The Employment and Output Effects of Short-Time Work in Germany*

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Abstract

We study the employment and output effects of the short-time work (STW) policy in Germany between 2009 and 2010. This intervention facilitated reductions in hours worked per employee with the goal of preventing layoffs. Using confidential German micro-level data we estimate a search model with heterogeneous multi-worker firms. Our findings suggest that STW can prevent increases in unemployment during a recession. However, the policy leads to a decrease in the allocative efficiency of the labor market, resulting in significant output losses.

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1 Introduction

In 2009 Germany experienced the largest drop in GDP among OECD countries. Figure 1 shows that GDP fell by 6.9% in the first quarter of 2009 (OECD average -4.8%). Despite this, the German unemployment rate was relatively unaffected, as Figure 2 suggests. During the recession, the unemployment rate increased by less than one percentage point. This experience stands in sharp contrast to other OECD economies, where the unemployment rate increased markedly during the recession and in many cases remained high in the post-crisis period.

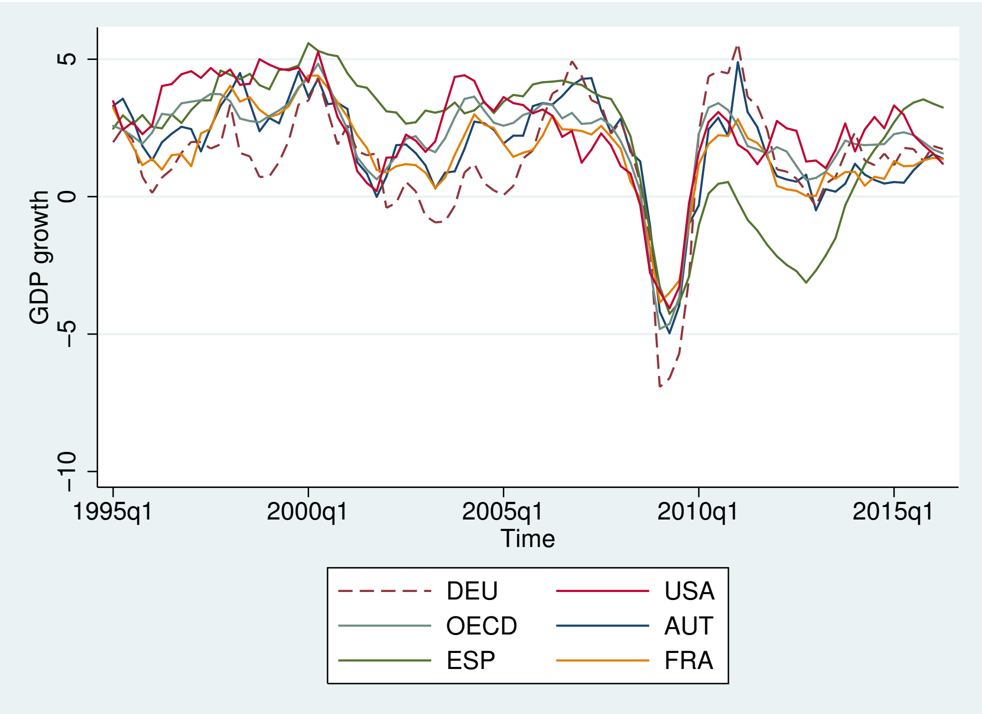

Figure 1: Quarterly GDP growth compared to one year ago for selected OECD-countries. The y-axis shows the growth rate in %. The red dashed line shows Germany. *Source:* OECD.

The economic press has largely attributed this 'German miracle' to the use of 'short-time work' (STW) or 'short-time compensation'. In this paper we ask whether STW played an important role in explaining the distinct response of the German labor market. STW describes a policy instrument which aims at mitigating the negative impact of shocks on the labor market. It enables firms to reduce labor demand via the intensive margin (the number of hours worked per employee) instead of the extensive margin (the number of employees). Absent STW, unilateral reductions in hours worked below the contracted number of hours by the employer (or employee) are illegal in Germany. Affected workers are eligible for a partial compensation of their earnings loss from the social security system. A firm that wishes to temporarily reduce hours per worker must formally apply for STW to the government. In normal times, such reductions in working time are subject to a strict set of legal requirements.[1]

[1] The German Code of Social Law, Book 3 (SGB III) defines short-term work. The requirements for STW are 1.) The hours reduction must not be preventable, meaning employees must not have accumulated overtime or holidays,

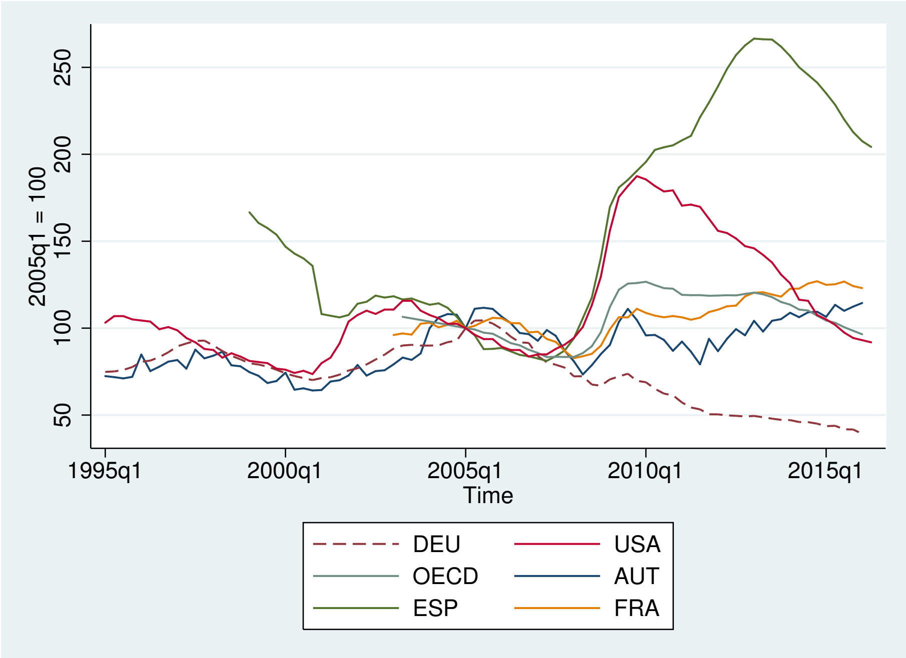

Figure 2: Unemployment Rates for selected OECD-countries. 2005q1 = 100. The red dashed line shows Germany. *Source:* OECD.

In 2009 the STW instrument was significantly extended. For the remainder of this paper, this extension will be referred to as the 'STW policy'. The German government dramatically loosened the eligibility criteria for firms and significantly expanded the policy's scope.[2] During the recession years of 2009 and 2010 the German government compensated 60% (67% for workers with children) of the net earnings difference due to a working hours reduction. Hours worked were paid as usual. Newspaper ads were taken out by the government to encourage firms to apply for STW. The maximum duration of STW was extended from six to 18 and later 24 months. At its height the program included around 60,000 establishments and approximately 1.5 million workers.[3] The extension of the policy was reversed in 2010.

We use confidential German plant-level micro data on the universe of German manufacturing plants (the 'AFiD-Panel Industriebetriebe') in order to estimate a structural model of the German labor market. Our model builds on Cooper, Haltiwanger, and Willis (2007) and Elsby and Michaels

and the firm must be unable to compensate the work stoppage with variations in intra-firm working hours that are permissible according to the work contract. 2.) At least a third of the firm's workforce must suffer an earnings loss of at least 10%. 3.) The firm must show that it is facing a *temporary* reduction in working time due to an economic downturn. The maximum duration of STW is six months. The firm must show that after this time full-time employment can be restored. There exist three different forms of short-time work: 1.) Due to economic distress (§170), 2.) seasonal fluctuations (§175) 3.) transfer payments mainly during the German reunification (§216b). In this paper we focus exclusively on the first type. The use of other types of STW has not significantly changed during the period under consideration.

[2]Eligibility criteria 2) and 3) referred to in footnote 1 were loosened. Most importantly, firms no longer needed to show that the hours reduction would only last a maximum of six months. The employers' contribution to social security was initially paid in full by the firm. In a subsequent modification, the employers' contribution was made proportional to the hours worked or even paid in full by the government in special cases.

[3]In May 2009 there were 1,442,667 workers on STW for economic reasons, up from 39,697 a year earlier. In the Appendix we give more details about the uptake of the policy over time.

(2013), which feature heterogeneous firms and homogeneous workers. Multi-worker firms are subject to persistent aggregate and idiosyncratic productivity shocks and choose both employment and hours worked. Our quantitative exercise uses a simulated method of moments (SMM) approach to match the distributions of hours and changes in German firms prior to the policy.

We use the model to answer two questions: (i) can short-time work save jobs? and (ii) what are the costs of STW in terms of productivity and output? We answer these questions by simulating counterfactual scenarios, in particular what the response to the recession would have been in the absence of STW. Our results indicate that STW can save jobs. However, the policy has negative effects on output. This result obtains because during STW, productive firms find it more costly to hire labor because fewer workers are released into the unemployment pool. In market economies the efficiency of the allocation of factors across production sites has been shown to play an important role for aggregate productivity (see Hsieh and Klenow (2009), Bartelsman, Haltiwanger, and Scarpetta (2013), Cooper and Schott (2016)). By intervening into the reallocation of factors across production sites, i.e. preventing labor from flowing towards the most productive firms, STW can generate adverse effects on GDP through this 'reallocation channel'. To uncover this channel, it is important to take the firm distribution into account by explicitly accounting for firm heterogeneity.

Other papers which study the STW policy in Germany during 2009 and 2010 include Burda and Hunt (2011), Balleer, Gehrke, Lechthaler, and Merkl (2016), Cahuc and Carcillo (2011), and Hoffmann and Lemieux (2016).[4] Burda and Hunt (2011) provide an overview of the institutional framework in Germany. They conclude that the main reasons for the performance of the German labor market during the years 2009/10 were a reticence to hire in the previous expansion, wage moderation, and flexibility in hours worked (mainly through STW but also through working-time accounts).[5] Balleer et al. (2016) build a search and matching model in which heterogeneous workers can be put on STW. In their model a persistent STW 'policy shock' generates positive output and employment effects because firms can reduce the working times of unprofitable workers. Our model is different from Balleer et al. (2016) because we consider heterogenous firms and homogenous workers. This allows us to study the productivity implications of the allocation of workers to firms. Another important difference is that we explicitly allow for an intensive margin of labor demand, even absent the STW policy.[6] In contrast to much of the previous research on the German labor market (e.g. Krause and Uhlig (2012), and Cahuc and Carcillo (2011)) we highlight the importance of firm heterogeneity, both in the data and in our model. Representative firm models as in Marimon and Zilibotti (2000) and Kudoh and Sasaki (2011), as well as reduced-form relationships ignore this heterogeneity and are therefore unable to capture the effects of STW on labor reallocation and output.[7]

[4]This paper is also related to the literature on the efficacy of hours reductions in static firm models (see e.g. Burdett and Wright (1989), Hunt (1998, 1999), Braun and Brgemann (2014)).

[5]Positive balances on working-time accounts have initially allowed firms to lower working hours without laying-off employees but they do not explain why the unemployment rate remained low even when this first buffer was fully exhausted. Firms were required to fully balance working-time accounts and reduce accrued holidays before being eligible for short time work.

[6]Furthermore, the selective application of STW to specific workers which Balleer et al. (2016) study might have been largely impossible in Germany due to legal constraints (see e.g. Kruppe and Scholz (2014)).

[7]During the early 2000s a series of labor market reforms was enacted in Germany (the so-called *Hartz reforms*).

	Count	Mean	SD	IQR	p10	Median	p90
N	38,839	98.5	142.6	73.8	19.4	48.2	228.0
H	33,617	156,300	20,576	11,694	3,578	8,366	35,107
H/N	34,303	135.8	35.7	31.6	104.5	134.0	167.9
PY	39,180	1,531,785	3,106,538	1,116,285	101,242	474,343	3,766,944

Table 1: Summary Statistics. *Note:* Summary statistics for Employment N, Hours H, Hours per Employee H/N, and Revenues PY. The table shows average values over all years. Revenues are deflated to 2005 Euros. *Source:* Afid Panel Industriebetriebe

2 Data

Our micro data comes from the 'AFiD-Panel Industriebetriebe', a confidential panel of the universe of German manufacturing plants administered by the German Federal Statistical Office in cooperation with the statistical offices of the German *Länder*. The panel contains annual data from plants with more than 20 employees between 1995 and 2010.[8] It covers a maximum of 68,000 plants per year. Participation in the surveys is mandatory. For the purposes of this paper we use an unbalanced panel of 39,180 plants.[9]

Our focus on the manufacturing sector is warranted for the purposes of this paper because the use of STW was heavily concentrated in this sector. At the height of the STW program in 2009, over 80% of workers and around 45% of plants that used STW were located in the manufacturing sector (see Appendix). In Germany, employment in this sector is heavily concentrated in medium-sized and/or family-owned firms (German *Mittelstand*). Including these firms is therefore crucial in any assessment of labor market policies. Using administrative micro data drastically reduces sampling bias and allows for a clear identification of the effect of the policy on employer behavior. A shortcoming of the data is that it contains no direct information on whether or not a plant used short-time work. This section produces ample evidence that the effect of the policy is visible in our sample.

They were aimed primarily at reducing long-term unemployment by combining unemployment insurance and social security benefits. The reform also increased the flexibility of firms in adjusting the number of employees in small firms but did not affect the flexibility of hours worked. Firm level data do not suggest a structural break in the demand for full-time workers, but it is possible that less regulation facilitated employment growth between 2005 and 2008. However, there are legal constraints to transforming full-time positions into marginal employment during a crisis. Krause and Uhlig (2012) evaluate the impact of those reforms on employment. They find a large reduction in unemployment due to the reforms but attribute the behaviour of the German labor market during the 2009 recession to STW, which they do not model. Contrary to our approach, the search model in Krause and Uhlig (2012) is in large parts calibrated to the US labor market.

