# Optimal Short-Time Work Policy in and outside Recessions 

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#### Abstract

This paper analyses optimal short-time work policy in a search and matching model of the labor market. Workers and firms flexibly decide about hours worked and separations. The unemployment insurance system is taken as given, and a worker's monthly wage is rigid. Firms and workers are allowed to go on STW if their number of hours worked falls below a certain threshold. On STW, workers are compensated for working less than normal hours. In this context, STW can be seen as a state-contingent wage-subsidy directed to the least productive firms as only low productive firms choose low working hours. However, reducing separation with STW comes at the cost of an output loss. Firms and workers are incentivized to reduce the number of hours worked below the socially optimal to attract more STW benefits. To make the output loss as small as possible, the government should set the eligibility condition so strict that no firm that could survive without STW can enter STW. The STW benefits are then adjusted to reduce the inflated separation incentives by the moral hazard problems of the UI system. In a recession, the STW benefits but not the eligibility condition should get more generous. A drop in the job-finding rate, which is greatly amplified by the wage rigidity, increases the moral hazard problems of the UI system leading to more undesirable separations. Furthermore, STW cannot stabilize the job-finding rate. An obvious pick would be to combine it with a vacancy subsidy. However, moral hazard problems of STW shrink the positive effects substantially.


[^0]
## 1 Introduction

Each of the two major economic downturns of the 21st century, the Great Recession and the Covid-19 pandemic, saw steep increases in unemployment. This raised the question if and how governments should stabilize the labor market. Many OECD countries have answered this question by either introducing short-time work schemes (STW) for the first time or by extensively using their existing schemes (see Braun and Brügemann 2017 and Cahuc, Kramarz, and Nevoux 2021). STW schemes pay all or part of the wage bill when employers temporarily reduce hours worked. While widely used in practice, our understanding of the theory of shorttime work remains limited: We know little about why and how STW systems should be applied.

The current paper contributes to the understanding of STW policy. It develops a model that provides a rationale for STW to exist and analyzes the optimal design of STW policies, both in the steady-state and over the business cycle. The key findings of this paper are that STW schemes should exist even outside recessions to offset the moral hazard problems of an UI system. In recessions, its generosity should vary countercyclical over the business cycle to offset the anti-cyclical moral hazard problems of the UI system. These are further amplified by rigid monthly wages ${ }^{1}$. However, STW has difficulties stabilizing the job-finding rate. An obvious pick would be to combine the system with a vacancy subsidy. Nevertheless, STW's own moral hazard problems significantly reduce the effectiveness of the policy mix.

In more detail, we build a real business cycle model with Mortensen and Pissarides-type (see Mortensen and Pissarides 1993) matching frictions in the labor market. The model builds on an environment with a flexible intensive margin. It features endogenous separations and real costs of job destruction. Furthermore, we take the unemployment insurance system as given ${ }^{2}$ and account for rigid salaries in the business cycle. ${ }^{3}$ Therefore, the model entails two inefficiencies that give a reason for government intervention:
First, moral hazard problems of the UI system distort the private decisions in the economy. The unemployment benefits increase the workers' outside option, which helps workers to push through higher wages. Consequently, we see depressed vacancy posting and increased separation incentives (see Pissarides 2000).
As in Jung and Kuester (2015) or Mitman and Rabinovich (2015) the moral hazard problems of the UI system also increase in recessions. Compared to an economy without an UI system, UI benefits prevent the worker's outside option from dropping much in recessions ${ }^{4}$. This is because the decrease in the outside option due to a smaller probability of finding a job is partially

[^1]offset by the higher probability of receiving UI benefits or, in other words, the larger expected payments to the worker by the UI system. As a result, wages stay inefficiently high, inflating separations and decreasing job-finding rates.
Second, the wage rigidities amplify the business cycle and thus the moral hazard problems of the UI system. Following Jung and Kuester (2015), we model them as countercyclical bargaining power of the workers. Inefficiencies in the business cycle are then driven by a deviation from the Hosios-Condition (see Hosios 1990). As a result, inefficiently few vacancies are created in recessions, leading to too low job-finding probabilities. These again increase the UI system's moral hazard problems, leading to inefficiently many separations.

In an environment with a flexible intensive margin, STW can be seen as a state-contingent wage-subsidy that is financed by a production tax. Firms and workers are allowed to go on STW if their number of hours worked falls below a certain threshold. On STW, workers are compensated for working less than normal hours. Since firms with low working hours have the lowest productivity, STW benefits are directed to the least productive matches reducing separation incentives. However, using STW comes at the cost of an output loss. Firms and workers are incentivized to reduce the number of hours worked below the optimal to attract more STW benefits.

When the government sets up the STW system, it can choose the eligibility condition, that is, under which circumstances firms and workers can go on STW, and the STW benefits, that is, how much STW compensation a worker can receive. In order to minimize the output loss caused by the STW system, it chooses the eligibility condition so that only firms and workers that could not survive without STW can enter STW. In a sense, this condition excludes windfall gains. The government can steer the number of separations with the generosity of the STW benefits. They offset the negative effect of the UI's moral hazard problems on separations, giving STW a reason to exist even outside recessions.
In recessions, the generosity of the STW system needs to rise. Smaller job-finding probabilities due to lower aggregate productivity and, in particular, due to the wage-rigidity seriously increase the moral hazard problems of the UI system and, thus, the number of inefficient separations. The eligibility condition, however, should not be loosened. Since productivity falls, workers and firms reduce their working hours anyway, making much more of them eligible for STW.
STW, however, has difficulties to influence the job-finding rate. In order to stabilize employment, the planner reacts by decreasing the separation rate. This is done by increasing the generosity of the STW system. Increasing the generosity of STW redistributes resources from productive matches to unproductive matches and thus reduces the separation incentives.

These results correspond well to what actually happened in the corona crisis in Germany. The German government responded to the crisis by greatly increasing the accessibility and benefits of the system. Weber and Röttger (2022) found that despite the corona crisis, separation rates
dropped by roughly $10 \%$. Furthermore, new hires were significantly reduced
Interestingly, STW alone cannot stabilize output since it deteriorates the quality of the workforce by preserving unproductive matches (negative cleansing effect). However, consumption is much more stabilized as costs from firing and recruiting workers are saved. Perfect consumption stabilization is, however, unattainable. The rise in the STW benefits increases the moral hazard problems of STW itself, leading to too few hours worked and thus to a reduction in the ability of short-time work to stabilize output and consumption.
One interesting caveat for policymakers is that STW neither needs a fiscal expansion in steadystate nor does it inflate fiscal costs in recessions. There are two reasons for this. First, benefits are only addressed to the least productive firms. As a result, only a few firms are on STW, which keeps the costs of the system down. Secondly, unemployment is heavily reduced, leading to fewer UI benefit recipients.

Another problem of STW mentioned above is that it is unable to stabilize the job-finding rate. In order to solve this problem, we could combine the STW system with a vacancy subsidy. The idea is that the vacancy subsidy stabilizes the job-finding rate while STW takes care of the separation rate. This works perfectly fine if STW had no moral hazard problems on its own. In fact, STW and the vacancy subsidy would then be able to implement the planner allocation.
However, vacancy subsidies make it also easier for a firm to replace a worker. Therefore, they increase separation rates. Without moral hazard problems of STW, the STW system can easily deal with this side-effect. Moral hazard problems of STW make it costly to stabilize separations, making the vacancy subsidy much less effective.

The paper proceeds as follows. Chapter 2 relates the paper to the existing literature. Chapter 3 introduces the model. We begin by describing the decentralized economy. Afterwards, the planner problem is described. Based on this, we can determine how the decentralized economy deviates from the planner economy. Chapter 4 discusses the parametrization of the model and shows that the model can replicate key US labor market facts. Chapter 5 discusses STW policy. We start by describing the key properties of STW. Then we set up the planner problem. Building on it, we derive the optimal STW policy in and outside recessions. Chapter 6 adds the vacancy subsidy to the mix. Chapter 7 concludes.

## 2 Literature

As discussed in Cahuc, Kramarz, and Nevoux (2021) and Osuna and García-Pérez (2021), the theoretical literature of STW is still scarce. It can be divided roughly into three classes:

The first class of the literature analyzes STW using static implicit contract models. Burdett and Wright (1989) start the discussion by comparing the effects of an UI system to the effects
of a STW system. They find that while an UI system leads to inefficient separations, STW suffers from an inefficient low number of hours worked per worker. Therefore, both systems can lead to different distortions in the economy. Van Audenrode (1994) also focuses on the generosity of these systems. He finds that STW systems will only lead to major fluctuations of total hours worked if the system is more generous than a traditional UI system. Braun and Brügemann (2017) look at the interaction of a STW system with an UI system. They find that STW systems can be welfare improving by reducing the distortions caused by an UI system.

The second class looks at partial equilibrium models of the labor market. Cahuc, Kramarz, and Nevoux (2021) develop a model that shows that STW can save jobs in firms that are hit by strong negative revenue shocks. However, it also reduces the number of hours worked in firms that are not in danger of becoming bankrupt. These windfall effects make rescuing firms via STW much more costly for politics. Niedermayer and Tilly (2016) analyze STW in a life cycle framework with human capital depreciation in unemployment. They find that while STW can reduce unemployment, the welfare effects are fairly modest.

The third class considers general equilibrium search and matching models which can be roughly divided into two strands. The first strand of this literature builds on the model of Balleer et al. (2016). They use small firms to develop a tractable dynamic stochastic labor market model of STW. As the rest of the literature, they find that STW can save jobs. However, how well STW can do that depends on whether the government imposes a discretionary or a rule-based policy. While rule-based systems act as automatic stabilizers, discretionary STW policy is ineffective. Building on Balleer et al. (2016), Gehrke, Lechthaler, and Merkl (2017) augment their model by implementing it into a New Keynesian business cycle model to disentangle the role of institutions and shocks in explaining the "German labor market miracle". They find that labor market performance shocks rather than STW are key to understanding the miracle. Dengler and Gehrke (2021) expand this model with incomplete asset markets to study the effect of STW on precautionary savings. They find that under incomplete markets, STW can significantly stabilize the labor market. This effect is even more pronounced at the zero lower bound.

The second strand of literature builds on Cooper, Meyer, and Schott (2017). They build a STW model with heterogenous multi-worker-firms. Their main result is that while STW can save jobs in recessions, it comes at the cost of reducing allocative efficiency in the economy, leading to significant output losses. Giupponi and Landais (2018) build a simplified version of the model of Cooper, Meyer, and Schott (2017) abstracting from endogenous lay-offs. They suggest that STW is significantly more effective for larger but temporary shocks than for persistent ones. Furthermore, they propose that subsidizing labor hoarding by STW might reduce the inefficiencies of restrictions like wage or financial rigidities.

Next to the two strands mentioned above, Osuna and García-Pérez (2021) implement STW
into a dual labor market with two types of jobs, i.e., permanent and temporary ones, typical for the Spanish labor market. Their steady-state results show that STW schemes do not reduce unemployment in every case.

This paper connects to the implicit contract literature, especially to Braun and Brügemann (2017) in analyzing the interaction of STW and an UI system. However, the implicit contract literature cannot draw on general equilibrium implications that seem important for STW.
Therefore, this paper relates to the general equilibrium search and matching literature, especially to Balleer et al. (2016) and Cooper, Meyer, and Schott (2017) in analyzing the role of STW over the business cycle. In contrast to both papers, we assume a flexible intensive margin so that our results are not driven by an exogenous inflexibility in hours choice but by the role of STW as a subsidy. This paper adds an optimal policy perspective to this strand of the literature. Similar to Balleer et al. (2016), we use small firms and time-independent idiosyncratic productivity shocks to keep the model tractable.
Furthermore, this paper deviates from Balleer et al. (2016) or Cooper, Meyer, and Schott (2017) in allowing wage rigidities to amplify the business cycle. In this regard we follow Giupponi and Landais (2018) as they also look at the role of wage rigidity. In their model, STW helps to cut rigid wages which allows firms to hire more workers. However, the impact on endogenous separations is not fully modelled, as no endogenous separations exist in equilibrium. In contrast to Giupponi and Landais (2018), this paper puts the focus on the impact of STW on endogenous separations. The impact of STW on the value of the firm and thus production in our model is negligible as a production tax offsets the positive effects.

Outside the STW literature, this paper orientates towards Pissarides (2000) and Jung and Kuester (2015) in embedding the STW system into a wider policy mix. In chapter 9, Pissarides (2000) discusses the role and interaction of hiring subsidies, wage subsidies, wage taxes, unemployment benefits and lay-off taxes in realigning the steady state decentralized economy with the planner equivalent. Jung and Kuester (2015) discuss in a model with genuine role for unemployment insurance the optimal policy mix between vacancy subsidies, lay-off taxes and unemployment benefits in steady-state and over the business cycle. The novel part in this paper is to introduce STW into an optimal policy mix and combine it with a vacancy subsidy.

## 3 Model

In this section, we construct a search and matching model of the labor market that allows us to compare the optimal decisions in the planner economy to the private decisions of the decentralized economy.

The economy is populated by a continuum of workers of measure one and infinitely many one-worker firms. Each firm produces a homogeneous and non-storable good. We consider a
closed economy. Each period, firms and workers are subject to aggregate and idiosyncratic shocks. The aggregate shock can be interpreted as a shock on the supply side, similar to a supply chain shock in the Covid 19 pandemic or the current energy cost shock in the context oft the Ukrainian - Russian conflict. Nonetheless, they are ex-ante homogeneous to their match-efficiency.

The period structure underlies the following timeline: At the beginning of the period, firms are hit by an aggregate productivity shock, followed by the idiosyncratic shock. Based on this shock, separations are determined. Afterward, vacancies are posted and matches are formed. At the end of the period, the output is produced.
In the decentralized economy, Nash-Bargaining will take place, before the value of the idiosyncratic shock is known. Based on the idiosyncratic shock, STW take-up is determined.


Figure 1: Period Timeline

### 3.1 Decentralized Economy

In the decentralized economy, separations and vacancy posting decisions are taken by firms and workers.

Firm Side Each firm that enters a match with a worker can either produce or separate from the worker. There is an aggregate component $a_{t}$ that is common to all matches and an idiosyncratic component $\epsilon_{j}$ that is, for analytical tractability, i.i.d. across time and matches with the distribution function $G(\epsilon) .{ }^{5}$
Firm-specific output $y_{t}(\epsilon)$ depends on the firm-specific productivity $a_{t} \cdot \epsilon$ which is divided in an aggregate productivity part $a_{t}$ and the idiosyncratic part $\epsilon$, the number of hours worked $h_{t}(\epsilon)$

[^2]and the resource costs of the firm $\left(\mu_{\epsilon}-\epsilon\right) \cdot c_{f}:{ }^{6}$
\[

$$
\begin{equation*}
y_{t}(\epsilon)=a_{t} \cdot \epsilon \cdot h_{t}(\epsilon)^{\alpha}-\left(\mu_{\epsilon}-\epsilon\right) \cdot c_{f} \tag{1}
\end{equation*}
$$

\]

In line with Krause and Lubik (2007) we assume that the idiosyncratic shock $\epsilon_{j}$ follows a lognormal distribution $\epsilon_{j} \sim \mathcal{L N}\left(\mu, \sigma^{2}\right)$ with $\mu_{\epsilon}=E\left[\epsilon_{j}\right]=\exp \left(\mu+\frac{1}{2} \cdot \sigma^{2}\right)$. Furthermore, we assume that aggregate productivity follows an $\mathrm{AR}(1)$ process:

$$
\begin{equation*}
a_{t}=\mu_{a}+\rho_{a} \cdot\left(a_{t-1}-\mu_{a}\right)+\zeta_{t}, \quad \rho_{a} \in[0,1), \quad \zeta_{t} \sim \mathcal{N}\left(0, \sigma_{a}^{2}\right) \tag{2}
\end{equation*}
$$

The value of a worker for a firm, who is not on STW, and whose idiosyncratic shock has realized to $\epsilon$, is:

$$
\begin{equation*}
J_{t}(\epsilon)=y_{t}(\epsilon)-w_{t}-\tau_{J, t}+\beta \cdot E_{t}\left[J_{t+1}\right] \tag{3}
\end{equation*}
$$

The firm gets the production value of the match but pays the wage-sum $w_{t}$ to the worker. Furthermore, firms have to pay the lump sum $\operatorname{tax} \tau_{J, t}$ on production. The future expected value of a worker for a firm $E_{t}\left[J_{t+1}\right]$ is discounted by $\beta$.

