varepsilon_t\right)\big) = c_K \frac{1}{2} K\left(\varepsilon_t\right)^2,$$

which assures interior solutions. The firm chooses the optimal level of the working time reduction $K\left(\varepsilon_t\right)$ by maximizing the contemporaneous profit of a worker on STW

$$\max_{K(\varepsilon_t)} \pi_t = \left(a_t - w_t\left(\varepsilon_t\right) - \varepsilon_t\right)\Big(1 - K\left(\varepsilon_t\right)\Big) - c_f - C\Big(K\left(\varepsilon_t\right)\Big).$$

Note that the reduction in working time does not only reduce the output of the worker but also reduces the wage payments and the idiosyncratic cost. However, it does not reduce the fixed cost c_f which is independent of the production level. The optimal hours reduction of STW for a given ε_t is

$$K^*\left(\varepsilon_t\right) = -\frac{a_t - w_t\left(\varepsilon_t\right) - \varepsilon_t}{c_K}.$$

Naturally, the lower the profitability of a worker, i.e., the higher the realization of ε_t, the higher the working time reduction ($\frac{\partial K^*(\varepsilon_t)}{\partial \varepsilon_t} > 0$). We can now describe the firing decision of the firm, which depends on the working time reduction K. Workers are fired if the losses they generate are higher than the firing cost:

$$\Big(a_t - w_t\left(\varepsilon_t\right) - \varepsilon_t\Big)\big(1 - K\left(\varepsilon_t\right)\big) - C\Big(K\left(\varepsilon_t\right)\Big) - c_f + \beta E_t J_{t+1} < -f.$$

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

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

Now we are able to define the endogenous separation rate

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

and the endogenous short-time work rate

$$\chi_t = \int_{v_t^k}^{v_t^f} g\left(\varepsilon_t\right) d\varepsilon_t.$$

B.3 Employment dynamics

Employment in period t is equal to those workers who have not been fired and those who have been newly hired (from the pool of unemployed) and not immediately fired

$$n_t = \left(1-\phi_t\right) n_{t-1} + \left(1-\phi_t\right) \eta_{t-1} u_{t-1}.$$

Note that $u_t = 1 - n_t$. Then,

$$n_t = \left(1-\phi_t\right) n_{t-1} + \left(1-\phi_t\right) \eta_{t-1} \left(1-n_{t-1}\right).$$

B.4 Wage bargaining

B.4.1 Collective wage bargaining

Collective wage bargaining is the predominant regime in continental Europe and in Germany. Therefore, we use a simple model of collective wage bargaining for our baseline scenario. We assume that the wage is bargained between the median firm and the median incumbent worker for whom the realization of the profitability shock equals its expectation of zero, which implies that the median worker will not be on STW. Every worker who is working full time earns this wage. Every worker who is on STW gets a share of this wage, according to her working time (plus some reimbursement for the lost wage income). Hence, the wage does not depend on the idiosyncratic profitability of a worker, i.e., $w_t(\varepsilon) = w_t$.

The profit of the median worker-firm pair (with idiosyncratic profitability shock zero) of a match is

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

In case of disagreement, production will come to a halt (e.g., due to a strike) and bargaining will resume in the next period. This stands in contrast to the standard assumption under individual bargaining where the match is destroyed in case of disagreement (see below). However, under collective bargaining it is unlikely or impossible that all workers become unemployed in case of a disagreement.[50] Hence, the match is not destroyed due to a disagreement. Thus, the fallback option of the firm is a strike scenario with no production:

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

[50] In Germany it is illegal to fire workers due to a strike.