[8]The data includes smaller plants if they belong to a *firm* with at least 20 employees. For the years 2007 to 2010 the cutoff to be included in the survey was increased to 50 employees. In our data this change did not significantly influence the distribution of our variables of interest, also because many smaller firms continued to voluntarily provide this information (data is available upon request). Furthermore, in the Appendix we show that the vast majority of workers on STW worked in medium and large firms.

[9]We start with 59,268 different plants before winsorizing the data. Plants with less than three consecutive observations account for 2.8 percent of all plant-year observations and were deleted from the final subsample. This leaves on average 39,180 plants per year. Of those, 19,373 plants were observed for all years between 1995 and 2010.

Descriptive statistics are shown in Table 1. The table shows time-series averages of total employment, total hours, hours per worker, and revenues. The average number of employees is 98.5. More than 50% of plants employ less than 50 workers, whereas the largest 10% employ more than 200 workers. Average hours worked at the plant level are computed as total hours worked divided by total employment in each month. The large differences between the 10th and the 90th percentile of the distribution of revenues illustrate substantial plant heterogeneity. The 2009 recession is clearly visible in our micro data: Between 2008 and 2009 mean (median) revenues fell by 9% (12%).

We use the micro data to decompose changes in total hours worked into an intensive and an extensive margin. Figure 3 shows a large reduction in total hours worked in 2009, with a reversal in 2010. This reflects the impact of the recession on labor demand of plants in our data. The figure shows that not only was the reduction in total hours unprecedented, it also reveals that almost 70% of it was driven by reductions in hours per worker. We attribute this to the use of STW. In previous recessions, for example in 2003, there was no similar extension of the STW instrument and also no comparable decrease in average hours.[10]

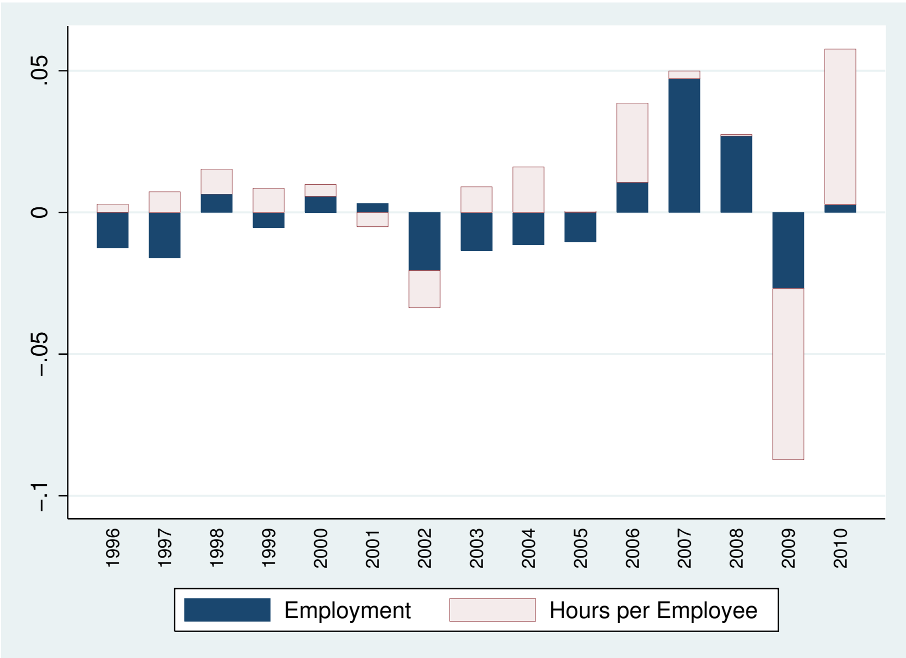

Figure 3: Decomposition of changes in total hours into the intensive and the extensive margin. The y-axis shows differences of the logarithm of total hours worked. The numbers are calculated using the average changes from the micro data. Source: author's calculations from the AFiD-Panel Industriebetriebe.

The fact that *Kurzarbeit* created an unprecedented flexibility in average hours is central to this study. This flexibility is shown in more detail in Figure 4, which shows the distribution of changes in average hours. The years 1995-2008 (blue) serve as references years, while the year 2009 (red) was the year of the STW policy. In 2010 (green) the policy was phased out. The figure shows the

[10]The Figure shows the difference in the cross-sectional average of the logarithm of total hours worked, which is the sum of log hours per employee and the log of the number of employees. Using the aggregate average, instead of the cross-sectional averages leaves the results virtually unchanged.

share of plants adjusting hours within a given interval for each of the three different time periods. We define inactive plants as those who adjust annual hours by less than 5%.

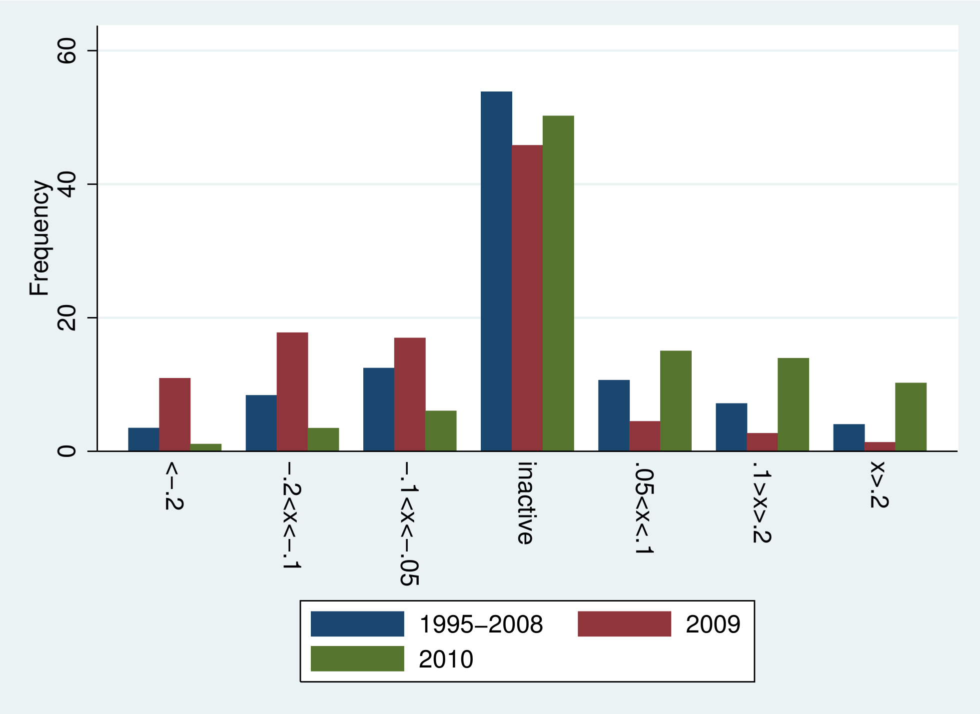

Figure 4: Distribution of changes in annual hours per worker. *Note:* The data is computed using year-to-year changes at the establishment-level. The different bins show the fraction of plants that changed the annual hours per worker by the indicated amount. Within each bin the order of the time periods is 2000-2008, 2009, 2010. *Source:* Author's calculations from the AFiD-Panel Industriebetriebe.

Three things stand out: 1.) Adjustments in average hours are prevalent, 2.) the hours change distribution between 1995 and 2008 is characterized by many small adjustments of less than 5% (including inactivity), whereas large adjustments of over 20% in average hours worked per employee are rare, and 3.) in 2009 the distribution significantly shifts towards negative hours adjustments. Only looking at aggregates in the number of hours worked per employee thus hides substantial heterogeneity among plants. The impact of the STW policy is clearly visible in our data: The fraction of plants that reduced average hours by more than 20% more than tripled in 2009. This unprecedented shifts reflects the ability of plants to reduce hours worked as a results of the STW policy. These negative hours adjustments were reversed in 2010, where large positive adjustments are prevalent in the data.

3 Model

In the next sections, we construct and estimate a search model of the labor market. The model is used to evaluate the effects of STW on the German economy.

We first describe the stationary economy without any constraints on firms' hours choices and without aggregate shocks. In the next subsection, we model the German labor market by imposing a lower bar on hours, below which firms cannot operate, $h \geq \underline{\text{h}}$. The STW policy removes this constraint and provides income support for workers whose hours are reduced. The policy is financed through lump-sum taxes on workers. In section 4.2 results under the policy intervention are shown for the stationary economy. In section 5.2 we add aggregate productivity shocks to the model and compare the response of the economy with and without STW.

The economy is populated by workers, firms, and a government. The time period is one month. Firms are subject to persistent, time-varying idiosyncratic productivity shocks ε. Firms choose the number of workers n and average hours h. Workers are homogeneous. The labor market is frictional. There exists a constant returns to scale matching technology $M = m(U, V)$, with the unemployment rate U and the vacancy rate V as inputs. A vacancy is matched to a worker during a period with probability $q = M/V = m(\frac{U}{V}, 1)$. The labor market tightness $\theta = V/U$ is a sufficient statistic for the job finding and vacancy filling probabilities. A worker finds a job with probability $\phi = q\theta$.

3.1 Economy without Hours Constraints

This sub-section describes the optimization problem of firms as well as the values of employment and unemployment for workers. Using these values, a wage function is obtained as the outcome of a bargain between a firm and multiple workers.

Firms The production technology uses labor as the only input and is given by $F(L)$. Define $L \equiv h \cdot n$ as total labor input, composed of the number of workers n and average hours h. The production function $F(L)$ is assumed to be strictly increasing and strictly concave. Hours adjustments are costless and instantaneous. Adjustments in the number of workers are costly because of the existence of vacancies creation costs.

The timing is as follows: At the beginning of a period the firm has n_{-1} workers and learns about its idiosyncratic productivity state ε. A firm in state (ε, n_{-1}) chooses n (equivalently, posts vacancies) and h to determine its scale of production. It then negotiates the wage with its n workers and produces output. If a firm is hiring (shown by the indicator function $\mathbb{1}^+$ in equation (1)), the change in employment is given by $n = n_{-1} + qv$. Taking into account the vacancy filling probability q the firm can perfectly choose the level of employment n. If a firm is firing we have $n = n_{-1} - f$. There are no firing costs and no exogenous quits. The firm's expected present discounted value in state $s = (\varepsilon, n_{-1})$ is given by

$$V(\varepsilon, n_{-1}) = \max_{h,n} \left\{ \varepsilon F(h \cdot n) - \omega(h, n, \varepsilon) \cdot h \cdot n - \frac{c_v}{q}(n - n_{-1})\mathbb{1}^+ + \beta \int V(\varepsilon', n) dG(\varepsilon'|\varepsilon) \right\}. \quad (1)$$

Here c_v is a linear vacancy creation cost. The discount factor is β. Worker compensation per hour is $\omega(\cdot)$, which will be derived below.

The FOC with respect to hours is given by

$$\varepsilon F_L(h \cdot n) - \omega(h, n, \varepsilon) \; - \; \omega_h(h, n, \varepsilon) \cdot h = 0. \tag{2}$$

Let $\mathcal{H}(\varepsilon, n)$ denote the optimal choice of hours given (ε, n). The firm chooses hours to equalize the marginal benefit from increasing total labor input by an additional hour with the marginal cost: The wage has to paid for one additional hour of work and existing workers have to be paid an increased wage to compensate for the hours increase. If $\Delta n \neq 0$ the first order condition for n yields

$$\varepsilon h F_L(h \cdot n) - \omega(h, n, \varepsilon) \cdot h - \omega_n(h, n, \varepsilon) \cdot nh - \frac{c_v}{q} \mathbb{1}^{+} + \beta D(\varepsilon, n) = 0, \tag{3}$$

where $D(\varepsilon, n) \equiv \int V_n(\varepsilon', n) dG(\varepsilon'|\varepsilon)$ is the marginal effect of current employment choices on the expected future value of the firm. The firm changes employment until the point where the marginal benefit of the employment change is equal to the expected marginal cost. The marginal benefit of an additional worker is given by the change in output plus the expected effect on the future value of the firm. The marginal costs include the additional hiring costs and the changes in wage payments.

Workers Workers' preferences are defined over consumption and leisure. The disutility from providing hours is parameterized by $\xi(h)$. We assume that $\xi'(h) > 0$, $\xi''(h) > 0$, and $\xi(0) = 0$. Workers are assumed to be risk-neutral. They can be either unemployed or employed.

The value of being employed in a firm in state (ε, n) is given by

$$W^e(\varepsilon, n) = \omega(h, \varepsilon, n) \cdot h - \xi(h) + \beta \mathbb{E}_{\varepsilon'|\varepsilon} \left[s W^{u\prime} + (1 - s) W^e(\varepsilon', n') \right] \tag{4}$$

where $h = \mathcal{H}(\varepsilon, n)$.

An employed worker's instantaneous utility consists of the hourly wage $\omega(\cdot)$ times h hours worked minus the disutility from providing h hours. A match can be (endogenously) severed with probability s. In that case the worker becomes unemployed next period and receives the future value of being unemployed, $W^{u\prime}$. With the counter-probability the worker remains employed in the firm, which is then in state (ε', n'). The expectation is taken over possible future levels ε' conditional on today's value of ε. The value of being unemployed is given by

$$W^u = b + \beta \mathbb{E}_{(\varepsilon', n')} \left[(1 - \phi) W^{u\prime} + \phi W^e(\varepsilon', n') \right]. \tag{5}$$

The instantaneous utility for an unemployed workers is the (exogenous) payoff b. With probability $1 - \phi$ the worker remains unemployed. With the counter-probability a match is formed with a hiring firm. That firm will be in state (ε', n') tomorrow. The expectation is taken over the distribution of (ε', n') among hiring firms.