Firms and workers are allowed to go on STW if their number of hours worked fall below a certain number:

$$
\begin{equation*}
h_{t}(\epsilon)<h_{t}\left(\epsilon_{s t w, t}\right)=D_{t} \tag{4}
\end{equation*}
$$

The STW threshold defined on temporary productivity then is implicitly defined by: $D_{t}=$ $h_{t}\left(\epsilon_{s t w, t}\right)$. Hijzen and Martin (2013) find that this kind of minimum hours' reduction is used as an eligibility condition by 15 out of 24 OECD countries that have STW in place. In the following sections, we will therefore report $D_{t}$, that is, the maximal number of hours worked, where firms and workers are allowed to go on STW.

The value of a worker for a firm, that is on STW, and whose idiosyncratic productivity has the value $\epsilon$, can be written as:

$$
\begin{equation*}
J_{s t w, t}(\epsilon)=y_{s t w, t}(\epsilon)-\underbrace{\frac{w_{t}}{\bar{h}} \cdot h_{s t w, t}(\epsilon)}_{\text {on STW: pay for hours worked only }}-\tau_{J, t}+\beta \cdot E_{t}\left[J_{t+1}\right] \tag{5}
\end{equation*}
$$

[^3]STW allows firms to pay only for the actual hours worked. This helps low-productive firms that demand fewer working hours anyway to reduce their wage costs. Outside STW, they would need to pay the full wage bill, regardless of the hours chosen. $\bar{h}$ denotes the mean hours worked in steady-state and, therefore, helps to rewrite the wage-sum into hourly wages.

The expected value of a worker for a firm right before the idiosyncratic shock has realized can be written as:

$$
\begin{equation*}
J_{t}=\int_{\epsilon_{s t w, t}}^{\infty} J_{t}(\epsilon) d G(\epsilon)+\int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}} J_{s t w, t}(\epsilon) d G(\epsilon)-G\left(\epsilon_{s, t}\right) \cdot\left(w_{e u, t}+F\right) \tag{6}
\end{equation*}
$$

If the idiosyncratic productivity $\epsilon$ is larger as the STW threshold $\epsilon>\epsilon_{s t w, t}$, then the firm produces regularly. If it falls below the threshold but is at least as large as the separation threshold $\epsilon_{s t w, t} \geq \epsilon \geq \epsilon_{s, t}$, then the firm goes on STW. If the productivity falls even further, $\epsilon<\epsilon_{s, t}$, then firm and worker separate. In this case, the firm has to pay the severance payment $w_{e u, t}$ and the separation costs F. $G\left(\epsilon_{s, t}\right)=P\left(\epsilon_{j}<\epsilon_{s, t}\right)$ denotes the separation probability, respectively the separation rate in the economy.
As in Jung and Kuester (2015), workers get no unemployment insurance in the period when they receive the severance payment. This reduces the elasticity of the separation rate on movements in the UI benefits, helping to solve the puzzle of Costain and Reiter (2008).
The separation threshold will later be determined by a generalized Nash-Bargaining, while the government will set the STW threshold.

Firms post vacancies $v_{t}$ until the expected costs of recruiting a worker equal the discounted expected value of a worker for the firm.

$$
\begin{equation*}
\frac{k_{v}}{q_{t}}=\beta \cdot E_{t}\left[J_{t+1}\right] \tag{7}
\end{equation*}
$$

Here $q_{t}$ denotes the probability of filling a vacancy and $k_{v}$ the cost of posting a vacancy.

Profits from the firm sector are distributed to the workers by dividends:

$$
\begin{align*}
\Pi_{t} & =\frac{n_{t}}{1-G\left(\epsilon_{s, t}\right)} \cdot\left(\int_{\epsilon_{s t w, t}}^{\infty}\left(y_{t}(\epsilon)-\tau_{J, t}\right) d G(\epsilon)+\int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}}\left(y_{s t w, t}(\epsilon)-\tau_{J, t}\right) d G(\epsilon)\right.  \tag{8}\\
& \left.-\left(1-G\left(\epsilon_{s t w, t}\right)\right) \cdot w_{t}-\int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}} \frac{w_{t}}{\bar{h}} \cdot h_{t}(\epsilon) d G(\epsilon)-G\left(\epsilon_{s, t}\right) \cdot\left(w_{e u, t}+F\right)\right) \\
& -k_{v} \cdot v_{t}
\end{align*}
$$

The dividend payments equal total output minus production tax, vacancy posting costs and wage-bill. STW reduces the expected wage bill by allowing firms to pay only the hours they actually use in production.

Worker Side The value of an employed worker with idiosyncratic productivity $\epsilon$ can be written as:

$$
\begin{equation*}
V_{t}(\epsilon)=w_{t}+\Pi_{t}-v\left(h_{t}(\epsilon)\right)+\beta \cdot E_{t}\left[V_{t+1}\right] \tag{9}
\end{equation*}
$$

Employed workers consume their wage-sum and dividends from the firms and derive disutility from hours worked. The expected value of being employed is denoted by $E_{t}\left[V_{t+1}\right]$.

The value of an employed worker on STW can be denoted as:

$$
\begin{equation*}
V_{s t w, t}(\epsilon)=\underbrace{\frac{w_{t}}{\bar{h}} \cdot h_{s t w, t}(\epsilon)}_{\text {reduced income from firm }}+\underbrace{\left(\bar{h}-h_{s t w, t}(\epsilon)\right) \cdot \tau_{s t w, t}}_{\text {STW subsidy }}+\Pi_{t}-v\left(h_{s t w, t}(\epsilon)\right)+\beta \cdot E_{t}\left[V_{t+1}\right] \tag{10}
\end{equation*}
$$

On STW, workers receive reduced income from the firm, as firms only need to pay the hours they actually use in production. In general, firms on STW are less productive and thus choose fewer working hours than usual. The STW benefits compensate for the reduced income. For every hour a worker works less than the mean hours worked, he receives STW benefits from the government.

The expected value of a worker at the beginning of the period is:

$$
\begin{equation*}
V_{t}=\int_{\epsilon_{s t w, t}}^{\infty} V_{t}(\epsilon) d G(\epsilon)+\int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}} V_{s t w, t}(\epsilon) d G(\epsilon)+G\left(\epsilon_{s, t}\right) \cdot\left(w_{e u, t}-b+U_{t}\right) \tag{11}
\end{equation*}
$$

As in the equation 6 for the expected value of the firm, households work normally if the idiosyncratic shock is large $\epsilon>\epsilon_{s t w, t}$, go on STW if $\epsilon \in\left[\epsilon_{s, t}, \epsilon_{s t w, t}\right]$ and get unemployed for $\epsilon<\epsilon_{s, t}$. Note, however, that when getting unemployed, the worker receives the severance payment instead of the unemployment benefits b.

The value of being unemployed at the beginning of the period can be written as:

$$
\begin{equation*}
U_{t}=b+\Pi_{t}+\beta \cdot E_{t}\left[f_{t} \cdot V_{t+1}+\left(1-f_{t}\right) \cdot U_{t+1}\right] \tag{12}
\end{equation*}
$$

Being unemployed, a worker receives unemployment benefits b plus dividends from the firms. With probability $f_{t}$, the worker finds a job and gets the value of being employed at the beginning of the next period. With the counter probability, the worker stays unemployed.

Nash-Bargaining The wage, the severance payment, the hours worked and the separation decision are determined by a generalized Nash-Bargaining where $\eta_{t-1}$ denotes the bargaining power of the worker.

$$
\begin{equation*}
\max _{w_{t}, h_{t}(\epsilon), \epsilon_{s, t}, w_{e u, t}} J_{t}^{1-\eta_{t-1}} \cdot\left(V_{t}-U_{t}\right)^{\eta_{t-1}} \tag{13}
\end{equation*}
$$

Wage and severance payment must be chosen to satisfy: ${ }^{7}$

$$
\begin{equation*}
\eta_{t-1} \cdot J_{t}=\left(1-\eta_{t-1}\right) \cdot\left(V_{t}-U_{t}\right) \tag{14}
\end{equation*}
$$

They split the joint surplus between workers and firms according to their bargaining weights. For simplicity, we assume that $w_{t}=w_{e u, t}$.

One problem of search and matching models is that they cannot produce enough cyclical fluctuations in the labor market, often referred to as the Shimer-Puzzle (see Shimer 2005). This puzzle is commonly resolved by introducing wage rigidity (see Hall 2005). In the implementation of wage rigidity, we follow Jung and Kuester (2015) and assume procyclical bargaining power of the firms.

$$
\begin{equation*}
\left(1-\eta_{t}\right)=\exp \left(\gamma_{w} \cdot a_{t}\right), \quad \gamma_{w}>0 \tag{15}
\end{equation*}
$$

If productivity falls, then the bargaining power of the firm decreases. We can relate this to wage rigidity as follows: If productivity falls in recessions, but wages are rigid, then a larger share of the joint surplus is claimed by the workers. In a model with Nash-Bargaining, this is equivalent to reducing the firms' or respectively increasing the workers' bargaining power. Fahr and Abbritti (2011), for instance, show that the existence of wage adjustment costs lead to the procyclical bargaining power of the firm.

Hours are chosen to maximize the joint surplus. As a result, outside STW, the marginal product needs to equal the marginal number of hours worked. This is the solution, that the planner would choose as well (see equation 28):

$$
\begin{equation*}
\alpha \cdot a_{t} \cdot \epsilon \cdot h_{t}(\epsilon)^{\alpha-1}=v^{\prime}\left(h_{t}(\epsilon)\right) \tag{16}
\end{equation*}
$$

Workers with low idiosyncratic productivity work less to save disutility of hours worked, while those with high idiosyncratic productivity will work more to make use of the extra productivity boost. This can be interpreted as some kind of perfect working time account. Working time accounts let workers do overtime in good times while reducing working time in bad times. Such flexible working times gain importance, for example, in Germany (see Ellguth, Gerner, and Zapf 2018). As argued above, the wage for the worker is independent of their working time and idiosyncratic productivity. Firms, therefore, get all the excess profits in high but bear the costs in low idiosyncratic productivity states. A reduction in aggregate productivity will reduce the working hours of every worker in the economy.

On STW things change. By reducing the number of hours worked, firms and workers can attract more STW benefits (see Cahuc, Kramarz, and Nevoux 2021). As a result, firms and

[^4]workers deviate from the optimal number of hours worked by working suboptimal few hours:
\[

$$
\begin{equation*}
\alpha \cdot a_{t} \cdot \epsilon \cdot h_{s t w, t}(\epsilon)^{\alpha-1}=v^{\prime}\left(h_{s t w, t}(\epsilon)\right)+\tau_{s t w, t} \tag{17}
\end{equation*}
$$

\]

The graph plots the number of hours firms and workers would work on and off STW. If the number of hours worked outside STW falls below $D_{t}$, firms and workers are allowed on STW and the number of hours drop below the optimal level:


Figure 2: Unannounced looseing of the Eligibility Condition

If they separate working hours fall to zero. Separations occur, if the joint surplus, after the idiosyncratic shock has been realized, becomes negative. The separation threshold can thus be determined by:

$$
\begin{equation*}
y_{s t w, t}(\epsilon)-v\left(h_{s t w, t}\left(\epsilon_{s, t}\right)\right)-\tau_{J, t}+\left(\bar{h}-h_{s t w, t}\left(\epsilon_{s, t}\right)\right) \cdot \tau_{s t w, t}+F+\frac{1-\eta_{t} \cdot f_{t}}{1-\eta_{t}} \cdot \frac{k_{v}}{q_{t}}=0 \tag{18}
\end{equation*}
$$

Firms and workers want to separate if period output minus disutility from work becomes negative but are disincentivized by potential separation costs. Furthermore, the firm wants to keep the worker employed to save search costs for a new worker while the worker would lose its expected value of being employed by the separation. However, this value is reduced by the opportunity of the worker to find a new job, which is represented by the fact that $1-\eta_{t} \cdot f_{t}<1$. The production tax reduces the joint surplus of the match, leading to a higher incentive to separate, while the STW benefits increase the joint surplus decreasing the separation incentive. Note that UI benefits might negatively influence the separation decision via a negative impact on the expected continuation value.

Budget Constraint Government We assume that the government must balance its budget every period. A lump-sum tax on production finances the UI system, and the STW system.

$$
\begin{equation*}
n_{t} \cdot \tau_{J, t}=\left(1-\frac{n_{t}}{1-G\left(\epsilon_{s, t}\right)}\right) \cdot b_{t}+n_{t} \cdot \int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}}\left(h-h_{s t w, t}(\epsilon)\right) \cdot \tau_{s t w, t} \frac{d G(\epsilon)}{1-G\left(\epsilon_{s, t}\right)} \tag{19}
\end{equation*}
$$

The unemployment insurance is set exogenously. The government will determine the optimal STW system. The production tax is then adjusted accordingly.

Labor Market Flows Based on the timing of the economy, we can formulate the law of motion of employment $n_{t}$ :

$$
\begin{equation*}
n_{t}=\left(1-G\left(\epsilon_{s, t}\right)\right) \cdot\left(n_{t-1}+m_{t-1}\right) \tag{20}
\end{equation*}
$$

Here, $m_{t}$ denotes the number of new matches formed. Unemployed $1-n_{t}$ and vacancies $v_{t}$ are matched according to a Cobb-Douglas matching function:

$$
\begin{equation*}
m_{t}=\chi \cdot v_{t}^{1-\gamma} \cdot\left(1-n_{t}\right)^{\gamma} \tag{21}
\end{equation*}
$$

The parameter $\chi$ determines the matching efficiency, and $\gamma \in(0,1)$ denotes the elasticity of the matching function for unemployment. The labor market tightness is defined as the ratio of vacancies to unemployed $\theta_{t}=\frac{v_{t}}{1-n_{t}}$. Based on the matching function and the labor market tightness, we can derive the probability to find a job $f_{t}$ and the probability to fill a vacancy $q_{t}$ :

$$
\begin{equation*}
f_{t}=\chi \cdot \theta_{t}^{1-\gamma}, \quad q_{t}=\chi \cdot \theta_{t}^{-\gamma} \tag{22}
\end{equation*}
$$

The number of separations $s_{t}$ can be determined by:

$$
\begin{equation*}
s_{t}=n_{t} \cdot \frac{G\left(\epsilon_{s, t}\right)}{1-G\left(\epsilon_{s, t}\right)} \tag{23}
\end{equation*}
$$

Good Market Clearing The aggregate output of the firms is defined as:

$$
\begin{equation*}
y_{t}=\frac{n_{t}}{1-G\left(\epsilon_{s, t}\right)} \cdot\left(\int_{\epsilon_{s t w, t}}^{\infty} y_{t}(\epsilon) d G(\epsilon)+\int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}} y_{s t w, t}(\epsilon) d G(\epsilon)\right) \tag{24}
\end{equation*}
$$

It is used to pay for aggregate vacancy posting costs $v_{t} \cdot k_{v}$, separation $\operatorname{costs} s_{t} \cdot F$, and aggregate consumption of the households $c_{t}$ :

$$
\begin{equation*}
y_{t}=\underbrace{v_{t} \cdot k_{v}+s_{t} \cdot F}_{\text {Reallocation Costs }}+c_{t} \tag{25}
\end{equation*}
$$

### 3.2 Planner Problem

In the centralized economy, we assume that the planner equally weights the utility of every household. Since all households are risk-neutral, he chooses the labor market density and the separation threshold so that output minus the total disutility of hours worked and reallocation costs are maximized. Reallocating a worker via the labor market generates separation and vacancy posting costs. He needs to respect that vacancies and unemployed workers are inefficiently matched by a matching function resulting in the law of motion of employment.

$$
\begin{align*}
& W_{t}^{P}=\underset{\theta_{t}, \epsilon_{s, t}, h_{t}(\epsilon)}{\arg \max } n_{t} \cdot \int_{\epsilon_{s, t}}^{\infty}\left[a_{t} \cdot \epsilon \cdot h_{t}(\epsilon)^{\alpha}-\left(\mu_{\epsilon}-\epsilon\right) \cdot c_{f}-v\left(h_{t}(\epsilon)\right)\right] \frac{d G(\epsilon)}{1-G\left(\epsilon_{s, t}\right)}  \tag{26}\\
&-n_{t} \cdot \frac{G\left(\epsilon_{s, t}\right)}{1-G\left(\epsilon_{s, t}\right)} \cdot F-\theta_{t} \cdot\left(1-n_{t}\right) \cdot k_{v}+\beta \cdot E_{t}\left[W_{t+1}^{P}\right]
\end{align*}
$$

$$
\begin{equation*}
\text { s.t. } \quad n_{t}=\left(1-G\left(\epsilon_{s, t}\right)\right) \cdot\left(n_{t-1}+f\left(\theta_{t-1}\right) \cdot\left(1-n_{t-1}\right)\right) \tag{27}
\end{equation*}
$$

Like firms and workers outside STW, the planner chooses working hours so that the marginal productivity of hours worked equals the marginal disutility from work: ${ }^{8}$

$$
\begin{equation*}
\alpha \cdot a_{t} \cdot \epsilon \cdot h_{t}(\epsilon)^{\alpha-1}=v^{\prime}\left(h_{t}(\epsilon)\right) \tag{28}
\end{equation*}
$$

The optimal hiring condition can be written as:


By creating and filling a new vacancy, the planner increases output and saves recruitment costs in the next period. However, increased hiring leads also to a congestion externality where firms crowd each other out when competing for the unemployed workers. This has a static and intertemporal component.
First, by increasing the number of vacancies, the probability of filling these vacancies decreases leading to higher recruitment costs. This shows up in the term $(1-\gamma)<1$. Second, by keeping the worker employed, the future labor market density is larger, and thus the probability of filling a vacancy stays smaller keeping up the recruitment costs per vacancy. This shows up in the term $\left(1-\gamma \cdot f_{t+1}\right)<1$ discounting the saved future recruitment costs.
The optimal labor market density is set so that the expected costs of filling a vacancy equals

[^5]its social benefits described above.