The median workers' surplus W from a match is

$$W_t = w_t + \beta E_t \left(1 - \phi_{t+1}\right) W_{t+1} + \beta E_t \phi_{t+1} U_{t+1},$$

where U is the value of unemployment. The workers' fallback option under disagreement is

$$\tilde{W}_t = b + \beta E_t \left(1 - \phi_{t+1}\right) W_{t+1} + \beta E_t \phi_{t+1} U_{t+1}.$$

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

Defining γ as workers' bargaining power the Nash product is given by

$$\begin{aligned} \Pi_t &= \left(W_t - \tilde{W}_t\right)^{\gamma} \left(F_t - \tilde{F}_t\right)^{1-\gamma} \\ &= \left(w_t - b\right)^{\gamma} \left(a_t - w_t\right)^{1-\gamma}. \end{aligned}$$

Maximizing the Nash product with respect to the wage yields

$$\left(1 - \gamma\right)\left(w_t - b\right) = \gamma \left(a_t - w_t\right),$$

or

$$w_t = \gamma a_t + \left(1 - \gamma\right) b.$$

B.4.2 Collective wage bargaining with income taxes

With proportional income taxes τ_t the value of a worker changes to

$$W_t = w_t \left(1 - \tau_t\right) + \beta E_t \left(1 - \phi_{t+1}\right) W_{t+1} + \beta E_t \phi_{t+1} U_{t+1}.$$

Thus, the maximized Nash product yields

$$\left(1 - \gamma\right)\left(w_t \left(1 - \tau_t\right) - b\right) = \gamma \left(a_t - w_t\right)\left(1 - \tau_t\right).$$

And the wage with income taxes is

$$w_t = \gamma a_t + \frac{1 - \gamma}{1 - \tau_t} b.$$

B.4.3 Individual bargaining

Alternatively let us assume that each worker-firm pair bargains individually over wages and that the government does not allow the usage of STW to have an impact on the wage. The profit of the firm now depends on the idiosyncratic component

$$F_t\left(\varepsilon_t\right) = a_t - w_t\left(\varepsilon_t\right) - \varepsilon_t - c_f + E_t \beta \left(1 - \phi_{t+1}\right) F_{t+1}.$$

Note that we now use the conditional value of a job F_{t+1} (conditional on survival), instead of the unconditional value J_{t+1} because this simplifies the derivations to follow. In case of disagreement, the match is destroyed. The firm can post a new vacancy, but the value of an open vacancy is zero due to the free entry condition. Thus, the fallback option is

$$\widetilde{F}_t = 0,$$

The worker's surplus W from the match is

$$W_t(\varepsilon_t) = w_t(\varepsilon_t) + E_t\beta(1-\phi_{t+1})W_{t+1} + E_t\beta\phi_{t+1}U_{t+1},$$

The workers' fallback option under disagreement is unemployment

$$U_t = b + E_t\beta\eta_t(1-\phi_{t+1})W_{t+1} + E_t\beta(1-\eta_t(1-\phi_{t+1}))U_{t+1}.$$

Again the Nash product is

$$\Pi_t = (W_t(\varepsilon_t) - U_t)^{\gamma}\left(F_t(\varepsilon_t) - \tilde{F}_t\right)^{1-\gamma},$$

implying the following functional form

$$(1-\gamma)(W_t(\varepsilon_t) - U_t) = \gamma F_t(\varepsilon_t),$$

which yields

$$\begin{aligned} w_t(\varepsilon_t) &= \gamma(a_t - \varepsilon_t - c_f) + (1-\gamma)b + \\ &\quad E_t\beta\left[\gamma(1-\phi_{t+1})F_{t+1} + (1-\gamma)(\eta_t - 1)(1-\phi_{t+1})(W_{t+1} - U_{t+1})\right]. \end{aligned}$$

Since $(1-\gamma)(W_t - U_t) = \gamma F_t$ holds for any ε this can be simplified to

$$\begin{aligned} w_t(\varepsilon_t) &= \gamma(a_t - \varepsilon_t - c_f) + (1-\gamma)b + \\ &\quad E_t\beta\left[\gamma(1-\phi_{t+1})F_{t+1} + \gamma(\eta_t - 1)(1-\phi_{t+1})F_{t+1}\right], \\ &= \gamma(a_t - \varepsilon_t - c_f) + (1-\gamma)b + E_t\beta\gamma\eta_t(1-\phi_{t+1})F_{t+1}. \end{aligned}$$

Noting that $\kappa/q_t = \beta E_t(1-\phi_{t+1})F_{t+1}$ and $\eta_t/q_t = \theta_t$ this becomes

$$w_t(\varepsilon_t) = \gamma(a_t - \varepsilon_t - c_f) + (1-\gamma)b + \gamma\kappa\theta_t.$$

This is equation (26) in the main text.