Wage Setting Because of the existence of labor market frictions, quasi-rents exist from forming a match over which workers and firms bargain. Wages are determined through a Nash bargain between a firm and its many workers over the surplus of the match. Since the production technology features decreasing returns to scale, we adopt the bargaining solution proposed in Stole and Zwiebel (1996) by extending the framework in Elsby and Michaels (2013) to include hours worked. Wages are set after employment has been determined, meaning that at the time of the negotiations the hiring costs are sunk. A worker's surplus from forming a match is given by the value of being employed in a firm in state (ε, n) minus the value of being unemployed. The firm's marginal surplus of forming the match with any given worker is given by

$$S(\varepsilon, n) = \varepsilon h F_L(h \cdot n) - \omega(h, n, \varepsilon)h - \omega_n(h, n, \varepsilon)hn + \beta D(\varepsilon, n). \tag{6}$$

The bargaining power of the worker is parameterized as η. Nash-bargaining over the marginal surplus implies that the surplus is shared according to

$$W^e(\varepsilon, n) - W^u = \frac{\eta}{1-\eta} S(\varepsilon, n). \tag{7}$$

The wage then solves the following differential equation.[11]

$$\omega(h, \varepsilon, n) \cdot h = (1-\eta)\left[b + \xi(h)\right] + \eta \left[\varepsilon h F_L(h \cdot n) + \beta\phi \frac{c_v}{q} - \omega_n(h, n, \varepsilon) \cdot h \cdot n\right]. \tag{8}$$

Wages are increasing in the worker's bargaining power, the marginal product of labor, the hiring costs, the value of leisure, and the disutility of labor. The term $w_n(h, n, \varepsilon) \cdot h \cdot n$ represents the effect of a marginal worker on the firm's marginal product of labor. If the negotiations were to fail, this increases all the other workers' marginal product of labor, thus increasing the average wage payments for the firm. With respect to Elsby and Michaels (2013) there is an additional effect from the disutility of providing hours: The optimal choice of hours now influences the effect a marginal worker can have on the marginal product of labor. By choosing a larger number of hours, the firm can decrease the marginal product and partially offset the spillover into the remaining workers' marginal product in case of a failed wage negotiation.

For the remainder of the analysis, assume $F(h \cdot n) = (h \cdot n)^\alpha$. The total wage paid per worker is given by

$$\omega(h, \varepsilon, n) \cdot h = (1-\eta)\left[b + \xi(h)\right] + \eta \left[\frac{\varepsilon \alpha h^\alpha n^{\alpha-1}}{1-\eta(1-\alpha)} + \beta\phi \frac{c_v}{q}\right]. \tag{9}$$

Optimal Labor Demand Given the wage in (9), we can solve for firm's hours choice analytically. Plugging the wage into (2), the first order condition for hours, we obtain

$$h^* = \left[\frac{\varepsilon \alpha n^{\alpha-1}}{\xi'(h^*)\left(1-\eta(1-\alpha)\right)}\right]^{\frac{1}{1-\alpha}}. \tag{10}$$

[11] All the expressions to solve (7) and derive the wage can be found in Appendix B

This determines the firm's hours policy $\mathcal{H}(\varepsilon, n)$. The firm's employment policy can be obtained by combining the first-order conditions for employment (3) with the wage (9):

$$(1-\eta)\left[\frac{\varepsilon\alpha h^{\alpha}n^{\alpha-1}}{1-\eta(1-\alpha)}-(b+\xi(h))\right]-\eta\phi\frac{c_v}{q}-\frac{c_v}{q}\mathbb{1}^{+}+\beta D(\varepsilon,n)=0 \tag{11}$$

The optimal employment policy is defined by cutoff values in idiosyncratic productivity ε. If productivity today is below a certain threshold, the firm will fire workers. Similarly, if ε is above a certain threshold, the firm will post additional vacancies. The region between those two cutoffs defines the region of inactivity. The thresholds are denoted as ψ_v and ψ. The inverse of the threshold values, $\psi_v^{-1}(\varepsilon)$ and $\psi^{-1}(\varepsilon)$, define the optimal choice of employment given the level of productivity ε today. This employment policy will be denoted as $\mathcal{N}(\varepsilon, n_{-1})$ and takes the form

$$\mathcal{N}(\varepsilon,n_{-1})=\begin{cases}\psi_v^{-1}(\varepsilon) & \text{if } \varepsilon>\psi_v(n_{-1}),\\ n_{-1} & \text{if } \varepsilon\in\left[\psi(n_{-1}),\psi_v(n_{-1})\right],\\ \psi^{-1}(\varepsilon) & \text{if } \varepsilon<\psi(n_{-1}),\end{cases} \tag{12}$$

where the functions $\psi_v(\cdot)$ and $\psi(\cdot)$ satisfy

$$(1-\eta)\left[\frac{\psi_v(n)\alpha h^{\alpha}n^{\alpha-1}}{1-\eta(1-\alpha)}-(b+\xi(h))\right]-\eta\phi\frac{c_v}{q}+\beta\int V_n(\varepsilon',n)dG(\varepsilon'|\psi_v(n))\equiv\frac{c_v}{q} \tag{13}$$

and

$$(1-\eta)\left[\frac{\psi(n)\alpha h^{\alpha}n^{\alpha-1}}{1-\eta(1-\alpha)}-(b+\xi(h))\right]-\eta\phi\frac{c_v}{q}+\beta\int V_n(\varepsilon',n)dG(\varepsilon'|\psi(n))\equiv 0 \tag{14}$$

If ε is time-invariant the first order condition for employment (3) reduces to

$$n=\left(\frac{\varepsilon\alpha h^{\alpha}}{\Gamma}\left[\frac{1-\eta}{1-\eta(1-\alpha)}\right]\right)^{\frac{1}{1-\alpha}}, \tag{15}$$

where $\Gamma=(1-\eta)[b+\xi(h)]+\eta\phi\frac{c_v}{q}$. It increases if ε increases and decreases with b and the worker's disutility of labor. This expression will be used in the calibration of the model.

Distribution of Firms The distribution of firms over productivity and employment will be denoted as $\lambda(\varepsilon, n_{-1})$. Its law of motion is governed by the process for idiosyncratic profitability shocks and the firm's policy function for employment, $\mathcal{N}(\varepsilon, n_{-1})$. The stationary equilibrium of the model is described by a time invariant (stationary) distribution λ^*.

Equilibrium A stationary equilibrium are policy functions $\mathcal{N}(\varepsilon, n_{-1})$ and $\mathcal{H}(\varepsilon, n)$, a stationary distribution $\lambda^*(\varepsilon, n_{-1})$ and a wage schedule $\omega(\cdot)$, such that policy functions solve the firm's problem, the wage solves the bargaining problem between workers and firms, and the distribution λ^* is a fixed point.

3.2 Hours Constraint and Short-Time Work

To capture the rigidities of the German labor market in terms of hours adjustments, we let $\underline{\mathrm{h}}$ represent some notion of "normal" hours per worker, as in Burdett and Wright (1989). Firms must set $h \geq \underline{\mathrm{h}}$, which introduces an additional constraint on the firm optimization problem compared to the setup above, where implicitly $\underline{\mathrm{h}} = 0$.

We can now introduce the 'STW policy', which will be represented by the parameter Ξ. The optimal hours policy as a function of Ξ becomes

$$h^* = \max\left\{\underline{\mathrm{h}} - \Xi, \left[\frac{\varepsilon \alpha n^{\alpha-1}}{\xi'(h^*)\,(1-\eta(1-\alpha))}\right]^{\frac{1}{1-\alpha}}\right\}. \tag{16}$$

This defines $\mathcal{H}(\varepsilon, n; \Xi)$. Hours must be set to at least $\underline{\mathrm{h}} - \Xi$. In this way the policy can have an effect on hours (and therefore also employment) by increasing Ξ in an environment in which the lower bound on hours is binding. The policy parameter can take values $\Xi \in [0, \underline{\mathrm{h}}]$, with 0 representing 'no policy', and $\Xi = \underline{\mathrm{h}}$ representing 'full flexibility'.

Government The government provides short-term compensation and levies lump-sum taxes on workers to balance its budget. In line with the German STW policy, the government replaces a fraction τ_Ξ of the regular full time wage of workers whose hours are reduced. For each worker on STW the government pays $\tau_\Xi \cdot (\underline{h} - h)\,\omega(h, \varepsilon, n)$.

The government levies a lump sum tax τ_t on all workers in the economy in order to pay for the STW policy. The size of the labor force is L. The government breaks even in each period.

$$L \cdot \tau_t = \tau_\Xi \cdot \int_{s=(\varepsilon, n_{-1})} (\underline{h} - h_t) \cdot \mathbb{1}_h\, \omega(h_t, \varepsilon_t, n_t) \lambda_t(ds). \tag{17}$$

The indicator $\mathbb{1}_h$ takes the value of one if $\underline{h} > h$. When the policy is not in place $\tau_\Xi = 0$. Since the policy is financed in a lump-sum fashion, taxes do affect the negotiation because they do not change a worker's surplus from finding a match.

4 Calibration and Estimation

This section presents our parameter values as well as their moment implications. This model is fit prior to the policy intervention and is then used to explore the effects of STW.

4.1 Parameterization

The stationary model is fit to the German economy prior to the 2009 recession.[12] There is an hours constraint $\underline{\mathrm{h}} > 0$ but no STW policy, i.e. $\Xi = 0$. The model is solved at a monthly frequency. The discount factor is set at $\beta = 0.9967$, corresponding to an annual interest rate of 4%.

[12]Though as noted below, some parameters come from US studies due to data limitations.

The top block of Table 2 indicates the calibrated parameters. The matching function is assumed to be of the form $M = \mu U^{\gamma} V^{1-\gamma}$. We set the match elasticity to $\gamma = 0.6$ as in Petrongolo and Pissarides (2001). We target a monthly job-finding probability of $\phi = 0.0622$ (Ravenna and Schott (2016)). The German Employment Agency publishes a monthly series of the number of vacancies. We find an average labor market tightness of $\theta = 0.091$. This implies that in the steady state $\mu = 0.1622$.[13] The resulting monthly vacancy-filling probability is $q = 0.6835$. The parameter α, which governs the decreasing returns to scale in production, is taken from Cooper et al. (2007) and set to 0.65.[14] Workers' disutility of labor is given by $\xi(h) = \xi_0 h^{1+\frac{1}{\xi_1}}$.[15]

Parameter	Meaning	Value	Reason
		Calibrated	
β	Discount factor	.9967	Annual $r = 4\%$
γ	Matching elasticity	.6	Petrongolo and Pissarides (2001)
μ	Matching efficiency	.1622	$\theta = 0.091$
α	$F(L) = L^{\alpha}$	.65	Cooper et al. (2007)
$\bar{\varepsilon}$	Mean of ε	1	Normalization
b	Unemployment benefit	.024	Average employment = 98.5
ξ_0	Disutility of work (scale)	.124	Average hours = 1
η	Worker bargaining power	.413	Labor share 0.76
		Estimated	
ξ_1	Disutility of work	4.42	Table 3
c_v	Vacancy cost	.065	Table 3
ρ_{ε}	Persistence of ε	.983	Table 3
σ_{ε}	Std. dev. of ε	.037	Table 3

Table 2: Model Parameters.

The parameters b, ξ_0, and η are jointly calibrated by targeting the average levels of employment, hours worked, and the labor share. From the micro data we obtain a target for the average establishment size of 98.5 workers. As in Cooper et al. (2007) we normalize hours such that in the steady state without time-varying ε, average hours are equal to one.[16] We calibrate η by targeting the labor share in manufacturing in Germany between 1995-2008, which is 0.76 (Source: OECD).

The remaining parameters are estimated via simulated method of moments (SMM). These parameters are the vacancy-posting costs c_v, the disutility of labor ξ_1, and the parameters governing the evolution of idiosyncratic productivity shocks, ρ_{ε} and σ_{ε}. There exists no one-to-one mapping of parameters into moments here. We therefore chose moments that are informative about the underlying parameters. The estimated parameter values are shown in Table 2. The estimation is summarized

[13] Since $\phi = \mu\theta^{1-\gamma}$.

[14] Our data does not allow us to estimate the parameter α directly from the German plant-level data.

[15] This implies that the hours policy can be written as

$$\mathcal{H}(\varepsilon, n; \Xi) = \max\left\{ \underline{\mathrm{h}} - \Xi, \left[\frac{\varepsilon \alpha n^{\alpha-1}}{\xi_0 (1 + \frac{1}{\xi_1}) (1 - \eta(1-\alpha))} \right]^{\frac{1}{1-\alpha+\frac{1}{\xi_1}}} \right\}$$

[16] This is taken to represent the average number of hours worked in the German manufacturing sector. Using our micro-data this corresponds to 35 hours.

in Table 3.

Moment	Data	Model
$\frac{L-N}{L} = \frac{\delta}{\phi+\delta}$	.09	.09
$\Delta h < \lvert 5\% \rvert$ (annual)	.538	.542
$\Delta n < \lvert 5\% \rvert$ (annual)	.476	.440
$cv(n)/cv(h)$	5.63	5.66
Distance $L(\Theta)$	-	0.001382

Table 3: Estimated Parameters

A key consistency requirement is that the stock and flow concepts of unemployment consistently yield an unemployment rate of 9.04%. That is the average unemployment rate in Germany between 1992 and 2009, the same period that was used to compute labor market tightness.[17] The jointly estimated parameters must ensure that this consistency requirement is met.