The separation condition can be written as:

$$
\begin{equation*}
\underbrace{a_{t} \cdot \epsilon_{s, t} \cdot h_{t}\left(\epsilon_{s, t}\right)^{\alpha}-\left(\mu_{\epsilon}-\epsilon_{s, t}\right) \cdot c_{f}-v\left(h_{t}\left(\epsilon_{s, t}\right)\right)}_{\text {Social costs from keeping an unproductive worker employed }}=\underbrace{-F-\frac{1-\gamma \cdot f_{t}}{1-\gamma} \cdot \frac{k_{v}}{q_{t}}}_{\text {Costs from reallocating worker via labor market }} \tag{30}
\end{equation*}
$$

By keeping a worker in a firm, the planner can save costs from reallocating workers via the labor market, that is, costs from laying off and rehiring the worker. However, keeping unproductive workers in a firm reduces the quality of the work-force. Consequently, mean productivity and thus output fall. Furthermore, total disutility from work increases.
Note that there are two types of recruitment costs that are saved if a worker stays employed: First, resources that would have been spent on posting vacancies and second, the congestion externality that comes with the vacancy posting. However, the costs from the congestion externality are reduced, as separations lead to more unemployment and thus a larger probability to fill a vacancy.

$$
\begin{equation*}
F+\frac{1-\gamma \cdot f_{t}}{1-\gamma} \cdot \frac{k_{v}}{q_{t}}=\underbrace{F}_{\text {Saved Separation Costs }}+\underbrace{\frac{1}{1-\gamma} \frac{k_{v}}{q_{t}}}_{\text {Saved Recruitment Costs }}-\underbrace{\frac{\gamma}{1-\gamma} \cdot f_{t} \cdot \frac{k_{v}}{q_{t}}}_{\text {Positive Externality of Separation }} \tag{31}
\end{equation*}
$$

Note that this postive externality from separations depends on the job-finding rate $f_{t}$. If the job-finding rate is low, then time spent in unemployment is large, leading to a larger loss in output.

### 3.3 Decentralized vs. Planner Economy

We now look at how the separation and hiring decisions in the decentralized economy deviate from the planner economy. This helps us unterstand how STW should react in this economy. To do this, we exclude STW from the equations.
Using the vacancy posting decision of the firms, the separation decision of firms and workers, their value function, and the government's budget constraint, we can derive the decentralized job-creation and separation decisions. A derivation can be found in the appendix in section A.3 .

The job-creation condition in the decentralized economy can be written as:

$$
\begin{align*}
\frac{k_{v}}{q_{t}} & =\beta \cdot\left(1-\eta_{t}\right) \cdot E_{t}\left(\int_{\epsilon_{s, t+1}}^{\infty}\left[y_{t+1}(\epsilon)-v\left(h_{t+1}(\epsilon)\right)-\tau_{t}^{b}\right] d G(\epsilon)\right.  \tag{32}\\
& \left.-b+G\left(\epsilon_{s, t+1}\right) \cdot(-F)+\left(1-G\left(\epsilon_{s, t+1}\right)\right) \cdot \frac{1-\eta_{t+1} \cdot f_{t+1}}{1-\eta_{t+1}} \cdot \frac{k_{v}}{q_{t+1}}\right)
\end{align*}
$$

Likewise, the separation condition in the decentralized economy can be written as.

$$
\begin{equation*}
y_{t}\left(\epsilon_{s, t}\right)-v\left(h_{t}\left(\epsilon_{s, t}\right)\right)-\tau_{t}^{b}=-F-\frac{1-\eta_{t} \cdot f_{t}}{1-\eta_{t}} \cdot \frac{k_{v}}{q_{t}} \tag{33}
\end{equation*}
$$

Here, $\tau_{t}^{b}$ denotes the fiscal externality of the UI system.

$$
\begin{equation*}
\tau_{t}^{b}=\frac{1-n_{t} /\left(1-G\left(\epsilon_{s, t}\right)\right)}{n_{t}} \cdot b \tag{34}
\end{equation*}
$$

Distortions The economy suffers from two types of distortion provoked by the exogenously set UI system and a deviation from the Hosios-Condition $\gamma \neq \eta_{t}$.

First, the UI system causes a moral hazard problem in the job-creating and the separation decision. The unemployment benefits $b$ increase the outside option for the worker. As a result, workers can push through larger wages. The increased wage reduces the firms' expected profits, leading to a reduced number of vacancies posted. We see this in the right-hand side of the job-creation condition in the term $-b$ when comparing the decentralized economy (equation 32) to the planner economy (equation 29).

By reducing the number of vacancies, we reduce the time it takes for a firm to recruit a worker. As a result, replacing a worker gets more affordable, or respectively the continuation value of a worker for a firm shrinks. On the other hand, workers are less afraid of becoming unemployed as their income is partly replaced by the unemployment insurance reducing the willingness to stay in the firm. Both effects lead to an increase in the number of separations. We can see this by inserting equation (32) into (33) and comparing it to the planner counterparts (see equations 29 and 30).
These effects are strengthened by the fiscal externality of the UI system, represented by $-\tau_{t}^{b}$ in the equations above. A production tax finances the UI system. This distorts the match value of the firm and worker downwards, depressing vacancy postings and inflating separations further. To sum up, the unemployment insurance distorts the private separation and job-creation conditions in the decentralized economy, leading to a socially undesirable reduction in the job-finding rate and an increase in the separation rate. Both inflate unemployment.

Second, a deviation from the Hosios-Condition (see Hosios 1990) causes further distortions. In the decentralized economy, the job-creation decisions depends on the bargaining power of the firm $\eta_{t-1}$, instead of the elasticity of the matching function for unemployment $\gamma$. As a result, a deviation of the bargaining power of the worker from the elasticity of the matching function prevents firms and workers from internalizing the congestion externality of job-postings into their decisions. An inflated $\eta_{t-1}>\gamma$ bargaining power of the worker, for instance, leads to a reduction in the bargaining power of the firm. Consequently, the value of a firm falls, resulting in inefficiently few job-creations (compare equations 32 and 29).

## 4 Calibration and Solution Procedure

We calibrate the baseline model for a period length of one month to US data reported by Shimer (2005). As a baseline, we choose the model with wage rigidity and exogenous unemployment insurance but no STW system. Picking US data has the advantage that no nationwide STW system has been implemented influencing the data. Table 1 summarizes the chosen parameter values, table 2 the US business properties reported by Shimer (2005) and table 3 the respective business cycle properties of the model.

| Parameter | Description | Value | Reason |
| :---: | :---: | :---: | :---: |
| $G\left(\epsilon_{s}\right)$ | Target ss separation rate | 0.034 | Shimer (2005) |
| $f$ | Target ss job-finding rate | 0.45 | Shimer (2005) |
| $q$ | Target ss vacancy filling rate | 0.338 | Haan, Ramey, and Watson (2000) |
| $\beta$ | Discount rate | 0.996 | Jung and Kuester (2015) |
| $\psi$ | Inverse Frisch-elasticity | 2.5 | Whalen and Reichling (2017) |
| $\gamma$ | Elasticity matching function with respect to unemployment | 0.7 | Shimer (2005). |
| $\eta$ | Bargaining power worker | 0.7 | Implements Hosios-Condition |
| $\gamma_{w}$ | Coefficient reaction bargaining power to productivity shock | 13.7 | s.d. job-finding rate close to 0.118 |
| F | Separation costs | 0.95 | s.d. separation rate of 0.075 |
| $b$ | UI benefits | 0.4 | Ca. $40 \%$ replacement rate of wage |
| $\alpha$ | Labor elasticity production function | 0.65 | Christoffel and Linzert (2010) |
| $\bar{h}$ | "normal" hours worked | 0.875 | Mean hours worked in baseline |
| $\rho_{a}$ | Autocorr. productivity shock | 0.985 | Jung and Kuester (2015) |
| $\mu_{a}$ | Mean aggregate productivity | 1 | Normalization |
| $\sigma_{a}$ | s.d. aggregate productivity | 0.003 | s.d. labor productivity of 0.02 |
| $\mu$ | Parameter steering mean of lognormal distribution | 0.04 | Normalize wage to 1 |
| $\sigma$ | Parameter steering variance of lognormal distribution | 0.12 | Krause and Lubik (2007) |
| $\chi$ | Matching parameter | 0.413 | Calculated by target ss |
| $k_{v}$ | Vacancy posting costs | 0.121 | Calculated by target ss |
| $c_{f}$ | Strength resource cost shock | 11.05 | Calculated by target ss |

Table 1: Parameters for identical firm set-up

Following Jung and Kuester (2015), we set the discount factor to $\beta=0.996$. As target steady-states we choose a monthly steady-state job-finding rate of $f=0.45$ and a separation rate of $G\left(\epsilon_{s}\right)=0.034$ as reported in the US data section of Shimer (2005). To implement the job-finding rate, we set vacancy posting costs to $k_{v}=0.121$. To implement the separation rate, the strength of the resource cost shock is set to $c_{f}=11.05$. The matching efficiency parameter $\chi=0.413$ is determined by targeting a monthly vacancy filling rate of $q=0.338$. This is the monthly equivalent of the quarterly job-filling rate of 0.71 reported in Haan, Ramey, and

Watson (2000). Similar to Shimer (2005), we set the bargaining power of the worker to $\eta=0.7$, which is, according to Petrongolo and Pissarides (2001), within the reasonable set of parameter estimates. In order to ensure that inefficiencies in the steady-state are only driven by the unemployment insurance, we implement the Hosios-Condition (see Hosios 1990) by setting the elasticity of the matching function with respect to unemployment equal to the bargaining power of the firm: $\gamma=\eta$. The unemployment benefits are set to $b=0.4$ which ensures a replacement rate of $40 \%$ of the wage. This is a value commonly used in the literature, for instance by Shimer (2005), and is close to the empirical value reported by Engen and Gruber (2001).

The parameter $\bar{h}$ which represents the mean hours worked in a firm is set to it's steady-state value in the baseline economy: $\bar{h}=0.875$. Similar to Christoffel and Linzert (2010), we set the labor elasticity of the production function to $\alpha=0.65$. The disutility of work has the common functional form of $\mathrm{v}(\mathrm{h})=\frac{h^{1+\psi}}{1+\psi}$. Whalen and Reichling (2017) find a central estimate for the Frish-elasticity relevant for policy work of $\psi^{-1}=0.4$. We, therefore, set the inverse Frish-elasticity to $\psi=2.5$.

Table 2: Business Cycle Properties reported by Shimer (2005)

|  |  | u | v | $\theta$ | f | $G\left(\epsilon_{s}\right)$ | p |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Standard deviation |  | 0.190 | 0.202 | 0,382 | 0.118 | 0,075 | 0,02 |
| Quarterly autocorrelation |  | 0.936 | 0.940 | 0.941 | 0.908 | 0.733 | 0.878 |
|  | u | 1 | -0.894 | $-0,971$ | -0.949 | 0.709 | -0.408 |
| Correlation matrix | v | 0 | 1 | 0.975 | 0.897 | -0.684 | 0.364 |
|  | f | 0 | 0 | 1 | 0.948 | -0.715 | 0.396 |
|  | $G\left(\epsilon_{s}\right)$ | 0 | 0 | 0 | 1 | -0.574 | 0.369 |
|  | $\theta$ | 0 | 0 | 0 | 0 | 1 | -0.524 |
|  | p | 0 | 0 | 0 | 0 | 0 | 1 |

Notes: The table lists the second moments of the data reported by Shimer (2005). u, v, f, and $\mathrm{G}\left(\epsilon_{s}\right)$ are expressed as quarterly averages of monthly series. $p$ is the seasonally adjusted average labor productivity in the non-farm business sector. All variables are reported as log-deviations from a HPTrend with smoothing parameter $10^{5}$.

In order to reach a standard deviation (s.d.) of 0.02 of labor productivity over the business cycle, we set the standard deviation of the aggregate productivity shock to $\sigma_{a}=0.003$ and follow Jung and Kuester (2015) in setting the autocorrelation to $\rho_{a}=0.985$. Similar to Jung and Kuester (2015), we set the coefficient for the procyclical bargaining power of the firm to $\gamma_{w}=13.7$. This ensures reasonable fluctuations in the job-finding rate over the business cycle (compare table 2 and 3). To ensure a standard deviation of the separation rate of 0.075 , we set the separation costs to $\mathrm{F}=0.95 .{ }^{9}$

[^6]As Krause and Lubik (2007), we set the parameter for the variance of log-normal distribution of the the idiosyncratic shock to $\sigma=0.12$. In order to normalize the wage to 1 , we adjust the parameter that stears the mean to $\mu=0.04$.

Compare the business cycle facts from the baseline economy from table 3 to the facts reported by Shimer (2005) in table 2. With the calibration chosen above, we can closely replicate the business cycle properties from the data. Note that a large chunk of the fluctuations is driven by our assumption of the procyclical bargaining power of the firms. Therefore, a lot of these fluctuations must be inefficient, which gives room for the policymaker to intervene.

Table 3: Business Cycle Properties Baseline Model

|  |  | u | v | $\theta$ | f | $G\left(\epsilon_{s}\right)$ | p |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| Standard deviation |  | 0,179 | 0,202 | 0,38 | 0,114 | 0,075 | 0,02 |
| Quarterly autocorrelation |  | 0,978 | 0,954 | 0,969 | 0,969 | 0,971 | 0,969 |
|  | u | 1 | $-0,989$ | $-0,997$ | $-0,997$ | 0,998 | $-0,997$ |
| Correlation matrix | v | 0 | 1 | 0,998 | 0,998 | $-0,997$ | 0,998 |
|  | f | 0 | 0 | 1 | 1 | -1 | 1 |
|  | $G\left(\epsilon_{s}\right)$ | 0 | 0 | 0 | 1 | -1 | 1 |
|  | $\theta$ | 0 | 0 | 0 | 0 | 1 | -1 |
|  | p | 0 | 0 | 0 | 0 | 0 | 1 |

Notes: The table reports the second moments of the model. As in the data of Shimer (2005), all variables are quarterly averages of monthly series and reported as log-deviations. p denotes the average output per person, that is $p=E\left[y_{t}(\epsilon) \mid \epsilon \geq \epsilon_{s, t}\right]$.

Another problem of search and matching models typically is that they cannot simultaneously produce realistic business cycle fluctuations and a realistic elasticity of unemployment with respect to changes of the unemployment insurance (see Costain and Reiter 2008). In order to match the business cycle facts of the data, we would need a small surplus calibration as in Hagedorn and Manovskii (2008) . Small movements in productivity result in relatively large movements of the joint surplus leading to an amplification of the job-finding rate. However, this is also true for unemployment benefits resulting in an inflated elasticity. The workaround is wage rigidity, as in our model, which allows for a large surplus calibration while still matching the business cycle facts. As a result, our model generates a realistic unemployment reaction to the UI system. Costain and Reiter (2008) report that the semi-elasticity of unemployment with respect to the replacement ratio is between 2 and 3 . Our model generates a semi-elasticity of 2.73 in the steady-state of the baseline economy, which seems to be a reasonable value.

To solve the model, we rely on first-order perturbation using the code of Schmitt-Grohe and Uribe (2004) based on the symbolic toolbox of Matlab. The code that automatically calculates the optimal policy responses in later sections is self-written.

## 5 STW Policy

### 5.1 How does STW work?

Before we can analyze what optimal STW policy should look like, we must determine how STW works in the model. To do so, we simulate an unannounced introduction of STW into a model without STW and in similar fashion adjust the eligibility condition and STW benefit in isolation. The STW benefits is set equal to the level of unemployment benefits and the STW benefits is set so that as few workers as possible can enter STW.