B.5 Budget constraint

B.5.1 Lump-sum taxes

In our baseline version, we assume lump-sum taxation. To aggregate (which is necessary to know the government costs for STW), it is useful to define the stock of workers at the beginning of the period (before separations take place).

$$n_t^B = n_{t-1} + \eta_{t-1}\left(1 - n_{t-1}\right).$$

The budget constraint is

$$b\left(1-\phi^x\right) n_t^B \chi_t \frac{\int_{v_t^k}^{v_t^f} K\left(\varepsilon_t\right) g(\varepsilon) d\varepsilon_t}{\chi_t} + bu_t = T_t,$$

where T_t are lump-sum taxes. Using the definition of total separations (equation 12 in the main text), the law of motion for employment (equation 18 in the main text) and the beginning-of-period stock of workers n_t^B, we know that $\frac{n_t}{1-\phi_t^e} = \left(1-\phi^x\right) n_t^B$. This results in equation (24) from the main text

$$b\frac{n_t}{1-\phi_t^e}\int_{v_t^k}^{v_t^f} K\left(\varepsilon_t\right) g(\varepsilon) d\varepsilon_t + bu_t = T_t.$$

B.5.2 Income taxes

In a robustness check, we assume proportional income taxes under collective bargaining. We assume that the extra-expenses due to short-time work are financed by this tax. Thus, the modified budget constraint is

$$\begin{aligned}
&\tau_t w_t \left(n_t^B \left(1 - \phi_{t+1}^e - \chi_t\right) + n_t^B \chi_t \frac{\int_{v_t^k}^{v_t^f} \left(1 - K\left(\varepsilon_t\right)\right) g\left(\varepsilon_t\right) d\varepsilon}{\chi_t} \right) \\
&= b n_t^B \chi_t \frac{\int_{v_t^k}^{v_t^f} K\left(\varepsilon_t\right) g\left(\varepsilon_t\right) d\varepsilon}{\chi_t}
\end{aligned}$$

B.6 Aggregation

Output is equal to production minus frictional costs (fixed costs of production, firing costs and vacancy posting costs). As a result, output is

$$\begin{aligned} Y_t &= (1-\phi^x)\left(1-\phi^e_{t+1}-\chi_t\right) n^B_t \frac{\int_{-\infty}^{v^k_t}(a_t-\varepsilon_t)\,g(\varepsilon_t)\,d\varepsilon}{1-\phi^e_{t+1}-\chi_t} \\ &\quad + (1-\phi^x)\,\chi_t n^B_t \frac{\int_{v^k_t}^{v^f_t}(1-K(\varepsilon_t))\,(a_t-\varepsilon_t)\,g(\varepsilon_t)\,d\varepsilon}{\chi_t} \\ &- n_t c_f - (1-\phi^x)\,n^B_t \phi^e_t f - v_t\kappa. \end{aligned}$$

Using $\frac{n_t}{1-\phi^e_t} = (1-\phi^x)\,n^B_t$, we obtain expression (25) from the main text

$$\begin{aligned} Y_t &= \frac{n_t}{1-\phi^e_t}\int_{-\infty}^{v^k_t}(a_t-\varepsilon_t)\,g(\varepsilon_t)\,d\varepsilon + \frac{n_t}{1-\phi^e_t}\int_{v^k_t}^{v^f_t}(1-K(\varepsilon_t))\,(a_t-\varepsilon_t)\,g(\varepsilon_t)\,d\varepsilon \\ &\quad -n_t c_f - \frac{n_t}{1-\phi^e_t}\phi^e_t f - v_t\kappa. \end{aligned}$$