The hours change distribution is informative about the parameter ξ_1. It influences how firms adjust hours following a change in ε. We target the fraction of firms which is inactive in terms of hours adjustments.[18] This inactivity rate is equal to 53.8%. Similarly, we identify c_v via the fraction of employment inactivity (47.6%). Another moment we include in the estimation is $\frac{cv(n)}{cv(h)}$, the ratio of the cross-sectional coefficients of variation of employment and hours. This moment is informative about the relative importance of the hours and employment margins in the economy's steady state.

The estimation finds the vector of parameters $\Theta = (c_v, \xi_1, \rho_\varepsilon, \sigma_\varepsilon)$ that minimizes the (weighted) distance between moments calculated from the model and the data. This distance is denoted as $L(\Theta)$.

4.2 Moments

The estimated parameters generate simulated moments that lie close to their empirical counterparts, as Table 3 shows. The vacancy posting costs of $c_v = 0.0646$ imply that firms spend on average 1.07% of the total monthly wage bill on vacancy posting costs.[19] The estimated values of ρ_ε and σ_ε, as well as the steady state job destruction rate lie close to parameter values estimated in similar studies.[20]

The model generates an inactivity rate in hours of 54.2% and an hours change distribution which

[17] The law of motion for unemployment implies that $u^* = \frac{\delta}{\phi+\delta}$, where δ is the job destruction rate. The stock of unemployed is given by firms' employment policy, pinning down total employment N, which is $L - u^*$. There is no single parameter that is important for this requirement. Positive changes in ρ_ε and negative changes in σ_ε imply less labor turnover in equilibrium and a lower steady-state unemployment rate. The same is true for higher levels of c_v and ξ_1.

[18] As in the data we define 'inactivity' as adjustments smaller than 5% in absolute value. To correspond to our data equivalent, we use time-aggregation to compute year-to-year changes.

[19] Cooper et al. (2007) find that total monthly adjustment costs are 0.775% of firm profits. Silva and Toledo (2009) find that the labor costs of posting vacancies are 32.66% of the average monthly worker wage. In our model this figure is 35.68%.

[20] For example, we obtain a job destruction rate $\delta = 0.0056$, which is very close to the value of 0.00605 obtained by Ravenna and Schott (2016) using German worker-level data.The estimated baseline values in Bachmann and Bayer (2014) imply monthly values of $\rho_\varepsilon = .99725$ and $\sigma_\varepsilon = 0.0261$.

is very close to the data.[21] Similarly, the model's employment change distribution is characterized by a large inactivity region of 44%, which is slightly below its counterpart in the data. While the model produces a realistic employment change distribution, the absence of a richer structure of employment adjustment costs implies that the model produces too many large adjustments and too few small adjustments compared to the data (Cooper et al. (2007)).

An important object in determining the model's dynamics is the negotiated hourly wage between workers and firms. This is shown in Figure 5. The hourly wage is decreasing in the total number of employees n and the number of hours h. If n increases for a given h, this decreases the marginal product of labor and thus negatively affects the wage. When changing hours there are two effects at work. First, similarly to the case for changes in n, for a given n an increase in h decreases the marginal product of labor. This negatively affects the wage. However, the wage now also takes the worker's disutility for providing hours into account. As hours increase, this disutility effect becomes increasingly stronger.

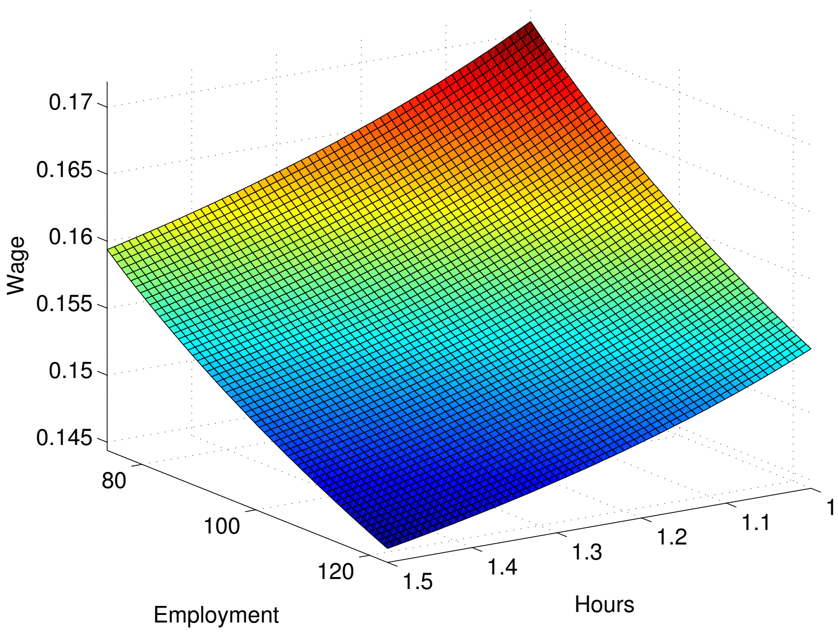

Figure 5: Hourly wage as a function of hours and employment when ε is equal to its unconditional mean. The plot is drawn for values around the optimal steady state policy function.

More productive firms are larger. The model also generates a positive relationship between the intensive and extensive margins of employment, workers and average hours. Large firms choose to work their workers for longer hours. The reason behind this has to do with labor hoarding: The presence of labor adjustment costs generates inactivity in the firm's employment policy. Facing the possibility of receiving a low idiosyncratic productivity shock, a large firm might find it optimal to be able to reduce total hours worked $(n \cdot h)$ through a reduction in hours. This positive relationship between n and h generates a positive relationship between firm size and hourly wage. Furthermore,

[21]This is shown Figures 21 and 22 in the Appendix.

the hourly wage is higher in larger (i.e. more productive) firms, because of the higher surplus generated by matches in these firms.

5 Policy Implications and Aggregate Shocks

We now add two exogenous aggregate states to the model. The first one is an aggregate productivity shock A. The second one is the STW policy. There are two levels of aggregate productivity, A^{low} and A^{high}. In a recession, i.e. when $A = A^{\text{low}}$, the STW policy can be active or not. The state when STW is active during a recession is denoted as A^{Ξ}. The three aggregate states are therefore $\{A^{\text{high}}, A^{\text{low}}, A^{\Xi}\}$. We assume that STW is always *unexpected* by firms.[22] The joint transition matrix Π of the aggregate state between periods t and $t+1$ is given by

$$\Pi = \begin{pmatrix} \rho & 1-\rho & 0 \\ 1-\rho & \rho & 0 \\ 1-\rho & \rho-\pi & \pi \end{pmatrix}.$$

The probability of a change in the productivity state absent STW is given by ρ. Once the economy is in the STW-recession state A^{Ξ}, the policy will continue with probability π. The probability of entering the high productivity state is not affected by the STW policy. The probability π is chosen to generate an expected duration of STW of six months.[23] We calibrate ρ to generate an average duration of a recession and expansion of three years.

To solve the model with aggregate variation we employ a computational strategy along the lines of Krusell and Smith (1998). Firms need to forecast the vacancy-filling probability q, which is an equilibrium object determined by $\lambda(\varepsilon, n_{-1})$, the joint distribution of firms' productivity and employment levels. To forecast q' firms use the information about current q as well as the aggregate productivity level A.

$$\log(q') = \beta_0 + \beta_1 \log(q) + \beta_2 A + \beta_3 A' + \beta_4 (A = A') + \nu$$

The resulting $R^2 = 0.9991$ and the maximum accumulated forecast error is 0.2%.[24]

5.1 STW without Aggregate Productivity Shocks

We are ultimately interested in assessing the effectiveness of the German STW policy during the recent recession. To begin, we consider the effects of STW without variations in aggregate productivity. This will allow us to isolate the effect of the policy and later study potential interactions with aggregate productivity.

[22] As a robustness exercise we compute results when the policy is not unexpected in Section 6. The results are qualitatively unchanged.

[23] The maximum duration of STW was six months before the 2009 episode. During 2009 the maximum duration was increased to 24 months.

[24] We solve the firm's and worker's optimization problem with the transition matrix Π supplementing the idiosyncratic shocks. The firm's state then becomes $s = (\varepsilon, n_{-1}; A, q)$.

A key implication of the constraint is that if a firm cannot choose $h < \underline{\mathrm{h}}$ after receiving a negative shock to idiosyncratic productivity, it must make additional reductions in labor demand via the extensive margin. The STW policy gives the firm additional flexibility in hours. This flexibility implies fewer layoffs and a lower unemployment rate. Because of its effect on the vacancy-filling rate, the lower unemployment rate leads to higher search costs for expanding firms that wish to hire new workers. This will produce a negative effect on output.

The direct effect of the policy is to eliminate the floor on hours. Figure 6 shows the cumulative firm distribution of average hours worked.[25] The blue solid line shows the case without the policy. It is truncated at $\underline{\mathrm{h}} = 1$, representing the hours floor $\underline{\mathrm{h}}$. The red dashed line shows the distribution under the STW policy. Without the constraint a significant fraction of firms chooses $h < \underline{\mathrm{h}}$. Absent the policy, firms create an hours-buffer in order to be able to respond to variations in ε without having to resort to firing.

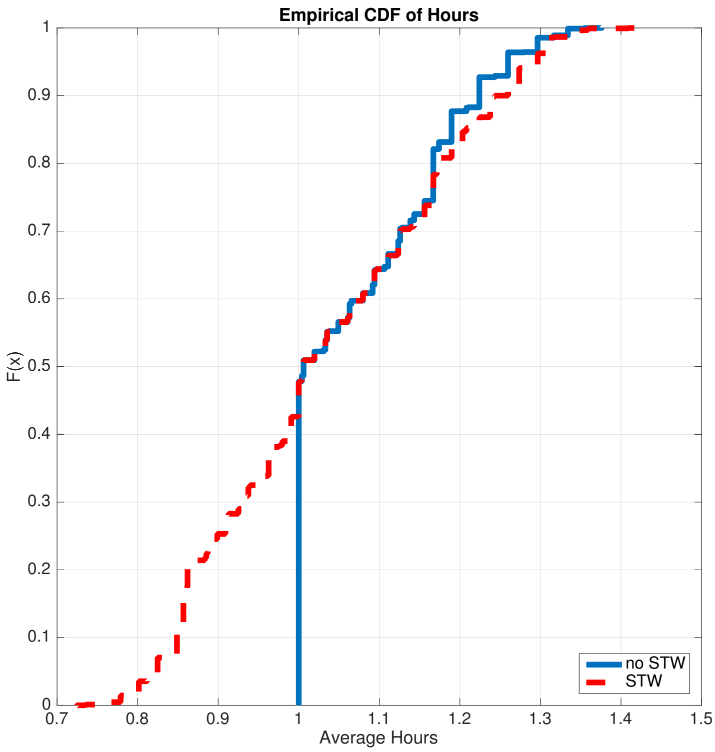

Figure 6: Empirical cumulative density function of average hours worked with and without STW.

Next, we show the transition from an economy with a binding hours floor to one with $\Xi = 1$, i.e. where the STW policy is permanently in place. This is represented by the blue, solid lines in Figure 7. This case is labeled 'GE' for 'general equilibrium', because the vacancy-filling probability q endogenously responds to changes in firms' policies. Figure 7 shows that under the STW policy employment increases by 2.5% (the unemployment rate falls to 75% of the steady state unemployment

[25] Results for the policy are shown for the case when the policy has been in place for a long enough time for the economy to converge to a firm distribution.

rate with $\Xi = 0$). Average hours worked decline by 4.5%, leading total hours worked to decrease. The vacancy-filling probability decreases by 7.9% (or 5.4 percentage points), implying an increase in vacancy-creation costs of 8.6%. As we will show below, this leads to less hiring by expanding firms, causing the observed drop in output of 0.94%.

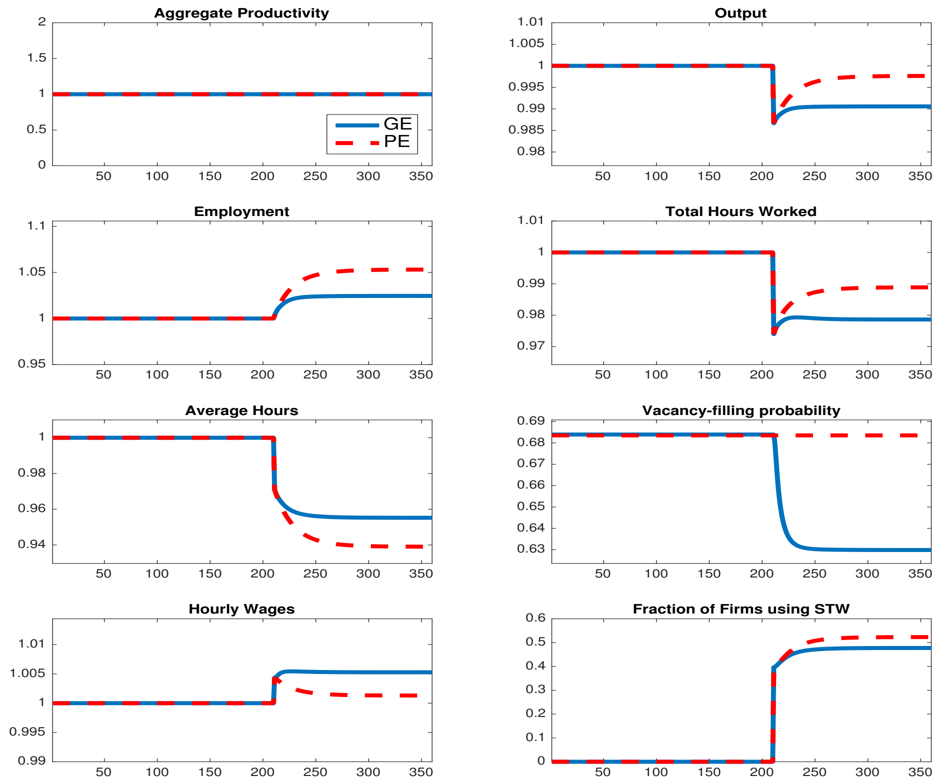

Figure 7: Transition from $\Xi = 0$ to $\Xi = 1$ with and without endogenous q

The endogeneity of q is crucial for the negative effect on output. The red, dashed lines in Figure 7 show the results for the transition into an economy with $\Xi = 1$ when q is exogenously fixed at its steady-steady value. This is abbreviated as 'PE', for 'partial equilibrium'. The positive employment response is now more than twice as large, driving the response of total labor input $h \cdot n$. Importantly, when firms do not face higher vacancy-creation costs as a result of the policy, total output is virtually unaffected. In partial equilibrium, the policy increases employment without the negative consequences for output.