### 5.1.1 Introduction of a STW system



Figure 3: Unannounced Introduction of STW

Regarding the introduction of the STW system, we can document three striking results (see figure 4). First, STW reduces the separation incentives. Firms and workers are allowed to go on STW, if the number of hours worked fall below a certain threshold. Firms then can cut their wage bill by paying only the hours that they actually need for production and workers get compensated for every hour they work less than usual. Since only firms with low productivity choose low working hours, the subsidy is directed to the least productive matches. This increases their match value and decreases separation incentives. The decentralized separation decision, respectively the value of the least productive match, can then be denoted as:

$$
\begin{equation*}
y_{s t w, t}(\epsilon)-v\left(h_{s t w, t}\left(\epsilon_{s, t}\right)\right)-\left(\frac{1}{n}-\frac{1}{1-G\left(\epsilon_{s}\right)}\right) \cdot b+\tau_{s t w, t}^{t o t a l}+F+\frac{1-\eta_{t} \cdot f_{t}}{1-\eta_{t}} \cdot \frac{k_{v}}{q_{t}}=0 \tag{35}
\end{equation*}
$$

Here $\tau_{\text {stw,t }}^{\text {total }}$ describes the net-transfer, that is the total STW subsidy minus its social security contribution:

$$
\begin{equation*}
\tau_{s t w, t}^{\text {total }}=\tau_{s t w, t} \cdot\left(\bar{h}-h_{s t w, t}\left(\epsilon_{s, t}\right)-\frac{1}{1-G\left(\epsilon_{s, t}\right)} \int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}}\left(\bar{h}-h_{s t w, t}(\epsilon)\right) d G(\epsilon)\right) \tag{36}
\end{equation*}
$$

As result, STW works only as a subsidy in this model. In a model with an inflexible number of hours worked STW could also work as an instrument to make working hours more flexible (see Balleer et al. (2016), Cooper, Meyer, and Schott (2017)).

Second, STW has only a small influence on the job-finding rate. The extra costs of STW needs to be financed by a rise in the production tax. The increase in the contribution offsets the positive effect of the subsidy on the value of the match. Deriving the job-creation condition, we see that the STW benefits have no direct impact on vacancy postings:

$$
\begin{align*}
\frac{k_{v}}{q_{t}}=\beta \cdot\left(1-\eta_{t}\right) \cdot E_{t} & \left(\int_{\epsilon_{s t w, t+1}}^{\infty}\left[y_{t}(\epsilon)-v\left(h_{t+1}(\epsilon)\right)-\frac{b}{n_{t}}\right] d G(\epsilon)\right.  \tag{37}\\
& +\int_{\epsilon_{s, t+1}}^{\epsilon_{s t w, t+1}}\left[y_{s t w, t}(\epsilon)-v\left(h_{s t w, t+1}(\epsilon)\right)-\frac{b}{n_{t}}\right] d G(\epsilon) \\
& \left.+G\left(\epsilon_{s, t+1}\right) \cdot(-F)+\left(1-G\left(\epsilon_{s, t+1}\right)\right) \cdot \frac{1-\eta_{t+1} \cdot f_{t+1}}{1-\eta_{t+1}} \cdot \frac{k_{v}}{q_{t+1}}\right)
\end{align*}
$$

The small rise in the job-finding rate comes from the fact that a reduction in unemployment reduces the costs of the UI and, thus, the production tax, raising the expected value of the firm.

Third, STW impacts the mean hours worked negatively. Any firm worker match would choose suboptimally low hours worked on STW, leading to an output loss.

### 5.1.2 Adjustment of Eligibility Condition and STW Benefits

STW provides the government with two instruments. It can choose the eligibility condition and the STW benefits.


Figure 4: Unannounced loosening of the Eligibility Condition

The eligibility condition determines when firms and workers are allowed to enter STW. If we relax the eligibility condition, more workers can go on STW. This significantly increases problems with the choice of working hours (see figure 2). Still, the job-finding rate is barely influenced due to the adjustment of the production tax. Surprisingly, the separations increase.

Since more firms are allowed on STW, the costs of the system rise. As a result, net-transfers to the least productive matches shrink, leading to a jump in separations.


Figure 5: Unannounced increase in the STW benefits

The STW compensation, on the other hand, increases the net-transfer to the least productive firms. Thus, the government can steer the separation decision with this instrument. However, it still comes at the costs of distorting hours worked. The job-finding rate barely moves again.

### 5.2 Optimisation Problem

In the decentralized economy, the government also weights the utility of every household equally. Since all households are risk-neutral, it tries to maximize output minus the disutility of work and reallocation costs. To do so, it can adjust the eligibility condition of STW and the STW benefits to influence the decentralized separation condition. As already demonstrated in the last section, STW comes at the costs of distorting the number of hours worked. This leads to a direct welfare loss caused by a reduction in output as demonstrated in the welfare function below. Therefore, the government faces a trade-off between setting the optimal separation rate and the moral hazard costs of the STW instrument.

$$
\begin{align*}
& W_{t}^{G}=  \tag{38}\\
& \underset{\theta_{t}, \epsilon_{s, t}, \epsilon_{s t w, t, h_{t}(\epsilon), \tau_{s t w, t}}^{\arg \max }}{ } \underbrace{n_{t} \cdot \int_{\epsilon_{s, t}}^{\infty}\left[y_{t}(\epsilon)-v\left(h_{t}(\epsilon)\right)\right] \frac{d G(\epsilon)}{1-G\left(\epsilon_{s, t}\right)}-n_{t} \cdot \frac{G\left(\epsilon_{s, t}\right)}{1-G\left(\epsilon_{s, t}\right)} \cdot F-\theta_{t} \cdot\left(1-n_{t}\right) \cdot k_{v}}_{\text {Utility without Moral Hazard Problems of STW }} \\
& \underbrace{-n_{t} \cdot \int_{\epsilon_{s}, t}^{\epsilon_{s t w}, t}\left[y_{t}(\epsilon)-v\left(h_{t}(\epsilon)\right)-y_{s t w, t}(\epsilon)+v\left(h_{s t w, t}(\epsilon)\right)\right] \frac{d G(\epsilon)}{1-G\left(\epsilon_{s, t}\right)}}_{\text {Utility loss from Moral Hazard Problems of STW }} \\
&+\beta \cdot E_{t}\left[W_{t+1}^{G}\right]
\end{align*}
$$

The government can achieve this by setting the hours condition so that $D_{t}=h_{t}\left(\epsilon_{s t w, t}\right)$. However, then we would only save firms with idiosyncratic productivity $\epsilon_{s, t}$. matches with larger productivity $\xi_{t}>\epsilon>\epsilon_{s t w, t}$ that are not eligible to go on STW might still be so unproductive, that they separate (see figure, red area).

Figure 6: Eligibility Condition is set too low


Notes: The green area describes the number of firms saved by STW. The red area denotes the number of workers that could have been saved with STW but were not eligible to go on STW since the eligibility condition was set too restrictive.

Here $\xi_{t}$ denotes the separations threshold of a firm without the STW subsidy, determined by:

$$
\begin{equation*}
y_{t}\left(\xi_{t}\right)-v\left(h_{t}\left(\xi_{t}\right)\right)-\tau_{J, t}+F+\frac{1-\eta_{t} \cdot f_{t}}{1-\eta_{t}} \cdot \frac{k_{v}}{q_{t}}=0 \tag{39}
\end{equation*}
$$

Saving less productive matches while allowing more productive matches to separate must clearly be inefficient. Thus, it must be optimal to choose the STW threshold so that $\epsilon_{s t w, t} \geq \xi_{t}$. Since the government barely can influence job-creation with the eligibility condition, it wants to minimize the utility loss from using STW. Consequently, it will let as few workers as possible on STW so that this condition will bind $\epsilon_{s t w, t}=\xi_{t}$. Note that the separation threshold of a firm without STW benefits and thus the optimal eligibility condition may vary within the business cycle.

Thus, we are left with determining $\tau_{s t w, t}$. To develop a deeper understanding on how STW benefits should be adjusted in the economy, we will first look at the steady-state result without moral hazard problems of STW. Afterwards, we compare the simulated results with moral hazard problems of STW to the one without to determine its impact.

### 5.3 Optimal STW Policy in Steady State

### 5.3.1 ... with hours distortions

The optimal net-transfer in an economy without moral hazard problems of STW can be denoted as: ${ }^{10}$

$$
\begin{align*}
\tau_{s t w}^{\text {total }} & =\underbrace{\frac{1}{1-\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-f)} \cdot \tau^{b}}_{\text {Fiscal Externality UI }}+\underbrace{\frac{\beta \cdot(1-f)}{1-\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-f)} \cdot b}_{\text {Moral Hazard Problem UI }}+\tilde{\lambda}_{\theta}  \tag{40}\\
\tau^{b} & =\left(\frac{1}{n}-\frac{1}{1-G\left(\epsilon_{s}\right)}\right) \cdot b . \tag{41}
\end{align*}
$$

The government should adjust the STW benefits so that the positive net inflow of the STW benefits to the least productive matches offsets the negative impact of the UI's moral hazard problems and fiscal externalities on the separation decision and corrects for its influence on the job-posting decision of the firm.

Especially interesting is the moral hazard term. To offset the moral hazard effects of an UI system, the net STW subsidy needs to equal the forgone expected discounted benefits payments of the government to the worker that arise from keeping the worker employed. In a sense, the government needs to pay the forgone UI payments via the STW system to firms and workers in order to offset its distortionary effects.

Note that the payments needed to offset these effects increase with declining job-finding rates. This is because lower job-finding rates imply longer expected unemployment spells and thus longer expected payment periods of the UI benefits increasing their expected total value. However, the separation probability decreases the term. This is because higher separation probabilities decrease the time a worker spends on average in a firm and thus reduces the time the worker forgoes payments by the UI system.
Note that this has important implications for recessions. In recessions, the job-finding probability falls while the separation rate rises. Since the job-finding rate often is much larger than the separation rate, we can infer that the fall in the job-finding rate dominates the rise in separations leading to an increase of the moral hazard problems of the UI system in recessions and thus the need for STW benefits. This is what we will see in the business cycle results.

For completion:

$$
\begin{equation*}
\tilde{\lambda}_{\theta}=\underbrace{\frac{\left(\frac{1-G\left(\epsilon_{s}\right)}{n^{2}} \cdot b\right)}{1-\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-f)}}_{\text {Reduction in Fiscal Externality }} \cdot \lambda_{\theta}+\underbrace{\left[\left(-\frac{1}{1-G\left(\epsilon_{s}\right)}\right) \cdot b-\tau_{s t a, t}^{\text {total }}\right] \cdot \frac{1-G\left(\epsilon_{s}\right)}{n}}_{\text {Keep unproductive Matches alive }} \cdot \lambda_{\theta} \tag{42}
\end{equation*}
$$

[^7]$\lambda_{\theta}$ denotes the influence a larger labor market density would have on welfare. Since the UI benefits distort the vacancy posting incentives downwards, we can conclude that the factor must be positive. Increasing the STW benefits has two influences on vacancy posting decision. On the one hand, it has a positive influence on vacancies. Increasing the STW benefits decreases separations which reduces unemployment and thus fiscal externalities of the STW system. On the other hand, the reduction in separations keeps unproductive matches alive reducing the expected value of a firm. Both effects, however, seem to play a minor role in the simulations. We have seen that the overall influence of STW on the job-finding rate is very small.

### 5.3.2 ... whithout hours distortions

Allowing for the moral hazard problems of STW, we are now interested in how the moral hazard problems of STW influence the setting of the STW benefits (see table 4). First of all, the government would choose to replace a much lower rate of the wage. The model's optimal replacement ratio drops from $600 \%$ to a more realistic $82 \%$. There are two reasons for this: On the one hand, we have seen that larger STW benefits lead to more significant output losses. On the other hand, firms and workers choose lower working hours on STW. In the model, the mean hours worked on STW falls from 0.8 to 0.26 . As a result, the net-transfer would be much larger for the same benefits.

| Name | Variable | Baseline | Optimal STW <br> Policy with <br> Moral Hazard | Optimal STW <br> Policy without <br> Moral Hazard |
| :--- | :--- | :--- | :--- | :--- |
| Separation Rate | $\mathrm{G}\left(\epsilon_{s}\right)$ | 0,034 | $0,020 \mid-41,1 \%$ | $0,012 \mid-64,8 \%$ |
| Job-Finding Rate | f | 0,450 | $0,450 \mid+0,0 \%$ | $0,452 \mid+0,5 \%$ |
| Unemployment | $1-n$ | 0.073 | $0,043 \mid-41.1 \%$ | $0.026 \mid-64.4 \%$ |
| Mean hours worked | - | - | 0,26 | 0.8 |
| on STW |  | 0 | 0,82 | 6,00 |
| STW benefits | $\tau_{s t w}$ | 0 | 0,510 | 0.486 |
| Net-Transfers STW | $\tau_{s t w}^{t o t a l}$ | 0 | 0,017 | $0.017 \mid 0 \%$ |
| Production Tax | $\tau_{J}$ | $0,016 \mid-9,6 \%$ |  |  |

Table 4: Steady-State Comparison

The optimal net-transfer is larger for the model with STW distortions. This might be surprising as we would expect the government to choose a smaller transfer to reduce the utility loss from using STW. However, the net-transfer with moral hazard problems increases the value of the match less. The net impact of STW on the value of the least productive match can be written as net-transfer minus utility loss of hours distortion:

$$
\begin{equation*}
\tau_{s t w, t}^{t o t a l}-\left[y_{t}\left(\epsilon_{s, t}\right)-v\left(h_{t}\left(\epsilon_{s, t}\right)\right)-y_{s t w, t}\left(\epsilon_{s, t}\right)+v\left(h_{s t w, t}\left(\epsilon_{s, t}\right)\right)\right] \tag{43}
\end{equation*}
$$

As a result, we see that the government can only reduce separations by $41,1 \%$ instead of $64.8 \%$. The moral hazard problems make it too costly to implement the optimal separation rate. Consequently, STW with moral hazard seriously hampers the government's willingness to reduce unemployment.

### 5.4 STW Policy in the Business Cycle

### 5.4.1 Inefficiencies in the Business Cycle

To understand how STW should react to the business cycle, we first have to study which inefficiencies amplify it. We assume that the business cycle is driven by real productivity shocks. Figure 7 shows the response of the planner economy, an economy with UI system and an economy with both UI system and wage rigidity to a $1 \%$ negative aggregate productivity shock. We will refer to the economy with UI system and wage rigidity as the baseline economy. Comparing the baseline economy and the economy with the UI system only to the planner allocation will give us a sense of the business cycle's inefficiencies.


Figure 7: Inefficiencies in the Business Cycle

Generally speaking a reduction in aggregate productivity due to a negative productivity shock reduces the joint surplus of firm-worker matches. As a result, firms will be less willing to pay the vacancy posting costs. Thus the number of vacancies and consequently the job-finding
rate fall. Furthermore, the reduced productivity implies that firms and workers are less willing to pay the high idiosyncratic resource costs, leading to a larger separation rate. A reduction in the job-finding rate combined with an increase in the separation rate drives down employment. Output and consumption fall mainly due to the reduction of aggregate productivity.
Note that these fluctuations can be efficient to some extent (see Figure 7, blue line). The social planner would also increase separations to save resource costs of production or reduce vacancy posting efforts if new workers add less to the output.

However, these fluctuations can be inefficiently amplified by the existence of the exogenous UI system and wage rigidity.

First of all, we look at how the moral hazard problems of the UI system affect the business cycle. The negative aggregate productivity shock decreases the job-finding rate in recessions. The UI system can partially offset the effect on the outside option since increasing the worker's unemployment spell also increases the expected payments from the UI system. A smaller decrease in the outside option then leads to too high wages, too many separations, and too few job postings (see Figure 2, red vs. blue line). Furthermore, increased unemployment drives up the costs of the UI, forcing the government to increase production taxes, amplifying the effect.

However, adding wage rigidity will explain the lion's share of the inefficiencies in the business cycle. If productivity falls, our wage rigidity decreases the firms' bargaining power, leading to a deviation from the Hosios-Condition. Since firms get less from the joint surplus, they cut vacancies to save on vacancy posting costs. As a result, the job-finding rate plummets, leading to a large increase in undesirable unemployment.
Furthermore, the large reduction in the job-finding rate amplifies the moral hazard problems of the UI system, as the expected payments of the UI system to an unemployed worker increases. Thus, we see additional inefficient separations (see Figure 7, black vs. red line).

### 5.4.2 Optimal STW Policy in the Business Cycle

Figure 8 shows the reaction of the economy with optimal STW policy with and without moral hazard problems to a $-1 \%$ negative productivity shock as well as the reaction of the planner and baseline economy.

As we have seen last section, the UI system's moral hazard problems and fiscal externalities but, more importantly, the wage rigidity inefficiently amplify the business cycle. Due to the budget balance assumption, STW has little influence on the job-finding rate. As a result, we see a large drop in vacancy posting incentives and thus the job-finding rate caused by the wage-rigidity.


Figure 8: Optimal STW Policy - Allocation

To offset the negative effect on employment, the planner needs to decrease the number of separations. He incentivizes firms and workers to cut back on separations and hoard labor by increasing the generosity of the STW system (see figure 9).
These results correspond surprisingly well to what actually happened in the corona crisis in Germany. Germany significantly increased the generosity of its STW system during the Covid19 pandemic. Weber and Röttger (2022) find that, as in our model, the separation rate fell, despite being in a recession. Furthermore, new hires decreased.

However, stabilizing the economy via the separation rate can be costly. By keeping unproductive workers employed, STW deteriorates the quality of the workforce (negative cleansing effect). In consequence, the mean productivity of firms falls. Thus, we see that despite stabilizing unemployment, STW does a much worse job in stabilizing output compared to the planner economy.
Nevertheless, the reaction of consumption in the economy without hours distortions is relatively close to the one of the planner. By hoarding labor, STW depresses reallocation of workers via the labor market in recessions and thus significantly reduces costs from firing and recruiting workers.


Figure 9: Optimal STW Policy - Instruments

Increasing the STW benefits to reduce separations adds the additional costs of distorting the optimal number of hours worked on STW downwards. To mitigate these costs, the government chooses a smaller increase in the STW benefits and thus reduces separations less compared to a system without these problems. Distorting the number of hours worked downwards, we see that the moral hazard problems of STW reduce its ability to stabilize output and thus consumption while employment keeps well stabilized.

Interestingly, the eligibility condition (see Figure 9) does not need to rise in recessions if we keep the number of firms and workers on STW minimal. Due to the negative aggregate productivity shock, firms and workers already have an incentive to work less, making much more firms and workers eligible for STW. This can also be seen in the larger fraction of workers on STW. We see this increase even though the eligibility condition gets minimally stricter and the separation rate rises.

One important note for policy maker is that using STW optimally over the business cycle is fiscally not more expensive than a system without STW. Since STW keeps employment stable, it prevents workers from entering the UI system keeping its costs down in recessions.

## 6 Combination with a Vacancy Subsidy

Looking at the business cycle, one major problem of STW is that it is unable to stabilize the job-finding rate as it cannot react on the wage-rigidity. In order to solve this problem, we could combine the STW system with a vacancy subsidy in the spirit of Michau (2015) and Jung and Kuester (2015). Both papers look at an optimal policy mix involving a lay-off tax and a vacancy subsidy.

### 6.1 How does a Vacancy Subsidy work?

First of all, what is a vacancy subsidy and how does it work? Formally, a vacancy subsidy is a subsidy that reduces the costs a firm has to pay to recruit a worker:

$$
\begin{equation*}
\left(1-\tau_{V, t}\right) \cdot \frac{k_{v}}{q_{t}}=\beta \cdot E_{t}\left[J_{t+1}\right] \tag{44}
\end{equation*}
$$

Therefore, the government can incentivize firms to post more vacancies by raising the vacancy subsidy. If we introduce a vacancy subsidy of $25 \%$ of vacancy posting costs into the economy, we see that the job-finding rate jumps (see figure 10):


Figure 10: Unannounced Introduction of a Vacancy Subsidy

However, vacancy subsidies also increase separation incentives (see figure 10). From the perspective of a firm, it become less costly to replace a worker. Consequently the value of a worker for a firm falls and it engages less in labor-hoarding. Using the decentralized job-creation condition, we can see this in the term $\left(1-\tau_{V, t}\right) \cdot \frac{k_{v}}{q_{t}}$ :

$$
\begin{equation*}
y_{s t w, t}(\epsilon)-v\left(h_{s t w, t}\left(\epsilon_{s, t}\right)\right)-\tau_{t}^{v, b}+\tau_{s t w, t}^{t o t a l}+F+\frac{1-\eta_{t} \cdot f_{t}}{1-\eta_{t}} \cdot\left(1-\tau_{V, t}\right) \cdot \frac{k_{v}}{q_{t}}=0 \tag{45}
\end{equation*}
$$

From the perspective of a worker, vacancy subsidies make it easier to find a new job, due to larger job-finding rates. This increases their outside option and makes them willing to quit for a larger wage. We can see this in the formular by recognising that $\frac{1-\eta_{t} \cdot f_{t}}{1-\eta_{t}}$ falls in the job-finding rate.

In the end, a vacancy subsidy can increase the job-finding rate at the cost of increasing separations. This makes its influence on employment generally ambiguous. In this model the vacancy subsidy leads to a slight fall in employment.

### 6.2 Optimal Policy Mix in Steady-State

### 6.2.1 ... without hours distortions

From a planner perspective, the core idea now is that the vacancy subsidy takes care of the optimal labor market density, while STW looks after the optimal number of separations. Note that both instruments might solve the weakness of the other. STW solves the problem of the vacancy subsidy of inflating separations. And the vacancy subsidy solves the inability of STW to influence vacancy postings. As long as the STW system has no moral hazard problems the idea works fine and we can restore the planner-allocation by choosing:

$$
\begin{align*}
\tau_{V} & =\underbrace{\Omega \cdot \frac{\eta-\gamma}{1-\gamma}}_{\text {Deviation from Hosios-Condition }}+\underbrace{\beta \cdot \frac{1-\eta}{1-\psi} \cdot \frac{b}{k_{v} / q}}_{\text {Moral Hazard Problem UI }}+\underbrace{\beta \cdot \frac{(1-\eta) \cdot\left(1-G\left(\epsilon_{s}\right)\right)}{1-\psi} \cdot \frac{\tau^{b, v}}{k_{v} / q}}_{\text {Fiscal Externalities }}  \tag{46}\\
\tau_{s t w}^{\text {total }} & =\underbrace{\frac{f}{1-\psi} \cdot \frac{\eta-\gamma}{1-\gamma} \cdot \frac{k_{v}}{q}}_{\text {Deviation from Hosios-Condition }}+\underbrace{\frac{1}{1-G\left(\epsilon_{s}\right)} \cdot \frac{\psi}{1-\psi} \cdot b}_{\text {Moral Hazard Problem UI }}+\underbrace{\frac{1}{1-\psi} \cdot \tau^{b, v}}_{\text {Fiscal Externalities }}  \tag{47}\\
\tau^{v, b} & =\underbrace{\left(\frac{1}{n}-\frac{1}{1-G\left(\epsilon_{s}\right)}\right) \cdot b}_{\text {Fiscal Externality UI }}+\underbrace{\frac{k_{v} \cdot v}{n}}_{\text {Fiscal Externality Vacancy Subsidy }} \tag{48}
\end{align*}
$$

With:

$$
\begin{align*}
\tau_{s t w}^{t o t a l} & =\tau_{s t w, t} \cdot\left(\bar{h}-h\left(\epsilon_{s}\right)-\frac{1}{1-G\left(\epsilon_{s}\right)} \int_{\epsilon_{s}}^{\epsilon_{s t w}}(\bar{h}-h(\epsilon)) d G(\epsilon)\right)  \tag{49}\\
\psi & =\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-\eta \cdot f)  \tag{50}\\
\Omega & =\frac{1-\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-f)}{1-\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-\eta \cdot f)} \tag{51}
\end{align*}
$$

In detail: the UI system's moral hazard problems and fiscal externalities cause the firms to post too few vacancies and inflate separations.
To entice firms to post more vacancies, we must choose a positive vacancy subsidy. The subsidy must be equal to the distortions that the moral hazard problems and fiscal externalities of the UI system cause on the firm's discounted value divided by the firm's expected value in the planner economy.
To discourage separations, we also need a positive net inflow of the STW benefits to the least productive matches. These internalize the negative effects that the fiscal and moral hazard problems of the UI system have on separations. Note that the net-subsidy is larger than in the
model without the vacancy subsidy:

$$
\begin{equation*}
\frac{\beta \cdot(1-f)}{1-\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-f)} \cdot b<\frac{\beta \cdot(1-f)}{1-\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-\eta \cdot f)} \cdot b \Leftrightarrow \eta<1 \tag{52}
\end{equation*}
$$

This is due to the fact, that STW needs to incorporate both: the direct negative effect of the UI benefits and the indirect negative impact of the vacancy subsidy on separation in its reaction to the UI system.
Additionally, the STW benefits need to internalize the negative fiscal externality of the vacancy subsidy.

Furthermore, deviations from the Hosios-Condition set wrong vacancy posting incentives. For instance, if the worker's bargaining power is too large, then the firm's value is too low, resulting in too few vacancies posted. In this case, we need to raise the vacancy subsidy.
In contrast to a system with STW policy only, STW should react to deviations to the HosiosCondition as it needs to offset the effect of the vacancy subsidy on separation incentives.

This result spills over to the business cycle where wage-rigidities increase the bargaining power of the workers.

### 6.2.2 ... with hours distortions

If STW exhibits moral hazard problems, the vacancy subsidy, and the STW system work less well together. The Moral Hazard Problems of the STW system make it costly to stabilize separations with STW. This seriously reduces the effectiveness of the vacancy subsidy. Remember from the last section that in order to stabilize vacancy postings with a STW subsidy, we need the STW system to offset its negative impacts on separations.

| Name | Variable | Baseline | Optimal Policy <br> Mix with <br> Moral Hazard | Optimal Policy <br> Mix without <br> Moral Hazard |
| :--- | :--- | :--- | :--- | :--- |
| Separation Rate | $\mathrm{G}\left(\epsilon_{s}\right)$ | 0,034 | $0,020 \mid-41,1 \%$ | $0,023 \mid-32,4 \%$ |
| Job-Finding Rate | f | 0,450 | $0.446 \mid-0,2 \%$ | $0,560 \mid+24,4 \%$ |
| Unemployment | $1-n$ | 0.073 | $0.043 \mid-41.1 \%$ | $0.026 \mid-64.4 \%$ |
| Vacancy Subsidy | $\tau_{V, t}$ | 0 | $-0,029$ | 0.507 |
| STW benefits | $\tau_{s t w}$ | 0 | 0,806 | 8.071 |
| Net-Transfers STW | $\tau_{s t w}^{t o t a l}$ | 0 | 0.490 | 0.624 |
| Production Tax | $\tau_{J}$ | 0,017 | $0.016 \mid-9,6 \%$ | $0,030 \mid+74,1 \%$ |

Table 5: Steady-State Comparison

In our model, under the assumption that the unemployment insurance only distorts the
steady-state, we see that the planner decides to set the vacancy subsidy close to zero. In fact, it is even slightly negative (see Table 5). Setting the vacancy subsidy negative decreases separations as it is more costly for firms to replace a worker. This reduces a bit the net transfer needed to stabilize separations and thus the moral hazard problems of STW. Overall, the allocation is almost identical to the economy without the vacancy subsidy.

### 6.3 Optimal Policy Mix in the Business Cycle

As suggested by the steady-state result, STW combined with a vacancy subsidy can perfectly restore the planner allocation over the business cycle as long as it does not distort the number of hours worked.

To implement the planner solution, the government needs to raise the vacancy subsidy and the STW benefits. The STW benefits react partly to the increased moral hazard and fiscal externalities of the UI system. However, the main reason for the increase is to counteract the adverse effects of the wage-rigidity on vacancy posting.
Nonetheless, the increase in the vacancy subsidy makes it easier for firms to replace their workers, driving up the separation incentives. To counteract this effect, the STW benefits need to rise. The rise is further increased to offset the increased fiscal externalities of the vacancy subsidy and UI system.


Figure 11: Optimal Policy Mix - Allocation

If STW itself exhibits moral hazard problems, the optimality result does not hold. In contrast to the steady-state, the planner actively tries to stabilize the economy with the vacancy subsidy. This is, in particular, to counter the wage-rigidity that STW alone cannot address. However, since offsetting the negative impact of the vacancy subsidy on separations with STW is costly, the government decides against fully stabilizing the job-finding rate. To counter unemployment, it chooses instead to stabilize separations more than in the planner solution. Even though the planner keeps employment almost perfectly stable, consumption deviates noticeably from the optimal response. This is mainly due to the fall in mean hours worked caused by the use of the STW system and partly due to the smaller cleansing effect.


Figure 12: Optimal Policy Mix - Instruments

Viewed superficially, vacancy subsidies and STW seem to be great complements when it comes to stabilizing the labor market. However, the vacancy subsidy's ability to increase separations combined mit the STW's problem of distorting the optimal number of hours worked seriously hamper its ability with regard to consumption and output.

## 7 Conclusion

STW can be seen as an instrument to reduce separations. However, stabilizing separations comes at the cost of an output loss as it distorts the number of hours worked on STW downwards. To minimize the moral hazard problems of STW, the government should set the eligi-
bility condition so strict that no firm that could survive without STW can enter STW. The STW benefits should be adjusted to offset the negative effects of the UI system on separations. In recessions, the generosity of the system has to grow to counter the increased moral hazard problems of the UI system caused by a fall in the job-finding rate and amplified by wage-rigidity. The eligibility conditon should get a little stricter as more firms and workers want to reduce their working hours in recessions anyway, increasing the number of firms that are eligible for STW.

However, the optimal short-time work policy suffers from two shortcomings that prevent it from implementing the planner allocation. First, it cannot stabilize the job-finding rate. And second, using STW leads to an output loss. As long as the moral hazard problems of STW do not exist, we can solve the first problem and reach the planner allocation by combining STW with a vacancy subsidy. However, The moral hazard problems of STW make the planner allocation not only unattainable but also reduce the vacancy subsidy's ability to stabilize the job-finding rate. Since stabilizing separations with STW is costly, STW cannot perfectly offset the positive impact of the vacancy subsidy on separations, making the instrument expensive to use.

In conclusion, STW can be used to counter the moral hazard problems of an UI system in and outside recessions. Therefore, it can be seen as an alternative to a US-style experience rating system. However, since the net benefit of STW depends on the number of hours worked, it creates a moral hazard problem that makes it a suboptimal instrument. In this model, a wage-subsidy that pays under the same rules as STW but whose amount is independent of the number of hours worked (similar to the model without hours distortions) could implement the planner solution when combined with a vacancy subsidy. An US-style experience rating system, respectively, a lay-off tax might also do the job. The advantage of these instruments is that they disincentivize separations independent of the hours' choice.
These suggestions results might not hold in a framework with inflexible hours worked as STW can then be seen as a flexibilization tool on top of its role as a subsidy.

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## A Derivations

## A. 1 Planner Economy

Solving the planner problem (see equations 26, 27) we can use the Lagrange-Method:

$$
\begin{align*}
\mathcal{L}=E_{0} \sum_{t=0}^{\infty} & \beta^{t} \cdot\left(n_{t} \cdot \int_{\epsilon_{s, t}}^{\infty}\left[a_{t} \cdot \epsilon \cdot h_{t}(\epsilon)^{\alpha}-\left(\mu_{\epsilon}-\epsilon\right) \cdot c_{f}-v\left(h_{t}(\epsilon)\right)\right] \frac{d G(\epsilon)}{1-G\left(\epsilon_{s, t}\right)}\right.  \tag{A.1}\\
& \left.-n_{t} \cdot \frac{G\left(\epsilon_{s, t}\right)}{1-G\left(\epsilon_{s, t}\right)} \cdot F-\theta_{t} \cdot\left(1-n_{t}\right) \cdot k_{v}\right) \\
& -\lambda_{t} \cdot\left(n_{t}-\left(1-G\left(\epsilon_{s, t}\right)\right) \cdot\left(n_{t-1}+\theta_{t-1} \cdot q\left(\theta_{t-1}\right) \cdot\left(1-n_{t-1}\right)\right)\right)
\end{align*}
$$

## First Order Conditions (FOC) of the Planner

FOC for hours worked:

$$
\begin{align*}
\frac{\partial \mathcal{L}}{\partial h_{t}(\epsilon)} & =\beta^{t} \cdot n_{t} \cdot\left(\alpha \cdot a_{t} \cdot \epsilon \cdot h_{t}(\epsilon)^{\alpha-1}-v^{\prime}\left(h_{t}(\epsilon)\right)\right) \cdot \frac{g(\epsilon)}{1-G\left(\epsilon_{s, t}\right)}=0  \tag{A.2}\\
& \Leftrightarrow \alpha \cdot a_{t} \cdot \epsilon \cdot h_{t}(\epsilon)^{\alpha-1}=v^{\prime}\left(h_{t}(\epsilon)\right) \tag{A.3}
\end{align*}
$$

This is equation 28.