To reinforce this point, consider the effects of the policy on average hours and employment growth for different types of firms. We group firms into three bins, based on their change in idiosyncratic productivity, $\Delta\varepsilon_{i,t} = \varepsilon_{i,t} - \varepsilon_{i,t-1}$. Firms with $\Delta\varepsilon_{i,t} < 0$ become less productive than in the previous period, firms with $\Delta\varepsilon_{i,t} = 0$ have the same productivity, while firms with $\Delta\varepsilon_{i,t} > 0$ become more productive. Note that the mass of firms in each group remains constant over time. Figure 8 compares the responses of average hours worked and the employment changes for each of these groups at the time the STW becomes active. The left (right) side shows the response for firms with negative (positive) productivity growth, while the top (bottom) panel shows the response of average hours (employment growth). As before, the solid blue line shows the results in general equilibrium, while the red dashed line shows the partial equilibrium responses.

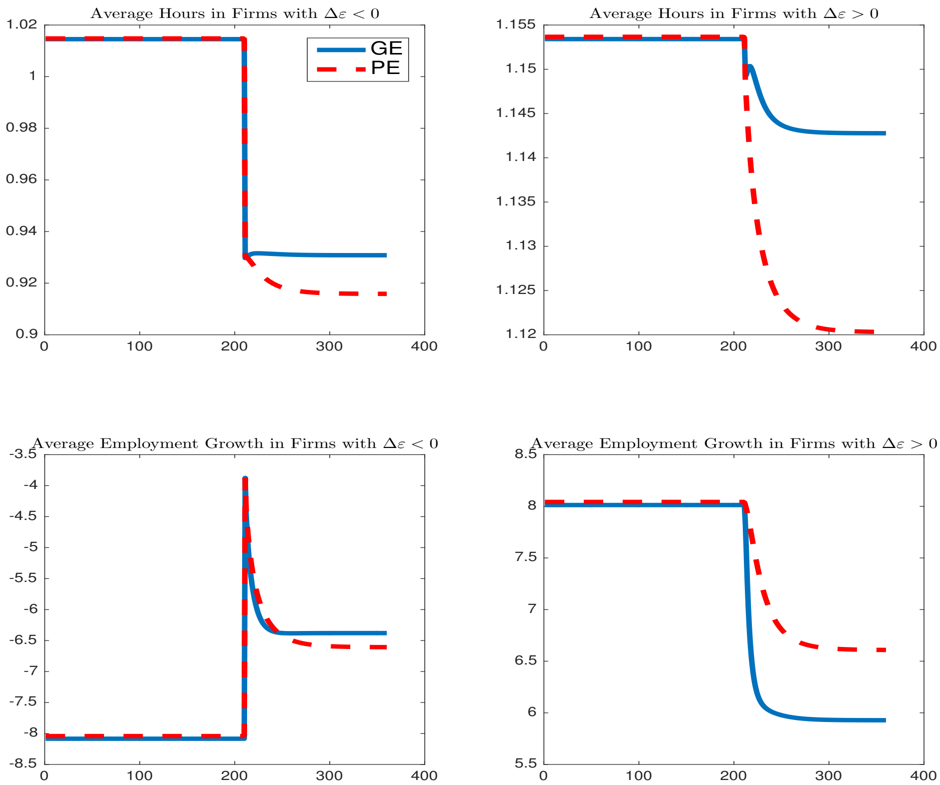

Figure 8: Average Hours and Employment Change by $\Delta\varepsilon$. *Note:* The x-axis shows time, the y-axis respectively shows average hours and employment growth. At $t = 200$ the policy change occurs.

The top panels show that one effect of the policy is a decrease in average hours for both types of firms. The bottom panels show that the two types of firms react differently in terms of employment adjustments. Firms with negative productivity growth reduce hours to $h < \underline{h}$ following the introduction of STW in $t = 200$. This effect is amplified in partial equilibrium, because firms do not face higher expected future hiring costs. As a result of the additional flexibility in hours, firms with $\Delta\varepsilon < 0$ fire *fewer* workers, as the bottom left panel shows. These firms actively use the STW policy: they substitute part of the reduction in employment for a reduction in hours.

Contrast this with the behavior of firms with positive ε growth. These firms reduce the 'hours buffer' and *reduce* employment growth. The difference between general and partial equilibrium in the bottom right panel of Figure 8 shows that a large part of this decrease is a result of the drop in q.[26]

[26] The remaining effect comes from the fact that the largest employment gains occur at firms close to the hours threshold, i.e. low-productivity firms. To reach the new optimal employment level after a positive shock to productivity therefore requires less growth.

Firms with positive productivity growth do *not* use the STW policy. Instead, they are negatively affected by it through higher vacancy creation costs.

The STW policy creates additional flexibility at the firm-level by making it possible for firms to overcome the hours variation friction. This has positive productivity effects because firms set hours such that static the first-order-condition (10) holds. On the other hand the policy leads to less employment growth in expanding firms. Because more labor is being retained at unproductive firms, expanding firms are faced with a higher vacancy creation cost. This leads to less employment growth in firms with positive productivity growth, which negatively affects output. As Figure 7 showed, the joint effect of these two forces is that employment increases but output falls. Figure 9 shows average labor productivity per worker and per hour. As a result of the policy, average labor productivity per worker falls, but average productivity per hours increases.

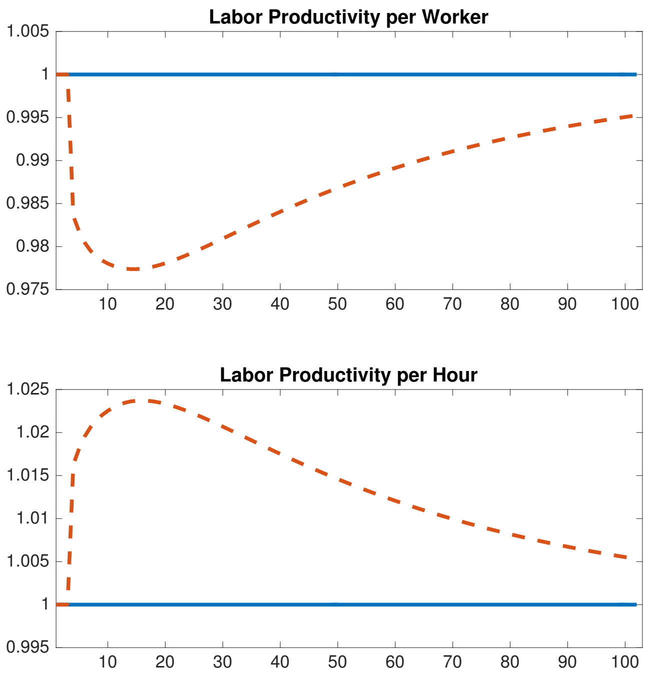

Figure 9: Average Labor Productivity per Hour and per Worker

5.2 STW during Recessions

We now show how the STW policy interacts with negative productivity shocks. We set $A^{\text{low}} = A^{\Xi} < 1$ to generate two recession states, one with, and one without the policy. Figure 10 shows two sets of impulse response functions. Starting in A^{high} the solid blue (red dashed) line shows the response of an economy experiencing a one-time productivity shock A^{low} (A^{Ξ}).

Following the negative productivity shock, firms demand less labor, as shown by the decrease in total labor input. The composition of this reduction is very different across the two recessions. Because the hours floor is binding absent the policy, only small reductions in average hours are

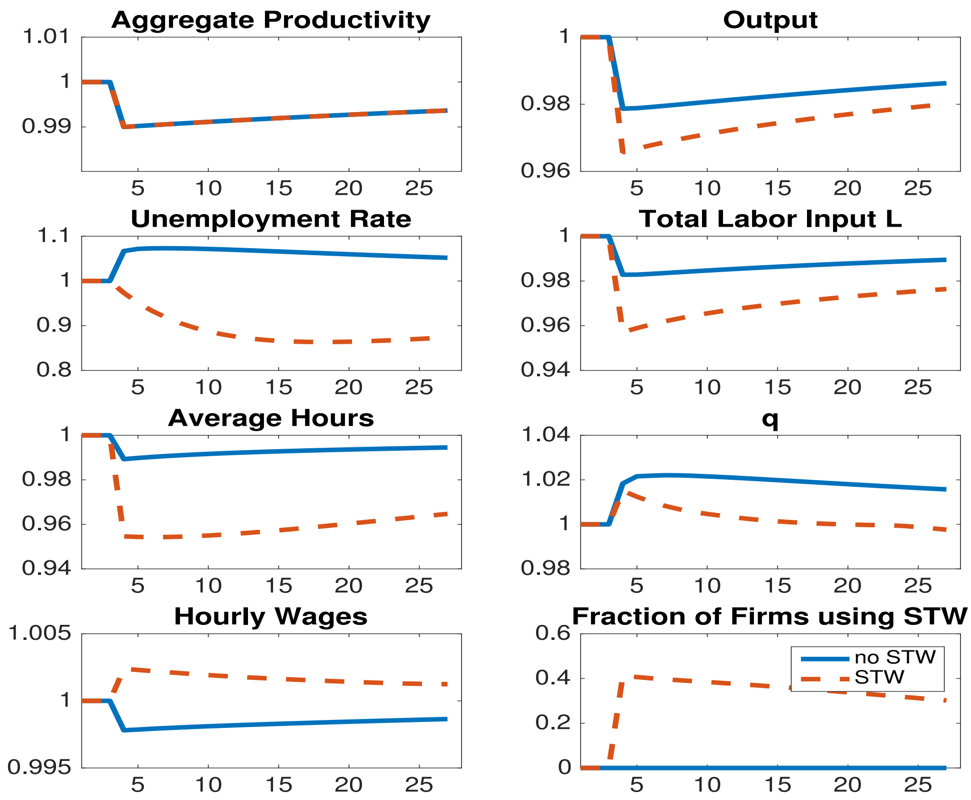

Figure 10: Impulse response functions. The solid blue (dashed red) lines show a recession without (with) STW in place.

feasible, leading to a fall in total employment and an increase in the unemployment rate. When the policy is in place, firms reduce average hours and retain a larger fraction of their employees. This is highlighted in Figure 11 for the case of firms with negative idiosyncratic productivity growth. As was shown above, these are the firms that are most actively using the policy. Firms with positive idiosyncratic productivity growth do not make use of the policy. They grow by less when the policy is in place, reacting to the relative decrease in q.[27]

As the top right panel of Figure 10 shows, the decline in output is stronger when the policy is in place. During the STW policy, output falls by an additional 1.3% of pre-recession output. This is related to the 'cleansing' effect of recessions: The increase in the vacancy-filling probability encourages job creation and is the reason why recessions can lead to labor reallocation that can ultimately be productivity-enhancing. With the STW policy the 'cleansing' channel is muted, growing firms hire less labor, leading to a decrease in the correlation of plant-level productivity and employment as Figure 12 shows. In recessions without the policy, the correlation increases, while with the STW policy the correlation declines. Every time a firm decides to hold on to a worker instead of releasing him

[27]In a recession without STW, inflows into unemployment lead to an increase in the vacancy-filling probability q. This incentivizes job creation. When the policy is in place, the small increase in q is the result of reductions both in unemployment and vacancy creation.

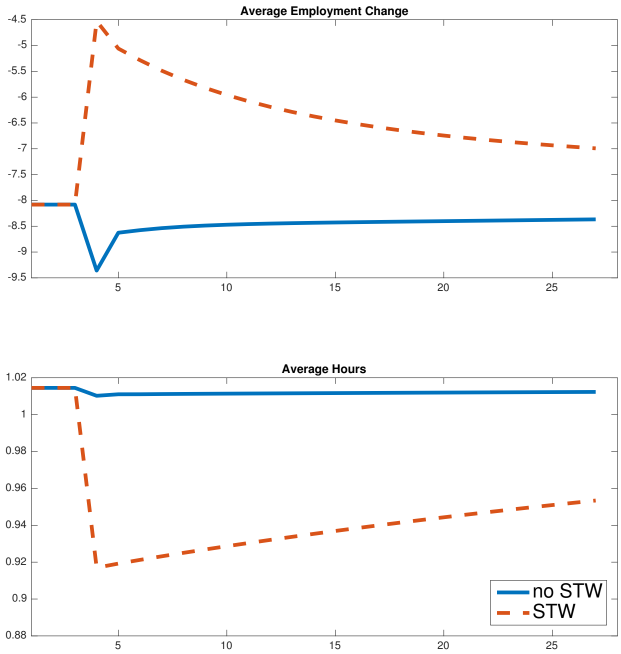

Figure 11: Outcomes for firms with $\Delta\varepsilon < 0$ during two recessions

Note: The top panel shows the average employment change, the bottom panel shows average hours.

or her into the pool of unemployed, the firm inadvertently decreases the vacancy-filling probability for all other firms. The individual firm does not take this externality into account when making its optimal employment decision. This implies that the economy's total production could be increased by reallocating labor between firms. This potential for reallocation is larger during the STW policy.