FOC for employment:

$$
\begin{align*}
\frac{\partial \mathcal{L}}{\partial n_{t}} & =\beta^{t} \cdot\left(\int_{\epsilon_{s, t}}^{\infty}\left[y_{t}(\epsilon)-v\left(h_{t}(\epsilon)\right)\right] \frac{d G(\epsilon)}{1-G\left(\epsilon_{s, t}\right)}-\frac{G\left(\epsilon_{s, t}\right)}{1-G\left(\epsilon_{s, t}\right)} \cdot F+\theta_{t} \cdot k_{v}\right)  \tag{A.4}\\
& -\lambda_{t}+\left(1-\theta_{t} \cdot q\left(\theta_{t}\right)\right) \cdot E_{t}\left[\lambda_{t+1} \cdot\left(1-G\left(\epsilon_{t+1}\right)\right)\right]=0 \\
\Leftrightarrow \lambda_{t} & =\beta^{t} \cdot\left(\int_{\epsilon_{s, t}}^{\infty}\left[y_{t}(\epsilon)-v\left(h_{t}(\epsilon)\right)\right] \frac{d G(\epsilon)}{1-G\left(\epsilon_{s, t}\right)}-\frac{G\left(\epsilon_{s, t}\right)}{1-G\left(\epsilon_{s, t}\right)} \cdot F+\theta_{t} \cdot k_{v}\right)  \tag{A.5}\\
& +\left(1-\theta_{t} \cdot q\left(\theta_{t}\right)\right) \cdot E_{t}\left[\lambda_{t+1} \cdot\left(1-G\left(\epsilon_{s, t+1}\right)\right)\right]
\end{align*}
$$

FOC for the labor market density:

$$
\begin{align*}
\frac{\partial \mathcal{L}}{\partial \theta_{t}} & =-\beta^{t} \cdot k_{v} \cdot\left(1-n_{t}\right)+E_{t} \lambda_{t+1} \cdot\left(1-G\left(\epsilon_{t+1}\right)\right) \cdot\left(q\left(\theta_{t}\right)+\theta_{t} \cdot q^{\prime}\left(\theta_{t}\right)\right) \cdot\left(1-n_{t}\right)=0  \tag{A.6}\\
& \Leftrightarrow E_{t}\left[\lambda_{t+1} \cdot\left(1-G\left(\epsilon_{s, t+1}\right)\right)\right]=\frac{\beta^{t}}{1+\theta_{t} \cdot \frac{q^{\prime}\left(\theta_{t}\right)}{q\left(\theta_{t}\right)}} \cdot \frac{k_{v}}{q\left(\theta_{t}\right)} \tag{A.7}
\end{align*}
$$

Note that we can express the elasticity of the matching function with respect to unemployment as:

$$
\begin{equation*}
\theta_{t} \cdot \frac{q^{\prime}\left(\theta_{t}\right)}{q\left(\theta_{t}\right)}=-\gamma \cdot \theta_{t} \cdot \frac{\chi \cdot \theta_{t}^{-\gamma-1}}{\chi \cdot \theta_{t}^{-\gamma}}=-\gamma \tag{A.8}
\end{equation*}
$$

Using this expression gives:

$$
\begin{equation*}
E_{t}\left[\lambda_{t+1} \cdot\left(1-G\left(\epsilon_{t+1}\right)\right)\right]=\frac{\beta^{t}}{1-\gamma} \cdot \frac{k_{v}}{q\left(\theta_{t}\right)} \tag{A.9}
\end{equation*}
$$

FOC separation threshold:

$$
\begin{align*}
\frac{\partial \mathcal{L}}{\partial \epsilon_{s, t}}=\beta^{t} \cdot( & -\frac{n_{t}}{1-G\left(\epsilon_{s, t}\right)} \cdot\left[y_{t}\left(\epsilon_{s, t}\right)-v\left(h_{t}\left(\epsilon_{s, t}\right)\right)\right] \cdot g\left(\epsilon_{s, t}\right)  \tag{A.10}\\
& +\frac{n_{t}}{1-G\left(\epsilon_{s, t}\right)} \cdot \int_{\epsilon_{s, t}}^{\infty}\left[y_{t}(\epsilon)-v\left(h_{t}(\epsilon)\right)\right] \frac{d G(\epsilon)}{1-G\left(\epsilon_{s, t}\right)} \cdot g\left(\epsilon_{s, t}\right) \\
& \left.-\frac{n_{t}}{1-G\left(\epsilon_{s, t}\right)} \cdot \frac{F}{1-G\left(\epsilon_{s, t}\right)} \cdot g\left(\epsilon_{s, t}\right)\right) \\
& -\lambda_{t} \cdot\left(n_{t-1}+\theta_{t-1} \cdot q\left(\theta_{t-1}\right) \cdot\left(1-n_{t-1}\right)\right) \cdot g\left(\epsilon_{s, t}\right)=0 \tag{A.11}
\end{align*}
$$

This is equivalent to:

$$
\begin{equation*}
\frac{\partial \mathcal{L}}{\partial \epsilon_{s, t}}=-\beta^{t} \cdot\left(\left[y_{t}\left(\epsilon_{s, t}\right)-v\left(h_{t}\left(\epsilon_{s, t}\right)\right)\right]-\int_{\epsilon_{s, t}}^{\infty}\left[y_{t}(\epsilon)-v\left(h_{t}(\epsilon)\right)\right] \frac{d G(\epsilon)}{1-G\left(\epsilon_{s, t}\right)}+\frac{F}{1-G\left(\epsilon_{s, t}\right)}\right)+\lambda_{t}=0 \tag{A.12}
\end{equation*}
$$

## Planner's Job-Creation Equation

Inserting the FOC for employment into the FOC for the labor market density gives:

$$
\begin{array}{r}
\frac{1}{1-\gamma} \cdot \frac{k_{v}}{q\left(\theta_{t}\right)}=\beta \cdot E_{t}\left[\left(\int_{\epsilon_{s, t+1}}^{\infty}\left[y_{t+1}(\epsilon)-v\left(h_{t+1}(\epsilon)\right)\right] \frac{d G(\epsilon)}{1-G\left(\epsilon_{s, t+1}\right)}-\frac{G\left(\epsilon_{s, t+1}\right)}{1-G\left(\epsilon_{s, t+1}\right)} \cdot F+\theta_{t} \cdot k_{v}\right.\right.  \tag{A.13}\\
\left.\left.\quad+\left(1-\theta_{t+1} \cdot q\left(\theta_{t+1}\right)\right) \cdot \frac{1}{\beta^{t+1}} \cdot E_{t+1}\left[\lambda_{t+2} \cdot\left(1-G\left(\epsilon_{s, t+2}\right)\right)\right]\right) \cdot\left(1-G\left(\epsilon_{s, t+1}\right)\right)\right]
\end{array}
$$

Rearranging and using that $E_{t+1}\left[\lambda_{t+2} \cdot\left(1-G\left(\epsilon_{s, t+2}\right)\right)\right]=\frac{\beta^{t+1}}{1-\gamma} \frac{k_{v}}{q\left(\theta_{t+1}\right)}$ gives:

$$
\begin{align*}
\frac{1}{1-\gamma} \cdot \frac{k_{v}}{q\left(\theta_{t}\right)}=\beta \cdot E_{t}[ & \int_{\epsilon_{s, t+1}}^{\infty}\left[y_{t+1}(\epsilon)-v\left(h_{t+1}(\epsilon)\right)\right] d G(\epsilon)-G\left(\epsilon_{s, t+1}\right) \cdot F  \tag{A.14}\\
& \left.+\left(1-G\left(\epsilon_{s, t+1}\right)\right) \cdot\left(\theta_{t+1} \cdot k_{v}+\frac{1-\theta_{t+1} \cdot q\left(\theta_{t+1}\right)}{1-\gamma} \cdot \frac{k_{v}}{q\left(\theta_{t+1}\right)}\right)\right]
\end{align*}
$$

Using that $\theta_{t+1}=\frac{\theta_{t+1} \cdot q\left(\theta_{t+1}\right)}{q\left(\theta_{t+1}\right)}$, we get:

$$
\begin{align*}
\frac{1}{1-\gamma} \cdot \frac{k_{v}}{q\left(\theta_{t}\right)}=\beta \cdot E_{t} & {\left[\int_{\epsilon_{s, t+1}}^{\infty}\left[y_{t+1}(\epsilon)-v\left(h_{t+1}(\epsilon)\right)\right] d G(\epsilon)-G\left(\epsilon_{s, t+1}\right) \cdot F\right.}  \tag{A.15}\\
& \left.+\left(1-G\left(\epsilon_{s, t+1}\right)\right) \cdot\left(\frac{1-\gamma \cdot \theta_{t+1} \cdot q\left(\theta_{t+1}\right)}{1-\gamma} \cdot \frac{k_{v}}{q\left(\theta_{t+1}\right)}\right)\right]
\end{align*}
$$

With $f_{t+1}=\theta_{t+1} \cdot q\left(\theta_{t+1}\right)$ and $q_{t}=q\left(\theta_{t}\right)$ this is equivalent to the job-creation equation 29 of the planner.

## Separation Decision Planner

Insert FOC for employment into FOC for separation threshold:

$$
\begin{array}{r}
\frac{\partial \mathcal{L}}{\partial \epsilon_{s, t}}=\left[y_{t}\left(\epsilon_{s, t}\right)-v\left(h_{t}\left(\epsilon_{s, t}\right)\right)\right]-\int_{\epsilon_{s, t}}^{\infty}\left[y_{t}(\epsilon)-v\left(h_{t}(\epsilon)\right)\right] \frac{d G(\epsilon)}{1-G\left(\epsilon_{s, t}\right)}+\frac{F}{1-G\left(\epsilon_{s, t}\right)}  \tag{A.16}\\
+\int_{\epsilon_{s, t}}^{\infty}\left[y_{t}(\epsilon)-v\left(h_{t}(\epsilon)\right)\right] \frac{d G(\epsilon)}{1-G\left(\epsilon_{s, t}\right)}-\frac{G\left(\epsilon_{s, t}\right)}{1-G\left(\epsilon_{s, t}\right)} \cdot F+\theta_{t} \cdot k_{v} \\
+\left(1-\theta_{t} \cdot q\left(\theta_{t}\right)\right) \cdot \frac{1}{\beta^{t}} \cdot E_{t}\left[\lambda_{t+1} \cdot\left(1-G\left(\epsilon_{t+1}\right)\right)\right]=0
\end{array}
$$

This can be simplified to:

$$
\begin{equation*}
\Leftrightarrow\left[y_{t}\left(\epsilon_{s, t}\right)-v\left(h_{t}\left(\epsilon_{s, t}\right)\right)\right]+F+\theta_{t} \cdot k_{v}+\left(1-\theta_{t} \cdot q\left(\theta_{t}\right)\right) \cdot \frac{1}{\beta^{t}} \cdot E_{t}\left[\lambda_{t+1} \cdot\left(1-G\left(\epsilon_{t+1}\right)\right)\right]=0 \tag{A.17}
\end{equation*}
$$

Inserting the FOC of the labor market density gives:

$$
\begin{equation*}
\left[y_{t}\left(\epsilon_{s, t}\right)-v\left(h_{t}\left(\epsilon_{s, t}\right)\right)\right]+F+\frac{1-\gamma \cdot \theta_{t} \cdot q\left(\theta_{t}\right)}{1-\gamma} \cdot \frac{k_{v}}{q\left(\theta_{t}\right)}=0 \tag{A.18}
\end{equation*}
$$

With $f_{t}=\theta_{t} \cdot q\left(\theta_{t}\right)$ and $q_{t}=q\left(\theta_{t}\right)$ this is equivalent to the separation decision of the planner expressed in equation 30 .

## A. 2 Nash-Bargaining

## Wage and Severance Payment

The FOC for the wage is:

$$
\begin{align*}
\eta_{t-1} \cdot & \left(\left(1-G\left(\epsilon_{s t w, t}\right)\right)+\int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}} \frac{h_{s t w, t}(\epsilon)}{\bar{h}} d G(\epsilon)\right) \cdot J_{t}  \tag{A.19}\\
& =\left(1-\eta_{t-1}\right) \cdot\left(\left(1-G\left(\epsilon_{s, t}\right)\right)+\int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}} \frac{h_{s t w, t}(\epsilon)}{\bar{h}} d G(\epsilon)\right) \cdot\left(V_{t}-U_{t}\right) \\
\Leftrightarrow \eta_{t-1} \cdot J_{t} & =\left(1-\eta_{t-1}\right) \cdot\left(V_{t}-U_{t}\right) \tag{A.20}
\end{align*}
$$

This is equivalent to the optimality condition of the wage 14.

The FOC for the severance payment is:

$$
\begin{align*}
\eta_{t-1} \cdot G\left(\epsilon_{s, t}\right) \cdot J_{t} & =\left(1-\eta_{t-1}\right) \cdot G\left(\epsilon_{s, t}\right) \cdot\left(V_{t}-U_{t}\right) \\
\Leftrightarrow \eta_{t-1} \cdot J_{t} & =\left(1-\eta_{t-1}\right) \cdot\left(V_{t}-U_{t}\right) \tag{A.21}
\end{align*}
$$

This is also equivalent to equation 14.

## Hours Worked

FOC of hours worked outside STW, that is for $\epsilon>\epsilon_{s t w, t}$ :

$$
\begin{equation*}
\alpha \cdot a_{t} \cdot \epsilon \cdot\left(h_{t}(\epsilon)\right)^{\alpha-1} \cdot g(\epsilon) \cdot\left(1-\eta_{t-1}\right) \cdot\left(V_{t}-U_{t}\right)=v^{\prime}\left(h_{t}(\epsilon)\right) \cdot g(\epsilon) \cdot \eta_{t-1} \cdot J_{t} \tag{A.22}
\end{equation*}
$$

Inserting optimality condition of the wage gives:

$$
\begin{equation*}
\alpha \cdot a_{t} \cdot \epsilon \cdot\left(h_{t}(\epsilon)\right)^{\alpha-1}=v^{\prime}\left(h_{t}(\epsilon)\right) \tag{A.23}
\end{equation*}
$$

This is the condition for optimal hours' choice (see equation 16).

FOC of hours worked on STW, that is for $\epsilon \leq \epsilon_{s t w, t}$ :

$$
\begin{equation*}
\left(\alpha \cdot a_{t} \cdot \epsilon \cdot\left(h_{t}(\epsilon)\right)^{\alpha-1}-\tau_{s t w, t}\right) \cdot g(\epsilon) \cdot\left(1-\eta_{t-1}\right) \cdot\left(V_{t}-U_{t}\right)=v^{\prime}\left(h_{t}(\epsilon)\right) \cdot g(\epsilon) \cdot \eta_{t-1} \cdot J_{t} \tag{A.24}
\end{equation*}
$$

Inserting the optimality condition for the wage gives:

$$
\begin{equation*}
\alpha \cdot a_{t} \cdot \epsilon \cdot h_{s t w, t}(\epsilon)^{\alpha-1}=v^{\prime}\left(h_{s t w, t}(\epsilon)\right)+\tau_{s t w, t} \tag{A.25}
\end{equation*}
$$

This is the condition for the optimal hours' choice (see equation 17).

## Separations

The FOC of the separation threshold is:

$$
\begin{align*}
& \eta_{t-1} \cdot\left(U_{t}+w_{e u, t}+v\left(h_{s t w, t}\left(\epsilon_{s, t}\right)\right)+b-\frac{w_{t}}{\bar{h}} \cdot h_{s t w, t}\left(\epsilon_{s, t}\right)\right.  \tag{A.26}\\
&\left.-\left(\bar{h}-h_{s t w, t}\left(\epsilon_{s, t}\right)\right) \cdot \tau_{s t w, t}-\Pi_{t}-\beta \cdot E_{t}\left[V_{t+1}\right]\right) \cdot J_{t}= \\
&\left(1-\eta_{t-1}\right) \cdot\left(\tau_{J, t}+\frac{w_{t}}{\bar{h}} \cdot h_{s t w, t}\left(\epsilon_{s, t}\right)-F-w_{e u, t}-y_{s t w, t}\left(\epsilon_{s, t}\right)-\beta \cdot E_{t}\left[J_{t+1}\right]\right) \cdot\left(V_{t}-U_{t}\right)
\end{align*}
$$

Inserting the optimality condition of the wage and rearranging gives:
$y_{s t w, t}\left(\epsilon_{s, t}\right)+\Pi_{t}-v\left(h_{s t w, t}\left(\epsilon_{s, t}\right)\right)-b-\tau_{J, t}+\left(\bar{h}-h_{s t w, t}\left(\epsilon_{s, t}\right)\right) \cdot \tau_{s t w, t}+\beta \cdot E_{t}\left[J_{t+1}+V_{t+1}\right]-U_{t}=0$

Inserting the value of an unemployed worker $U_{t}$ gives:

$$
\begin{align*}
y_{s t w, t}\left(\epsilon_{s, t}\right)-v\left(h_{s t w, t}\left(\epsilon_{s, t}\right)\right) & -\tau_{J, t}+\left(\bar{h}-h_{s t w, t}\left(\epsilon_{s, t}\right)\right) \cdot \tau_{s t w, t}  \tag{A.28}\\
& +\beta \cdot E_{t}\left[J_{t+1}+\left(1-f_{t}\right) \cdot\left(V_{t+1}-U_{t+1}\right)\right]=0
\end{align*}
$$

Inserting $J_{t}=\eta_{t-1} \cdot S_{t}$ and $V_{t}-U_{t}=\left(1-\eta_{t-1}\right) \cdot S_{t}$ gives:

$$
\begin{equation*}
y_{s t w, t}\left(\epsilon_{s, t}\right)-v\left(h_{s t w, t}\left(\epsilon_{s, t}\right)\right)-\tau_{J, t}+\left(\bar{h}-h_{s t w, t}\left(\epsilon_{s, t}\right)\right) \cdot \tau_{s t w, t}+\beta \cdot\left(1-\eta_{t} \cdot f_{t}\right) E_{t}\left[S_{t+1}\right]=0 \tag{A.29}
\end{equation*}
$$

Note that from the vacancy posting condition follows:

$$
\begin{array}{r}
\left(1-\tau_{V, t}\right) \cdot \frac{k_{v}}{q_{t}}=\beta \cdot E_{t}\left[J_{t+1}\right]=\beta \cdot\left(1-\eta_{t}\right) \cdot E_{t}\left[S_{t+1}\right] \\
\Leftrightarrow \beta \cdot E_{t}\left[S_{t+1}\right]=\frac{1-\tau_{V, t}}{1-\eta_{t}} \cdot \frac{k_{v}}{q_{t}} \tag{А.31}
\end{array}
$$

Inserting this gives:

$$
\begin{equation*}
y_{s t w, t}\left(\epsilon_{s, t}\right)-v\left(h_{s t w, t}\left(\epsilon_{s, t}\right)\right)-\tau_{J, t}+\left(\bar{h}-h_{s t w, t}\left(\epsilon_{s, t}\right)\right) \cdot \tau_{s t w, t}+\frac{1-\eta_{t} \cdot f_{t}}{1-\eta_{t}} \cdot\left(1-\tau_{V, t}\right) \cdot \frac{k_{v}}{q_{t}}=0 \tag{A.32}
\end{equation*}
$$

This is equivalent to equation 18.

## A. 3 Decentralized Economy

## Job-Creation Equation

The Job-Creation equation stems from the vacancy creation condition. Using that wages perfectly split the joint surplus between firms and workers according to their bargaining weights $J_{t}=\left(1-\eta_{t-1}\right) \cdot S_{t}$, where $S_{t}$ is the joint surplus gives:

$$
\begin{equation*}
\left(1-\tau_{V, t}\right) \cdot \frac{k_{v}}{q_{t}}=\beta \cdot E_{t}\left[J_{t+1}\right]=\beta \cdot\left(1-\eta_{t}\right) \cdot E_{t}\left[S_{t+1}\right] \tag{A.33}
\end{equation*}
$$

We, therefore, need to determine the joint surplus:

$$
\begin{equation*}
S_{t}=J_{t}+V_{t}-U_{t} \tag{A.34}
\end{equation*}
$$

Inserting for $J_{t}, V_{t}$ gives:

$$
\begin{align*}
& S_{t}=\int_{\epsilon_{s t w, t}}^{\infty}\left(y_{t}(\epsilon)-\tau_{J, t}\right) d G(\epsilon)+\int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}}\left(y_{s t w, t}(\epsilon)-\tau_{J, t}\right) d G(\epsilon)-\left(1-G\left(\epsilon_{s t w, t}\right)\right) \cdot w_{t}  \tag{A.35}\\
&-\int_{\epsilon_{s, t}}^{\epsilon_{s t w}, t} \\
& w_{t} \\
&+\left(1-G\left(\epsilon_{s t w, t}\right)\right) \cdot w_{t}+\int_{\epsilon_{s, t}, t}(\epsilon) d G(\epsilon)-G\left(\epsilon_{s, t}\right) \cdot\left(w_{e u, t}+F\right) \\
&+G\left(\epsilon_{s, t}\right) \cdot\left(w_{e u, t}-b\right)-\int_{\epsilon_{s, t}}^{\infty} v\left(h_{s t w, t}(\epsilon)\right) d G(\epsilon)+\left(1-G\left(\epsilon_{s, t}\right)\right) \cdot\left(\Pi_{t}+\beta \cdot E_{t}\left[J_{t+1}+V_{t+1}\right]-U_{t}\right)
\end{align*}
$$

Simplified we get:

$$
\begin{aligned}
S_{t} & =\int_{\epsilon_{s t w, t}}^{\infty}\left(y_{t}(\epsilon)-v\left(h_{t}(\epsilon)\right)-\tau_{J, t}\right) d G(\epsilon)+\int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}}\left(y_{s t w, t}(\epsilon)-v\left(h_{s t w, t}(\epsilon)\right)-\tau_{J, t}\right) d G(\epsilon) \\
& +\int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}}\left(\bar{h}-h_{s t w, t}(\epsilon)\right) \cdot \tau_{s t w, t} d G(\epsilon)-G\left(\epsilon_{s, t}\right) \cdot b \\
& +\left(1-G\left(\epsilon_{s, t}\right)\right) \cdot\left(\Pi_{t}+\beta \cdot E_{t}\left[J_{t+1}+V_{t+1}\right]-U_{t}\right)
\end{aligned}
$$

Inserting $J_{t}=\left(1-\eta_{t-1}\right) \cdot S_{t}$ and $V_{t}-U_{t}=\eta_{t-1} \cdot S_{t}$ gives:

$$
\begin{align*}
S_{t} & =\int_{\epsilon_{s t w}, t}^{\infty}\left(y_{t}(\epsilon)-v\left(h_{t}(\epsilon)\right)-\tau_{J, t}\right) d G(\epsilon)+\int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}}\left(y_{s t w, t}(\epsilon)-v\left(h_{s t w, t}(\epsilon)\right)-\tau_{J, t}\right) d G(\epsilon)  \tag{А.37}\\
& +\int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}}\left(\bar{h}-h_{s t w, t}(\epsilon)\right) \cdot \tau_{s t w, t} d G(\epsilon)-b \\
& +\left(1-G\left(\epsilon_{s, t}\right)\right) \cdot \beta \cdot E_{t}\left[\left(1-\eta_{t+1}\right) \cdot S_{t+1}+\left(1-f_{t}\right) \cdot \eta_{t+1} \cdot S_{t+1}\right]  \tag{A.38}\\
& =\int_{\epsilon_{s t w, t}}^{\infty}\left(y_{t}(\epsilon)-v\left(h_{t}(\epsilon)\right)-\tau_{J, t}\right) d G(\epsilon)+\int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}}\left(y_{s t w, t}(\epsilon)-v\left(h_{s t w, t}(\epsilon)\right)-\tau_{J, t}\right) d G(\epsilon) \\
& +\int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}}\left(\bar{h}-h_{s t w, t}(\epsilon)\right) \cdot \tau_{s t w, t} d G(\epsilon)-b+\beta \cdot\left(1-G\left(\epsilon_{s, t}\right)\right) \cdot\left(1-\eta_{t} \cdot f_{t}\right) \cdot E_{t}\left[S_{t+1}\right]
\end{align*}
$$

Inserting the vacancy posting condition gives:

$$
\begin{align*}
S_{t} & =\int_{\epsilon_{s t w, t}}^{\infty}\left(y_{t}(\epsilon)-v\left(h_{t}(\epsilon)\right)-\tau_{J, t}\right) d G(\epsilon)+\int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}}\left(y_{s t w, t}(\epsilon)-v\left(h_{s t w, t}(\epsilon)\right)-\tau_{J, t}\right) d G(\epsilon)  \tag{A.39}\\
& +\int_{\epsilon_{s, t}}^{\epsilon_{s t w}, t}\left(\bar{h}-h_{s t w, t}(\epsilon)\right) \cdot \tau_{s t w, t} d G(\epsilon)-b+\beta \cdot\left(1-G\left(\epsilon_{s, t}\right)\right) \cdot \frac{1-\eta_{t} \cdot f_{t}}{1-\eta_{t}} \cdot \frac{k_{v}}{q_{t}} \tag{A.40}
\end{align*}
$$

Inserting the budget constraint of the government gives:

$$
\begin{align*}
S_{t} & =\int_{\epsilon_{s t w, t}}^{\infty}\left(y_{t}(\epsilon)-v\left(h_{t}(\epsilon)\right)-\tau_{t}^{v, b}-\int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}}\left(\bar{h}-h_{s t w, t}(\epsilon)\right) \cdot \tau_{s t w, t} \frac{d G(\epsilon)}{1-G\left(\epsilon_{s, t}\right)}\right) d G(\epsilon)  \tag{A.41}\\
& +\int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}}\left(y_{s t w, t}(\epsilon)-v\left(h_{s t w, t}(\epsilon)\right)-\tau_{t}^{v, b}-\int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}}\left(\bar{h}-h_{s t w, t}(\epsilon)\right) \cdot \tau_{s t w, t} \frac{d G(\epsilon)}{1-G\left(\epsilon_{s, t}\right)}\right) d G(\epsilon) \\
& +\int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}}\left(\bar{h}-h_{s t w, t}(\epsilon)\right) \cdot \tau_{s t w, t} d G(\epsilon)-b+\beta \cdot\left(1-G\left(\epsilon_{s, t}\right)\right) \cdot \frac{1-\eta_{t} \cdot f_{t}}{1-\eta_{t}} \cdot \frac{k_{v}}{q_{t}} \\
& =\int_{\epsilon_{s t w, t}}^{\infty}\left(y_{t}(\epsilon)-v\left(h_{t}(\epsilon)\right)-\tau_{t}^{v, b}\right) d G(\epsilon)+\int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}}\left(y_{s t w, t}(\epsilon)-v\left(h_{s t w, t}(\epsilon)\right)-\tau_{t}^{v, b}\right) d G(\epsilon)-b \\
& +\beta \cdot\left(1-G\left(\epsilon_{s, t}\right)\right) \cdot \frac{1-\eta_{t} \cdot f_{t}}{1-\eta_{t}} \cdot\left(1-\tau_{V, t}\right) \cdot \frac{k_{v}}{q_{t}} \tag{A.42}
\end{align*}
$$

Inserting the joint surplus into the vacancy posting condition gives:

$$
\begin{align*}
\left(1-\tau_{V, t}\right) \cdot \frac{k_{v}}{q_{t}}=\beta \cdot\left(1-\eta_{t}\right) \cdot E_{t} & \left(\int_{\epsilon_{s, t+1}}^{\infty}\left[y_{t}(\epsilon)-v\left(h_{t+1}(\epsilon)\right)-\tau_{t+1}^{v, b}\right] d G(\epsilon)\right.  \tag{A.43}\\
& +\int_{\epsilon_{s, t+1}}^{\infty}\left[y_{s t w, t}(\epsilon)-v\left(h_{s t w, t+1}(\epsilon)\right)-\tau_{t+1}^{v, b}\right] d G(\epsilon) \\
& \left.-b+G\left(\epsilon_{s, t+1}\right) \cdot(-F)+\frac{1-\eta_{t+1} \cdot f_{t+1}}{1-\eta_{t+1}} \cdot\left(1-\tau_{V, t+1}\right) \frac{k_{v}}{q_{t+1}}\right)
\end{align*}
$$

With $\tau_{V, t}=0$ and thus $\tau_{t}^{v, b}=\tau_{t}^{b}$ we get equation 37. With $\epsilon_{s, t}=\epsilon_{s t w, t}, \tau_{V, t}=0$ and thus $\tau_{t}^{v, b}=\tau_{t}^{b}$ we get equation 32 .

## Separation Decision in the decentralized Economy

Inserting the budget constraint of the government into equation gives:

$$
\begin{align*}
y_{s t w, t}\left(\epsilon_{s, t}\right)-v\left(h_{s t w, t}\left(\epsilon_{s, t}\right)\right)-\tau_{t}^{v, b} & -\tau_{s t w, t} \cdot \int_{\epsilon_{s, t}}^{\epsilon_{s t w, t}}\left(\bar{h}-h_{s t w, t}(\epsilon)\right) \frac{d G(\epsilon)}{1-G\left(\epsilon_{s, t}\right)}  \tag{A.44}\\
& +\left(\bar{h}-h_{s t w, t}\left(\epsilon_{s, t}\right)\right) \cdot \tau_{s t w, t}+F+\frac{1-\eta_{t} \cdot f_{t}}{1-\eta_{t}} \cdot \frac{\left(1-\tau_{V, t}\right) \cdot k_{v}}{q_{t}}=0
\end{align*}
$$

This is equivalent to equation 45 . With $\tau_{V, t}=0$ this is equivalent to equation 35. With $\epsilon_{s, t}=\epsilon_{s t w, t}, \tau_{V, t}=0$ and thus $\tau_{t}^{v, b}=\tau_{t}^{b}$ and $y_{s t w, t}(\epsilon)=y_{t}(\epsilon), h_{s t w, t}(\epsilon)=h_{t}(\epsilon)$ we get equation 33.

## A. 4 Optimal Steady-State STW Policy without Hours Distortions

By inserting the government constraints into the job-creation and job-destruction condition, we get the following problem of the social planner:

$$
\begin{align*}
W_{t}^{P}=\underset{\theta_{t}, \epsilon_{s, t}, h_{t}(\epsilon), \tau_{s t w a l}^{\text {otal }}}{\arg \max } n_{t} \cdot \int_{\epsilon_{s, t}}^{\infty}\left[y_{t}(\epsilon)\right. & \left.-v\left(h_{t}(\epsilon)\right)\right] \frac{d G(\epsilon)}{1-G\left(\epsilon_{s, t}\right)}  \tag{A.45}\\
& -n_{t} \cdot \frac{G\left(\epsilon_{s, t}\right)}{1-G\left(\epsilon_{s, t}\right)} \cdot F-\theta_{t} \cdot\left(1-n_{t}\right) \cdot k_{v}+\beta \cdot E_{t}\left[W_{t+1}^{P}\right]
\end{align*}
$$

s.t. $\quad(I) \quad n_{t}=\left(1-G\left(\epsilon_{s, t}\right)\right) \cdot\left(n_{t-1}+f\left(\theta_{t-1}\right) \cdot\left(1-n_{t-1}\right)\right)$

$$
\begin{aligned}
& \text { (II) } \begin{array}{c}
\frac{1}{1-\eta_{t}} \frac{k_{v}}{q\left(\theta_{t}\right)}=\beta \cdot E_{t}\left(\int_{\epsilon_{s, t+1}}^{\infty}\left[y_{t+1}(\epsilon)-v\left(h_{t+1}(\epsilon)\right)-\frac{b}{n_{t+1}}\right] d G(\epsilon)\right. \\
\left.\quad+G\left(\epsilon_{s, t+1}\right) \cdot(-F)+\left(1-G\left(\epsilon_{s, t+1}\right)\right) \cdot \frac{1-\eta_{t+1} \cdot \theta_{t+1} \cdot q\left(\theta_{t+1}\right)}{1-\eta_{t+1}} \cdot \frac{k_{v}}{q\left(\theta_{t+1}\right)}\right) \\
(\text { III }) y_{t}\left(\epsilon_{s, t}\right)-v\left(h_{t}\left(\epsilon_{s, t}\right)\right)-\left(\frac{1}{n_{t}}-\frac{1}{1-G\left(\epsilon_{s, t}\right)}\right) \cdot b \\
\quad+\tau_{s t w, t}^{\text {total }}+F+\frac{1-\eta_{t} \cdot \theta_{t} \cdot q\left(\theta_{t}\right)}{1-\eta_{t}} \cdot \frac{k_{v}}{q\left(\theta_{t}\right)}=0
\end{array}
\end{aligned}
$$