5.2.1 STW in Germany

We now model the response of the economy to a large negative productivity shock. We set the level of aggregate productivity in a recession in order to generate a drop in revenue that corresponds to the the observed average decrease in the micro data. Figure 13 shows impulse response functions following a one-time negative shock to aggregate productivity. The two main effects of the policy are that the response in unemployment is milder and that the decrease in output is larger.

Under the policy, the resulting increase in unemployment is about 2.5%, compared to an increase of almost 40% without the policy. The large negative productivity shock leads to more firms using the policy. This reinforces the 'reallocation channel' and the negative effects on output. When the policy is active, output falls by an additional 1.45% of pre-recession output. This effect is larger than when productivity shocks were smaller.

Job creation and job destruction are shown in Figure 14. The recession without STW leads to a large spike in job destruction. Employment falls mainly due to inflows into unemployment. Job

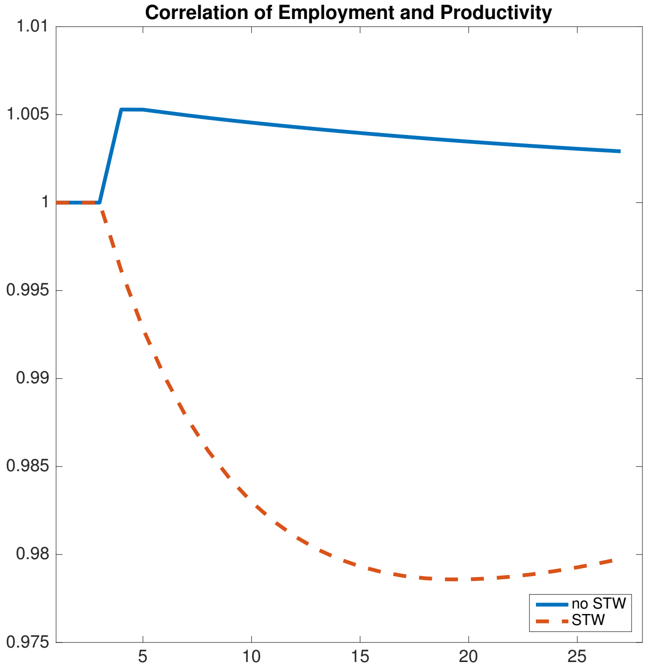

Figure 12: Cross-sectional correlation between productivity and employment

destruction remains high for as long as the recession continues. Job creation declines on impact but then overshoots. The reason for the overshooting is that after the initial employment adjustment it becomes cheaper for firms to create jobs because the vacancy-filling probability q rises. For the expanding firms, this effect can be stronger than the negative effect coming from total factor productivity. As a consequence, the unemployment rate peaks several period *after* the negative productivity shock. Not only do firms with positive idiosyncratic productivity growth not use the policy, the fastest-growing firms even react to the policy by substituting part of the increase in employment for an *increase* in hours.[28]

When the STW policy is active during the recession the increase in job destruction is much smaller. This is due to the additional flexibility in employment adjustments. Because fewer workers are released into the pool of the unemployed, the vacancy-filling probability increases by less, dampening the incentives for job creation, which is much slower to return to its pre-recession level. As a result, the unemployment rate peaks long after the negative productivity shock.

6 Discussion

In this section we discuss the robustness of our results and take the model's conclusion to the data.

[28]The average response of firms with positive productivity growth masks some heterogeneity within this group. Firms with small growth rates in productivity can be inactive in their employment choice and reduce hours. On the other hand, firms with larger growth rates grow by less but instead *increase* hours.

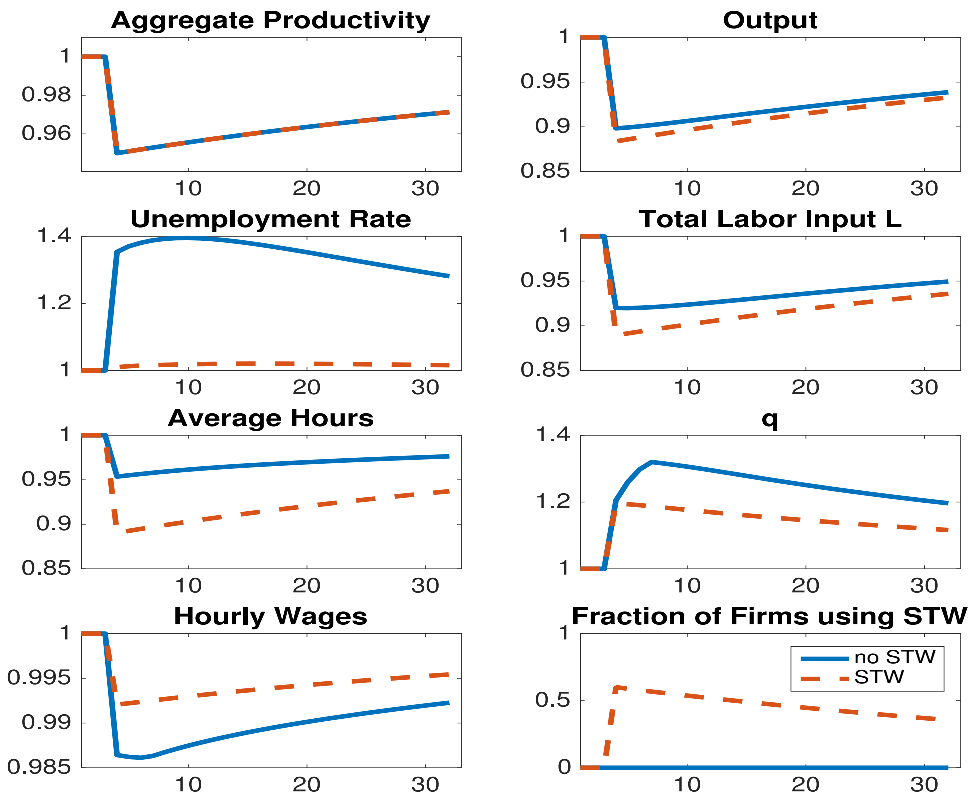

Figure 13: Impulse response functions. The solid blue (dashed red) lines show a severe recession without (with) STW in place.

6.1 Robustness

The effects of STW are ex-ante ambiguous. On the one hand, STW grants the firms additional flexibility. This flexibility implies higher steady-state levels of employment and output. On the other hand, the policy leads to more costly vacancy creation, implying less job creation and higher output losses.

We now show some robustness results of those key effects of the STW policy with respect to parameter changes. We quantify the effects of the STW policy through an employment gap and an output gap. These are defined with respect to a counterfactual scenario where the STW policy is absent. We compute impulse response functions for employment and output following two recessions. In the first recession, the STW policy is not active, in the second recession it is active. The gap is defined as the maximum difference between the two impulse response functions of employment and output. In our benchmark model, the employment gap is 0.038 and the output gap is -0.015. The latter number is the maximum difference in the impulse response functions in the upper-right panel in Figure 13.

We start by examining the importance of the models' parameters for the size of the employment and output gaps. Elasticities are shown in Table 4. To compute them we change a parameter and

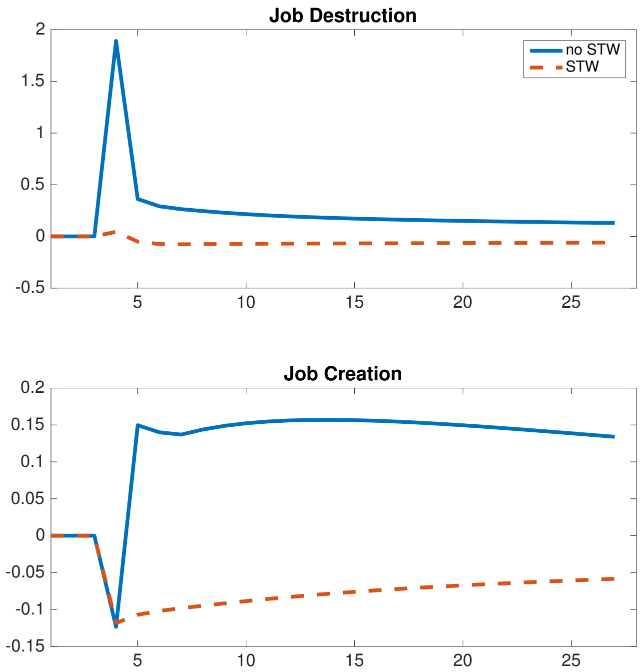

Figure 14: Job destruction and job creation. The solid blue (dashed red) lines show a recession without (with) STW in place. Both series are shown in log deviations from their values in steady state.

let the economy converge to its new steady state unemployment rate absent recessions. We then compute impulse response functions and the employment and output gaps following recessions with our without STW. The elasticities of the gaps are informative about which parameters are important in driving the key channels in the model following the introduction of STW.

Model	Employment Gap	Output Gap
b	0.52	-5.27
ξ_0	8.40	23.65
η	-2.60	2.09
c_v	-0.23	0.43
ρ_ε	34.31	-46.02
σ_ε	1.23	4.47
ξ_1	-0.14	1.33

Table 4: Elasticities of the Employment and Output Gaps with respect to Parameter Changes.

The parameters ξ_0 and ρ_ε generate the largest elasticities of the employment and output gaps. An increase in ξ_0 of 1% starting from its baseline value leads to an increase of the employment gap of 8.4%, and an increase of the output gap of 23.65%. This parameter governs the level of disutility of labor and is a key parameter of the wage equation. An increase in ξ_0 implies that the hours constraint is binding more often, which means that the STW policy is more effective in reducing unemployment, but at the same time further reduces employment, as firms trade off higher wages against decreasing returns. The parameter ρ_ε governs the persistence of idiosyncratic shocks.[29] An increase in ρ_ε leads to more inaction in firms' hours and employment policy functions. When the STW policy comes into effect, this larger inaction leads fewer employment adjustments by firms, causing an increase in the unemployment rate relative to the STW policy in the benchmark economy. Additionally, because the higher persistence implies less employment growth, the increase in q affects output less negatively, leading to a lower output gap.[30]

Next, we show the robustness of our results under alternative specifications of the policy. Table 5 summarizes our findings. The first row shows the benchmark model, i.e. the model considered in Section **??**. As was shown in Figure 13 the maximum difference in employment between a recession with and without the STW policy employment was 3.8%, while output was 1.5% lower compared to a recession without STW. In Row 2 we study the impact of the lower bound for hours for the results. If $\underline{h} < 1$, firms can reduce hours below 1 even in the absence of STW, giving them additional flexibly compared to the benchmark model.[31] To show the sensitivity of the results with respect to $\underline{h}$ we consider $\underline{h} = 0.95$.[32] While the results remain qualitatively unchanged, fewer firms now use the policy during a recession. As a result the relative reduction in the unemployment rate is smaller compared to the benchmark model, and the output loss due to the 'reallocation channel' shrinks.

Model	Employment Gap	Output Gap
Benchmark	.038	-.015
$\underline{h} = 0.95$	.029	-.010
Anticipated STW	.033	-.018
Hiring Credits	.005	.00008

Table 5: Robustness

Row 3 of Table 5 shows results for the case that firms expect the STW policy to occur. In this scenario there are four possible aggregate states, $\{A^{\text{high}}, A^{\text{low}}, A^{\text{low},\Xi}, A^{\Xi}\}$. The new, third state is a recession state from which the STW policy state A^{Ξ} can be reached with positive probability.[33]

[29] We compute the elasticity of the employment and output gaps with respect to changes in ρ_ε by a 0.1% increase in the parameter because otherwise ρ_ε would exceed unity.

[30] There is substantial non-linearity in the elasticity of the employment and output gaps with respect to the parameter ρ_ε, which is exacerbated by the fact that ρ_ε lies close to one.

[31] The assumption that $\underline{h} < 1$ could be justified with working time accounts for individual workers, which could be run down at the onset of a recession (Burda and Hunt (2011)). However, Balleer et al. (2016) conclude that during the Great Recession firms did *not* substitute working time accounts by short-time work. Firms with working time accounts also used more short-time work to adjust labor over the cycle than firms without working time accounts. Furthermore, according to Burda and Hunt (2011) *Kurzarbeit* constituted the most common source of changes in hours per worker between 2008 and 2009.

[32] We re-calibrate and re-estimate the model, including the law of motion for q.

[33] The aggregate transition matrix takes the following form:

$$\Pi = \begin{pmatrix} \rho & 1-\rho & 0 & 0 \\ 1-\rho & \rho-(1-\pi) & 1-\pi & 0 \\ 1-\rho & 0 & \rho-(1-\pi) & 1-\pi \\ 1-\rho & 0 & \rho-\pi & \pi \end{pmatrix}$$

A transition from A^{low} to $A^{\text{low},\Xi}$ leads to a small increase in employment and total hours worked because the probability of being affected by the binding hours floor in the future is now smaller. The results in Table 5 compare the effects of a normal recession with those from a direct transition into STW. Compared to the benchmark case the positive employment effects are smaller and the negative output effects are larger.[34]

Given that a downside of the STW policy is the adverse effect on hiring, a natural alternative to the STW policy could be hiring credits. Instead of preventing job destruction, this policy incentivizes job creation through a subsidy κ for each new vacancy that is created, lowering hiring costs to $(1-\kappa)c_v$.[35] We solve the model for $\kappa = 0.25$. The effect of the policy in mitigating the response of unemployment is limited. However, the policy entails positive output effects. Row 4 of Table 5 summarizes those effects. The failure of hiring credits in preventing unemployment occurs because the main impact on unemployment comes from the initial increase in job destruction. Contrary to STW, the hiring credits have virtually no effect on shrinking firms. Only a small fraction of firms has large enough growth in ε to be hiring during the recession. Those firms benefit from the policy and increase their level of employment. This leads to an almost unchanged unemployment rate on impact, but a faster return to pre-recession levels compared to a recession without the hiring credits policy. However, the hiring credits policy increase the correlation between firm-level employment and productivity. More labor is flowing to the firms with the highest productivity growth. The positive effects on output and productivity stemming from the hiring credits are the exact opposite of those of the STW policy.[36] In "sclerotic" labor markets, where hiring and firing is less prevalent than in more dynamic economies, the effectiveness of incentivizing job creation is limited.

6.2 Job Creation in Germany

The theoretical model predicts lower job creation following the use of STW. The aggregate data on job creation and job destruction supports this prediction. Because our micro data set only contains firms in the manufacturing sector, generating a 'control group' of firms that did not use the STW policy is not possible. We can, however, compare the manufacturing sector, in which the uptake of the policy was primarily located, to other sectors, in particular the service sector, where the use of STW was much less prevalent. Aggregate data on job creation, job destruction, and total employment by sector is available starting in 2004.

Figure 15 compares the log of job creation between the two sectors. Job creation has been normalized by its 2004 value. The figure shows a sharp decline in job creation in manufacturing relative to services (the dashed red line) at the time of the policy, which is indicated by the vertical line. A difference-in-difference estimation shows that the gap is statistically significant at the 5%

[34] There are positive employment and output effects in going from A^{low} to $A^{\text{low},\Xi}$. The employment (output) gap when we compare the transition from A^{high} to $A^{\text{low},\Xi}$ with A^{Ξ} is 0.028 (-.02).

[35] The tax revenue needed to finance this policy are $c_v \cdot \kappa$ times the number of vacancies created.

[36] The effectiveness of HC is limited, even when κ is set to a higher level. The reason is that the increase in the vacancy-filling probability q at the beginning of a recession is lower the higher is κ. This has the effect of increasing the total costs of hiring $\frac{\kappa c_v}{q}$.

level.[37]

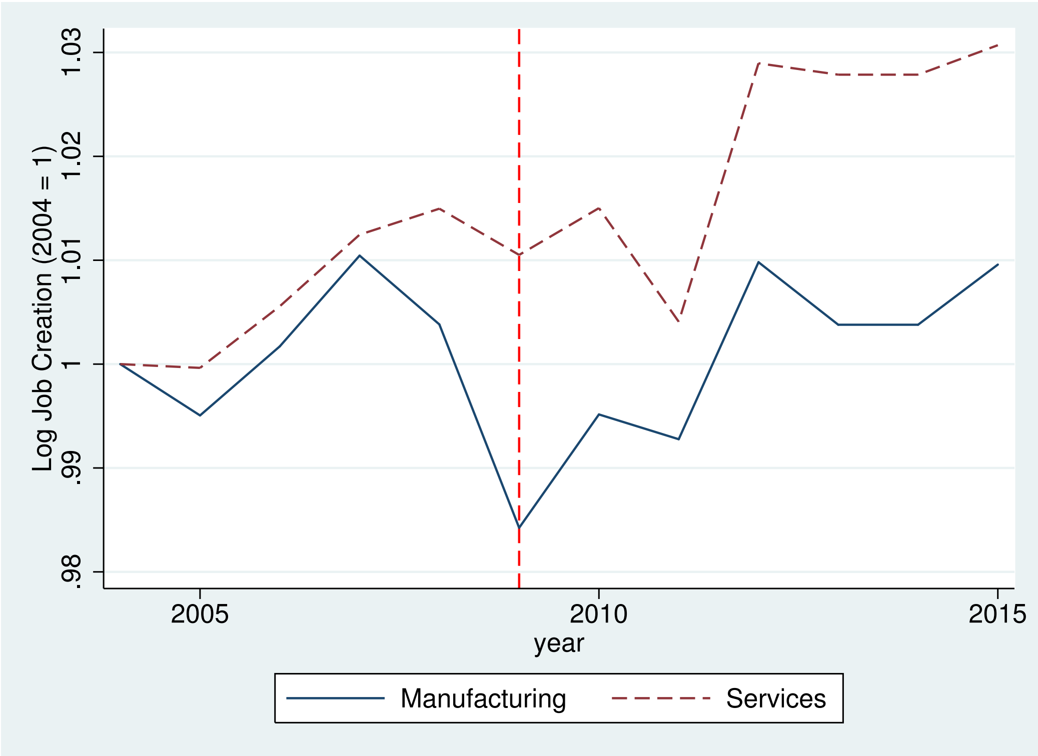

Figure 15: Job Creation, in logs, normalized to 2004 values. Source: German Employment Agency.

While these aggregate figures do not in themselves provide conclusive evidence of our theoretical channel, these results are in line with our predictions and with findings by related studies (e.g. Balleer et al. (2016)).

7 Conclusion

This paper studied the employment and productivity effects of short-time work in Germany between 2009 and 2010. The policy facilitated reductions in hours worked per employee with the goal of preventing layoffs. Using confidential German micro-level data we estimated a search model with heterogeneous multi-worker firms. Our findings suggest that STW was successful in preventing an increase in unemployment. However, the policy has led to a decrease in the allocative efficiency of the German labor market resulting in significant output losses. The aggregate data on job creation confirms the importance of this channel.

Advocates of the STW policy argue that it prevents inefficient layoffs. The idea is that firms would otherwise fire workers with firm-specific human capital, which is costly to replace. While our model captures some aspects of this through the fact that vacancy creation is costly, we abstract

[37] We run a standard diff-in-diff regression $\log JC_{i,t} = \beta_0 + \beta_1 \mathrm{STW}_t + \beta_2 \mathrm{treated}_{i,t} + \beta_3 \mathrm{DID}_{i,t} + \varepsilon_{i,t}$, where STW is a dummy that is 1 in 2009, treated is 1 for the manufacturing sector, and DID is the interaction between those two terms. We find that $\hat{\beta}_3 = -.178$ with a p-value of 0.011. The result is qualitatively robust to controlling for job destruction and employment.

from human capital accumulation. Presumedly this could give another justification for STW if firms in Germany were financially constrained during the crisis, such that some labor adjustments were indeed inefficient.

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A Data

Micro Data A detailed description the micro data we are using can be found (only in German) at `http://www.forschungsdatenzentren.de/bestand/afid-panel_industriebetriebe/fdz_afid-panel_industriebetriebe_metadaten.pdf`. The panel includes all plants which belong to up to 68'000 firms whose main activity or a significant share of activity lies in manufacturing or mining. Only plants within Germany are registered. The underlying data is collected on a monthly basis and then aggregated by year. The employment change distribution is shown in Figure 16.

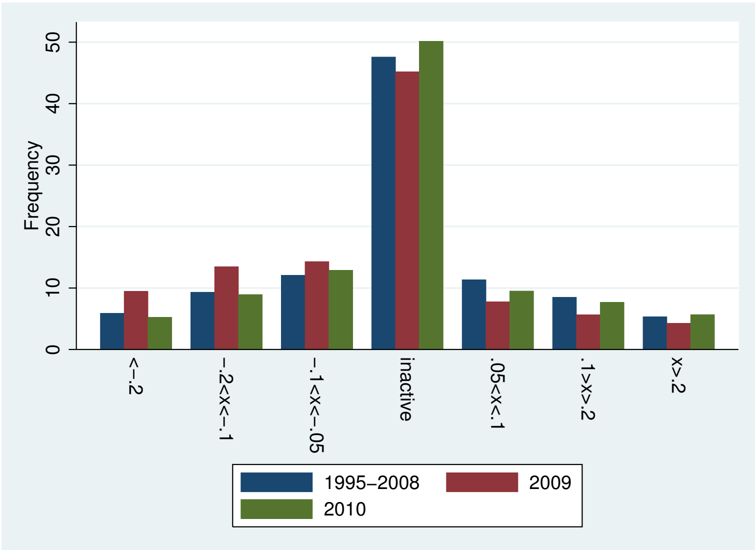

Figure 16: Distribution of annual average employment changes. Source: author's calculations from the micro data from the AFiD-Panel Industriebetriebe, Germany.

Macro Data The remaining graphs show aggregate data on the use of STW in Germany during the period under consideration in this study. The data comes from the German Federal Employment Agency.[38] Figure 17 shows the number of workers and firms using STW for economic reasons.[39]

Figure 18 shows the distribution of' hours reductions for workers using all types of STW. The vast majority of working time reductions during the 2009 recession were between 0% and 50%. Figure 19 shows the distribution of firm sizes for workers using all types of STW. It shows that most workers who were put on STW were working in medium and large firms.

Figure 20 shows the importance of manufacturing for the uptake of the STW policy. The graph is drawn by averaging over all observations from 2009. More than 80% of workers (or 78% of full-time equivalents) who were on STW during 2009 worked in manufacturing. Manufacturing firms represented around 45% of all firms who used STW in 2009. The numbers refer to STW for economic reasons.

[38]It should be noted that the statistics regarding the use of short-time work come from a more comprehensive data source starting in January 2009. We refer to the Federal Employment Agency's website for details.

[39]As was pointed out in the main text, we concentrate on the use of STW due to economic distress (§170). This decomposition in the aggregate numbers is available since 2008. The overwhelming majority of STW use is due to economic distress. Data for other uses of STW is available upon request.

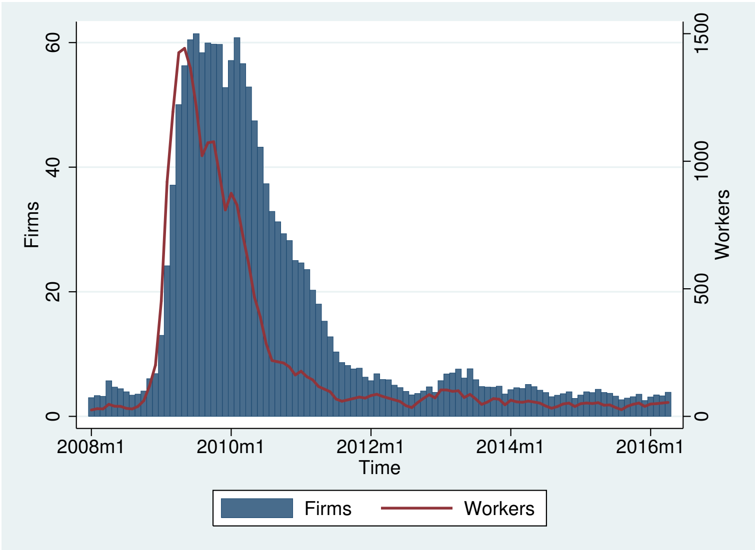

Figure 17: STW use between 1995 and 2010. Source: German Employment Agency

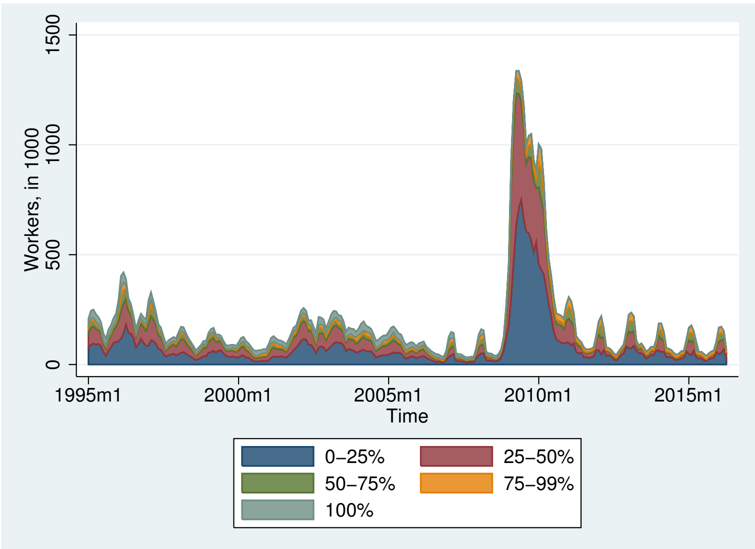

Figure 18: STW use between 1995 and 2010 by Length of STW. Source: German Employment Agency

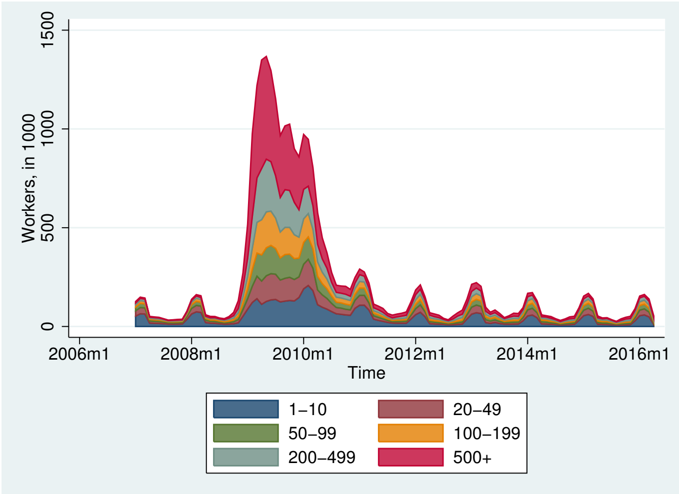

Figure 19: STW use between 1995 and 2010 by Firm Size. Source: German Employment Agency

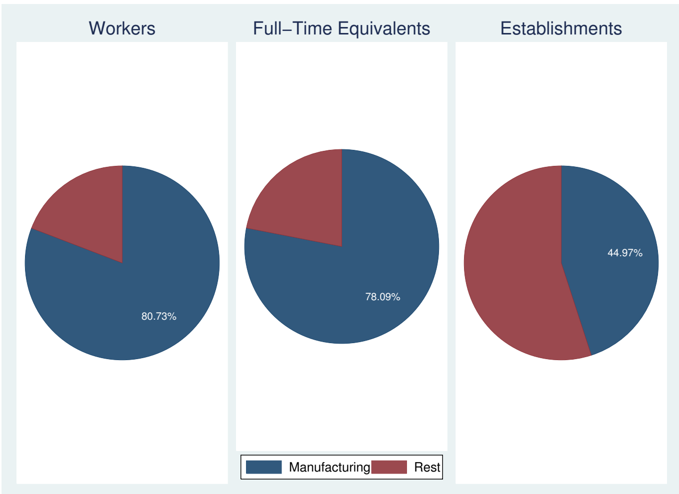

Figure 20: STW use in 2009 by Sector. Source: German Employment Agency

B The Wage

Note from the firm's envelope condition that the firm's marginal surplus has a recursive structure. It can be written as

$$S(\varepsilon,n)=\varepsilon hF_L(h\cdot n)-\omega(h,n,\varepsilon)h-\omega_n(h,n,\varepsilon)hn \quad + \\ \beta\int_{\psi_v(n)}^{\infty}\frac{c_v}{q}dG(\varepsilon'|\varepsilon)+\beta\int_{\psi(n)}^{\psi_v(n)}S(\varepsilon',n)dG(\varepsilon'|\varepsilon) \quad (18)$$

Next, we find an expression for the left-hand side of equation (7). The value of a worker who is unemployed at the beginning of the period is given by

$$W^u=b+\beta\left[(1-\phi)W^{u\prime}+\phi\int_0^{\infty}\int_{\psi(n)}^{\infty}\frac{W^e(\varepsilon',\psi_v^{-1}(\varepsilon))}{1-G(\psi_v(n))}dG(\varepsilon'|\varepsilon)dH(n)\right]. \quad (19)$$

Upon finding a job today, which occurs with probability ϕ, the new job must be in a firm that is posting vacancies. This implies that $\varepsilon>\psi_v(n_{-1})$ today, and that $n=\psi_v^{-1}(\varepsilon)$. The value of ε' is unknown, the worker is taking the expectation over it.[40] Under Nash sharing(7) the worker's expected surplus in an expanding firm is $W^e(\varepsilon',\psi_v^{-1}(\varepsilon'))dG(\varepsilon'|\varepsilon)-W^{u\prime}=\frac{\eta}{1-\eta}V_n(\varepsilon',\psi_v^{-1}(\varepsilon))$. From the first order condition of a hiring firm (3) we know that $S(\varepsilon',\psi_v^{-1}(\varepsilon'))=\frac{c_v}{q}$. Therefore

$$W^u=b+\beta\left[(1-\phi)W^{u\prime}+\phi\left(\frac{\eta}{1-\eta}\frac{c_v}{q}+W^{u\prime}\right)\right] \quad (20)$$

$$W^u=b+\beta W^{u\prime}+\beta\phi\frac{\eta}{1-\eta}\frac{c_v}{q}. \quad (21)$$

The value of an employed worker can be written as

$$W^e(\varepsilon,n)=\omega(h,\varepsilon,n)\cdot h-\xi(h) \quad + \\ \beta\left\{\int_0^{\psi(n)}\left[\tilde{s}W^{u\prime}+(1-\tilde{s})W^e(\varepsilon',\psi^{-1}(\varepsilon'))\right]dG(\varepsilon'|\varepsilon)\right. \\ \left.+\int_{\psi(n)}^{\psi_v(n)}W^e(\varepsilon',n)dG(\varepsilon'|\varepsilon)+\int_{\psi_v(n)}^{\infty}W^e(\varepsilon',\psi_v^{-1}(\varepsilon'))dG(\varepsilon'|\varepsilon)\right\}. \quad (22)$$

A worker in a firm in state (ε,n) receives an instantaneous compensation $\omega(h,\varepsilon,n)$ per hour worked and suffers the utility cost. If the firm receives $\varepsilon'<\psi(n)$ next period, it will fire workers. In that case workers are selected to be fired at random, so with endogenous probability $\tilde{s}$ the worker will be unemployed, receiving $W^{u\prime}$. With the counter-probability $(1-\tilde{s})$ he remains employed in a firm that will be in state $(\varepsilon',\psi^{-1}(\varepsilon'))$. Nash-sharing implies that $W^e(\varepsilon',\psi^{-1}(\varepsilon'))-W^{u\prime}=\frac{\eta}{1-\eta}S(\varepsilon',\psi^{-1}(\varepsilon'))$. From the first order condition we know that $S(\varepsilon',\psi^{-1}(\varepsilon'))=0$, implying $W^{u\prime}=W^e(\varepsilon',\psi^{-1}(\varepsilon'))$. If

[40] Moreover, there is a distribution of employment levels, $H(n)$, over which an unemployed worker will take expectations when evaluating the expected future benefits of being hired (over the employment levels of all hiring firms today).

the firm hires workers next period, employment will be $\psi_v^{-1}(\varepsilon')$. We saw above that Nash sharing then implies that $W^e(\varepsilon', \psi_v^{-1}(\varepsilon')) - W^{u\prime} = \frac{\eta}{1-\eta}\frac{c_v}{q}$. Finally, if the firm remains inactive, the expected value of an employed worker in the following period will be given by $W^e(\varepsilon', n)$. Nash sharing implies that $W^e(\varepsilon', n) - W^{u\prime} = \frac{\eta}{1-\eta} S(\varepsilon', n)$. Equation (22) can then be written as

$$W^e(\varepsilon, n) = \omega(h, \varepsilon, n) \cdot h - \xi(h) + \beta \left\{ \int_0^{\psi(n)} W^{u\prime} dG(\varepsilon'|\varepsilon) \quad + \right.$$
$$\left. \int_{\psi(n)}^{\psi_v(n)} \left[W^{u\prime} + \frac{\eta}{1-\eta} S(\varepsilon', n) \right] dG(\varepsilon'|\varepsilon) + \int_{\psi_v(n)}^{\infty} \left[W^{u\prime} + \frac{\eta}{1-\eta}\frac{c_v}{q} \right] dG(\varepsilon'|\varepsilon) \right\}. \quad (23)$$

After collecting the $W^{u\prime}$ terms we get

$$W^e(\varepsilon, n) = \omega(h, \varepsilon, n) \cdot h - \xi(h) + \beta W^{u\prime} \quad +$$
$$\beta \frac{\eta}{1-\eta} \int_{\psi(n)}^{\psi_v(n)} S(\varepsilon', n) dG(\varepsilon'|\varepsilon) + \beta \frac{\eta}{1-\eta} \int_{\psi_v(n)}^{\infty} \frac{c_v}{q} dG(\varepsilon'|\varepsilon). \quad (24)$$

Now we subtract W^u from both sides in (24). On the right-hand side we use the expression for W^u that was derived in (21).

$$W^e(\varepsilon, n) - W^u = \omega(h, \varepsilon, n) \cdot h - \xi(h) - b - \beta\phi \frac{\eta}{1-\eta}\frac{c_v}{q} \quad +$$
$$\beta \frac{\eta}{1-\eta} \int_{\psi(n)}^{\psi_v(n)} S(\varepsilon', n) dG(\varepsilon'|\varepsilon) + \beta \frac{\eta}{1-\eta} \int_{\psi_v(n)}^{\infty} \frac{c_v}{q} dG(\varepsilon'|\varepsilon). \quad (25)$$

Using the Nash sharing rule in (7) this expression must be equal to $\frac{\eta}{1-\eta} S(\varepsilon, n)$, which comes from (18).

$$\omega(h, \varepsilon, n) \cdot h - \xi(h) - b - \beta\phi \frac{\eta}{1-\eta}\frac{c_v}{q} +$$
$$\beta \frac{\eta}{1-\eta} \int_{\psi(n)}^{\psi_v(n)} S(\varepsilon', n) dG(\varepsilon'|\varepsilon) + \beta \frac{\eta}{1-\eta} \int_{\psi_v(n)}^{\infty} \frac{c_v}{q} dG(\varepsilon'|\varepsilon) =$$
$$\frac{\eta}{1-\eta} \left\{ h \cdot [\varepsilon F_L(h \cdot n) - \omega(h, n, \varepsilon) - \omega_n(h, n, \varepsilon) n] \quad + \right.$$
$$\left. \beta \int_{\psi_v(n)}^{\infty} \frac{c_v}{q} dG(\varepsilon'|\varepsilon) + \beta \int_{\psi(n)}^{\psi_v(n)} S(\varepsilon', n) dG(\varepsilon'|\varepsilon) \right\} \quad (26)$$

After canceling out the terms with the integrals, we obtain

$$\omega(h, \varepsilon, n) \cdot h - \xi(h) - b - \beta\phi \frac{\eta}{1-\eta}\frac{c_v}{q} = \frac{\eta}{1-\eta} \left\{ h \cdot [\varepsilon F_L(h \cdot n) - \omega(h, n, \varepsilon) - \omega_n(h, n, \varepsilon) n] \right\} \quad (27)$$

The bargained wage thus solves the differential equation

$$\omega(h,\varepsilon,n)\cdot h=(1-\eta)\left[b+\xi(h)\right]+\eta\left[\varepsilon hF_L(h\cdot n)+\beta\phi\frac{c_v}{q}-\omega_n(h,n,\varepsilon)\cdot h\cdot n\right]. \tag{28}$$

C Additional Quantitative Results

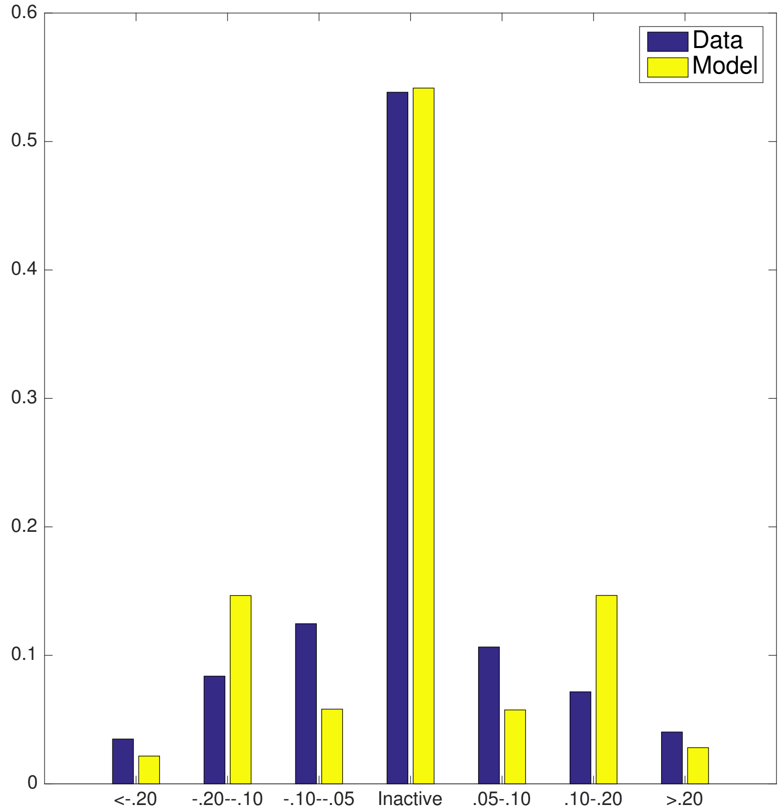

Figure 21: Hours Change Distribution. The data (model) is shown in blue (yellow).

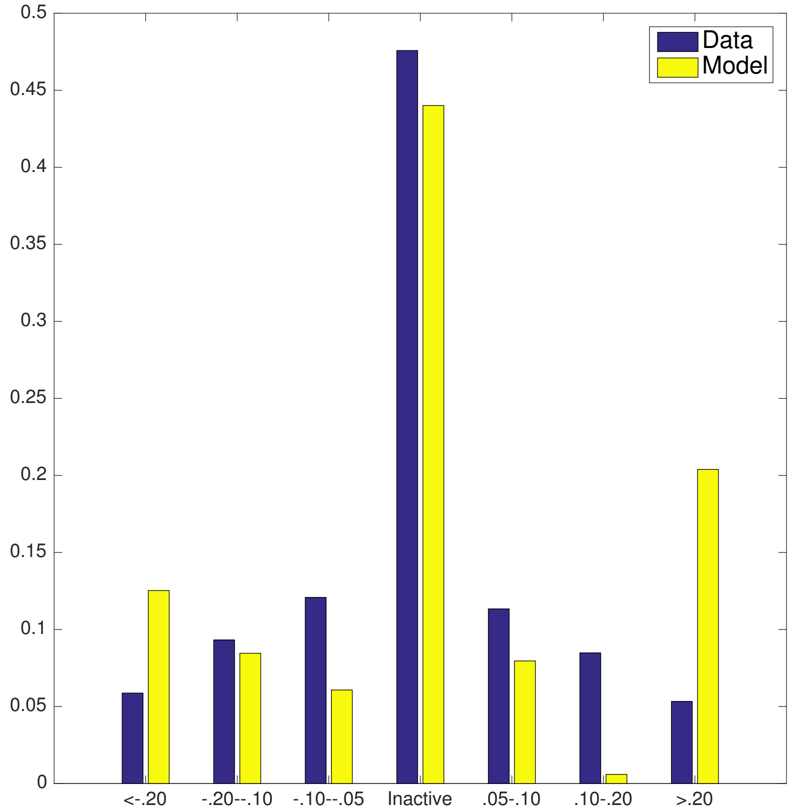

Figure 22: Employment Change Distribution. The data (model) is shown in blue (yellow).