For convenience, we optimize over $\tau_{s t w, t}^{t o t a l}$ instead of $\tau_{s t w, t}$ for convenience. Both approaches are equivalent. There is no need to optimize over the eligibility condition $\epsilon_{s t w, t}$ as it does neither influence the job-creation condition nor the job-destruction decision. Just the net-transfer via STW to the least productive matches matters. The corresponding Lagrangian, under the assumption that hours worked are set optimal, is:

$$
\begin{aligned}
\mathcal{L} & =E_{0} \sum_{t=0}^{\infty} \beta^{t} \cdot\left(n_{t} \cdot \int_{\epsilon_{s, t}}^{\infty}\left[y_{t}(\epsilon)-v\left(h_{t}(\epsilon)\right)\right] \frac{d G(\epsilon)}{1-G\left(\epsilon_{s, t}\right)}-n_{t} \cdot \frac{G\left(\epsilon_{s, t}\right)}{1-G\left(\epsilon_{s, t}\right)} \cdot F-\theta_{t} \cdot\left(1-n_{t}\right) \cdot k_{v}\right. \\
- & \lambda_{n, t} \cdot\left(n_{t}-\left(1-G\left(\epsilon_{s, t}\right)\right) \cdot\left(n_{t-1}+\theta_{t-1} \cdot q\left(\theta_{t-1}\right) \cdot\left(1-n_{t-1}\right)\right)\right) \\
- & \lambda_{\theta, t} \cdot\left(\frac{1}{1-\eta_{t}} \frac{k_{v}}{q\left(\theta_{t}\right)}-\beta \cdot E_{t}\left(\int_{\epsilon_{s, t+1}}^{\infty}\left[y_{t+1}(\epsilon)-v\left(h_{t+1}(\epsilon)\right)-\frac{b}{n_{t+1}}\right] d G(\epsilon)\right.\right. \\
& \left.\left.\quad+G\left(\epsilon_{s, t+1}\right) \cdot(-F)+\left(1-G\left(\epsilon_{s, t+1}\right)\right) \cdot \frac{1-\eta_{t+1} \cdot \theta_{t+1} \cdot q\left(\theta_{t+1}\right)}{1-\eta_{t+1}} \cdot \frac{k_{v}}{q\left(\theta_{t+1}\right)}\right)\right) \\
& \left.-\lambda_{\epsilon, t} \cdot\left(y_{t}\left(\epsilon_{s, t}\right)-v\left(h_{t}\left(\epsilon_{s, t}\right)\right)-\left(\frac{1}{n_{t}}-\frac{1}{1-G\left(\epsilon_{s, t}\right)}\right) \cdot b+\tau_{s t w, t}^{t o t a l}+F+\frac{1-\eta_{t} \cdot \theta_{t} \cdot q\left(\theta_{t}\right)}{1-\eta_{t}} \cdot \frac{k_{v}}{q\left(\theta_{t}\right)}\right)\right)
\end{aligned}
$$

FOC for employment:

$$
\begin{aligned}
\frac{\partial}{\partial n_{t}} & =\int_{\epsilon_{s, t}}^{\infty}\left[y_{t}(\epsilon)-v\left(h_{t}(\epsilon)\right)\right] \frac{d G(\epsilon)}{1-G\left(\epsilon_{s, t}\right)}-\frac{G\left(\epsilon_{s, t}\right)}{1-G\left(\epsilon_{s, t}\right)} \cdot F+\theta_{t} \cdot k_{v} \\
& -\lambda_{n, t}+\beta \cdot\left(1-\theta_{t} \cdot q\left(\theta_{t}\right)\right) \cdot E_{t}\left[\lambda_{n, t+1} \cdot\left(1-G\left(\epsilon_{s, t+1}\right)\right)\right]+\lambda_{\theta, t-1} \cdot\left(1-G\left(\epsilon_{s, t}\right)\right) \frac{b}{n_{t}^{2}}-\lambda_{\epsilon, t} \cdot \frac{b}{n_{t}^{2}}
\end{aligned}
$$

FOC for the labor market density:

$$
\begin{align*}
\frac{\partial}{\partial \theta_{t}} & =-\left(1-n_{t}\right) \cdot k_{v}+\beta \cdot\left(1-n_{t}\right) \cdot(1-\gamma) \cdot q\left(\theta_{t}\right) \cdot E_{t}\left[\lambda_{n, t+1} \cdot\left(1-G\left(\epsilon_{s, t+1}\right)\right)\right]  \tag{A.47}\\
& -\frac{1}{1-\eta_{t}} \cdot \frac{k_{v}}{q\left(\theta_{t}\right)} \cdot \gamma \cdot \frac{\lambda_{\theta, t}}{\theta_{t}}+\frac{1}{1-\eta_{t}} \cdot\left(\frac{\gamma}{\theta_{t} \cdot q\left(\theta_{t}\right)}-\eta_{t}\right) \cdot k_{v} \cdot\left(\left(1-G\left(\epsilon_{s, t}\right)\right) \cdot \lambda_{\theta, t-1}-\lambda_{\epsilon, t}\right)
\end{align*}
$$

Rewriting gives:

$$
\begin{equation*}
\beta \cdot E_{t}\left[\lambda_{n, t+1} \cdot\left(1-G\left(\epsilon_{s, t+1}\right)\right)\right]=\left(\frac{1+\chi_{t}}{1-\gamma}\right) \cdot \frac{k_{v}}{q\left(\theta_{t}\right)} \tag{A.48}
\end{equation*}
$$

Where $\chi_{t}$ can be expressed as:

$$
\begin{equation*}
\chi_{t}=\frac{1}{1-n_{t}} \cdot \frac{1}{1-\eta_{t}} \cdot \frac{1}{\theta_{t} \cdot q\left(\theta_{t}\right)} \cdot\left(\gamma \cdot \lambda_{\theta, t}-\left(\gamma-\theta_{t} \cdot q\left(\theta_{t}\right) \cdot \eta_{t}\right) \cdot\left(\left(1-G\left(\epsilon_{s, t}\right)\right) \cdot \lambda_{\theta, t-1}-\lambda_{\epsilon, t}\right)\right) \tag{А.49}
\end{equation*}
$$

The FOC for the separation condition denotes:

$$
\begin{align*}
\frac{\partial}{\partial \epsilon_{s, t}}= & -\frac{n_{t}}{1-G\left(\epsilon_{s, t}\right)} \cdot\left(y_{t}\left(\epsilon_{s, t}\right)-v\left(h\left(\epsilon_{s, t}\right)\right)\right) \cdot g\left(\epsilon_{s, t}\right)  \tag{A.50}\\
& +\frac{n_{t}}{1-G\left(\epsilon_{s, t}\right)} \cdot \int_{\epsilon_{s, t}}^{\infty}\left[y_{t}(\epsilon)-v\left(h_{t}(\epsilon)\right)\right] \frac{d G(\epsilon)}{1-G\left(\epsilon_{s, t}\right)} \cdot g\left(\epsilon_{s, t}\right) \\
& -\frac{n_{t}}{1-G\left(\epsilon_{s, t}\right)} \cdot \frac{F}{1-G\left(\epsilon_{s, t}\right)} \cdot g\left(\epsilon_{s, t}\right) \\
& -\lambda_{n, t} \cdot\left(n_{t-1}+\theta_{t-1} \cdot q\left(\theta_{t-1}\right) \cdot\left(1-n_{t-1}\right)\right) \cdot g\left(\epsilon_{s, t}\right) \\
& -\lambda_{\theta, t-1} \cdot\left(y_{t}\left(\epsilon_{s, t}\right)-v\left(h\left(\epsilon_{s, t}\right)\right)+F-\frac{b}{n_{t}}+\frac{1-\theta_{t} \cdot q\left(\theta_{t}\right) \cdot \eta_{t}}{1-\eta_{t}} \cdot \frac{k_{v}}{q\left(\theta_{t}\right)}\right) \cdot g\left(\epsilon_{s, t}\right) \\
& -\lambda_{\epsilon, t} \cdot\left(y_{t}^{\prime}\left(\epsilon_{t}\right)-h_{t}^{\prime}\left(\epsilon_{s, t}\right) \cdot v^{\prime}\left(h_{t}\left(\epsilon_{s, t}\right)\right)-\frac{g\left(\epsilon_{s, t}\right)}{\left(1-G\left(\epsilon_{s, t}\right)\right)^{2}} \cdot b\right)=0 \\
& =\left(y_{t}\left(\epsilon_{s, t}\right)-v\left(h\left(\epsilon_{s, t}\right)\right)\right)-\int_{\epsilon_{s, t}}^{\infty}\left[y_{t}(\epsilon)-v\left(h_{t}(\epsilon)\right)\right] \frac{d G(\epsilon)}{1-G\left(\epsilon_{s, t}\right)}+\frac{F}{1-G\left(\epsilon_{s, t}\right)} \cdot g\left(\epsilon_{s, t}\right)  \tag{A.51}\\
& +\lambda_{n, t} \\
& +\lambda_{\theta, t-1} \cdot\left(\left(-\frac{1}{1-G\left(\epsilon_{s, t}\right)}\right) \cdot b-\tau_{s t u, t}^{t o t a l}\right) \frac{1-G\left(\epsilon_{s, t}\right)}{n_{t}} \\
& +\lambda_{\epsilon, t} \cdot\left(y_{t}^{\prime}\left(\epsilon_{t}\right)-h_{t}^{\prime}\left(\epsilon_{s, t}\right) \cdot v^{\prime}\left(h_{t}\left(\epsilon_{s, t}\right)\right)-\frac{g\left(\epsilon_{s, t}\right)}{\left(1-G\left(\epsilon_{s, t}\right)\right)^{2}} \cdot b\right) \cdot \frac{1-G\left(\epsilon_{s, t}\right)}{n_{t}} \cdot \frac{1}{g\left(\epsilon_{s, t}\right)}=0 \tag{A.52}
\end{align*}
$$

The FOC for the total net-transfer of STW to the least productive firms gives:

$$
\begin{equation*}
\frac{\partial}{\partial \tau_{s t w, t}^{t o t a l}}=-\lambda_{\epsilon, t}=0 \tag{A.54}
\end{equation*}
$$

Since $\epsilon_{\epsilon, t}=0$ we can infer that the STW subsidy can implement the optimal number of separations.

Inserting the FOC for the labor market density into the FOC for employment gives the optimal vacancy posting decision:

$$
\begin{array}{r}
\frac{1}{1-\gamma} \cdot \frac{\left(1+\chi_{t}\right) \cdot k_{v}}{q_{t}}=  \tag{A.55}\\
\beta \cdot E_{t}\left[\int_{\epsilon_{s, t+1}}^{\infty}\left[y_{t+1}(\epsilon)-v\left(h_{t+1}(\epsilon)\right)+\lambda_{\theta, t} \cdot\left(1-G\left(\epsilon_{s, t}\right)\right) \cdot \frac{b_{t}}{n_{t}^{2}}\right] d G(\epsilon)+G\left(\epsilon_{s, t+1}\right) \cdot(-F)\right] \\
+\beta \cdot E_{t}\left[\left(1-G\left(\epsilon_{s, t+1}\right)\right) \cdot \frac{1-\gamma \cdot f_{t+1}+\left(1-f_{t+1}\right) \cdot \chi_{t+1}}{1-\gamma} \cdot \frac{k_{v}}{q_{t+1}}\right]
\end{array}
$$

Subtracting the decentralized job-creation condition from the optimal job-creation condition gives us an expression of how the two inefficiencies in the economy influence the job-creation decision and helps us to determine $\lambda_{\theta, t}$, that is the Lagrange-Multiplies, respectively the influence of a larger labor-market density on welfare:

$$
\begin{array}{r}
\left(\chi_{t}-\frac{\eta_{t}-\gamma}{1-\eta_{t}}\right) \cdot \frac{1}{1-\gamma} \cdot \frac{k_{v}}{q_{t}}=\beta \cdot E_{t}\left[b+\left(1-G\left(\epsilon_{s, t+1}\right)\right) \cdot\left(\tau_{t+1}^{v, b}+\lambda_{\theta, t+1} \cdot \frac{b_{t}}{n_{t}^{2}}\right)\right]  \tag{A.56}\\
+\beta \cdot E_{t}\left[\left(1-G\left(\epsilon_{s, t+1}\right)\right) \cdot\left(1-f_{t+1}\right) \cdot\left(\chi_{t+1}-\frac{\eta_{t+1}-\gamma}{1-\eta_{t+1}}\right) \cdot \frac{1}{1-\gamma} \cdot \frac{k_{v}}{q_{t+1}}\right]
\end{array}
$$

In Steady-State we get:

$$
\begin{equation*}
\left(\chi-\frac{\eta-\gamma}{1-\eta}\right) \cdot \frac{1}{1-\gamma} \cdot \frac{k_{v}}{q}=\beta \cdot \frac{b+\left(1-G\left(\epsilon_{s}\right) \cdot\left(\tau^{b}+\frac{b}{n^{2}}\right)\right.}{1-\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-f)} \tag{A.57}
\end{equation*}
$$

Inserting the FOC of the labor market density and the FOC for separation into the FOC for employment gives the optimal separation condition:

$$
\begin{array}{r}
y_{t}\left(\epsilon_{s, t}\right)-v\left(h_{t}\left(\epsilon_{s, t}\right)\right)+\lambda_{\theta, t-1}\left[-\frac{1}{1-G\left(\epsilon_{t}\right)} \cdot b_{t}-\tau_{s t w, t}^{t o t a l}\right] \cdot \frac{1-G\left(\epsilon_{s, t}\right)}{n_{t}}+\lambda_{\theta, t-1} \cdot \frac{1-G\left(\epsilon_{s, t}\right)}{n_{t}^{2}} \cdot b_{t} \\
F+\frac{1-\gamma \cdot f_{t}+\left(1-f_{t}\right) \cdot \chi_{t}}{1-\gamma} \cdot \frac{k_{v}}{q_{t}}=0 \tag{A.58}
\end{array}
$$

Subtracting the decentralized separation condition from the optimal separation condition allows us to derive an expression for the optimal net-transfer of STW to the least-productive firms:

$$
\begin{align*}
& \tau_{s t w, t}^{\text {total }}=\left(\frac{1}{n_{t}}-\frac{1}{1-G\left(\epsilon_{s, t}\right)}\right) \cdot b+\lambda_{\theta, t-1}\left[-\frac{1}{1-G\left(\epsilon_{t}\right)} \cdot b_{t}-\tau_{s t w, t}^{\text {total }}\right] \cdot \frac{1-G\left(\epsilon_{s, t}\right)}{n_{t}} \\
& +\lambda_{\theta, t-1} \cdot \frac{1-G\left(\epsilon_{s, t}\right)}{n_{t}^{2}} \cdot b_{t}+\left(1-G\left(\epsilon_{s, t}\right)\right) \cdot\left(1-f_{t}\right) \cdot\left(\chi_{t}-\frac{\eta_{t}-\gamma}{1-\eta_{t}}\right) \cdot \frac{1}{1-\gamma} \cdot \frac{k_{v}}{q_{t}} \tag{A.59}
\end{align*}
$$

With equation A. 57 we get in the steady-state for the net-transfers of the STW subsidy:

$$
\begin{aligned}
& \tau_{\text {stw }}^{\text {total }}=\lambda_{\theta}\left[\left(-\frac{1}{1-G\left(\epsilon_{t}\right)}\right) \cdot b_{t}-\tau_{s t u, t}^{\text {total }}\right] \\
&+\frac{1-G\left(\epsilon_{s}\right)}{n} \\
&+\frac{1}{1-\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-f)} \cdot\left(\tau^{v, b}+\lambda_{\theta} \cdot \frac{1-G\left(\epsilon_{s}\right)}{n^{2}} \cdot b\right) \\
& 1-\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-f) \\
&
\end{aligned}
$$

## A. 5 Optimal Steady-State Policy Mix without Hours Distortions

## Vacancy Subsidy:

Subtract the job-creation condition from the decentralized economy (equation A.43) without hours distortions $h_{\text {stw,t }}(\epsilon)=h_{t}(\epsilon)$ from equation of the planner equivalent (equation 29):

$$
\begin{align*}
& \frac{1}{1-\gamma} \cdot \frac{k_{v}}{q_{t}}-\frac{1-\tau_{V, t}}{1-\eta_{t}} \cdot \frac{k_{v}}{q_{t}}=  \tag{A.61}\\
& \beta \cdot E_{t}\left[\int_{\epsilon_{s, t+1}}^{\infty}\left[y_{t+1}(\epsilon)-v\left(h_{t+1}(\epsilon)\right)\right] d G(\epsilon)+G\left(\epsilon_{s, t+1}\right) \cdot(-F)\right] \\
& +\beta \cdot E_{t}\left[\left(1-G\left(\epsilon_{s, t+1}\right)\right) \cdot \frac{1-\gamma \cdot f_{t+1}}{1-\gamma} \cdot \frac{k_{v}}{q_{t+1}}\right] \\
& -\beta \cdot E_{t}\left[\int_{\epsilon_{s, t+1}}^{\infty}\left[y_{t+1}(\epsilon)-v\left(h_{t+1}(\epsilon)\right)-\tau_{t+1}^{v, b}\right] d G(\epsilon)-b+G\left(\epsilon_{s, t+1}\right) \cdot(-F)\right] \\
& -\beta \cdot E_{t}\left[\left(1-G\left(\epsilon_{s, t+1}\right)\right) \cdot \frac{1-\eta_{t+1} \cdot f_{t+1}}{1-\eta_{t+1}} \cdot\left(1-\tau_{V, t+1}\right) \frac{k_{v}}{q_{t+1}}\right]
\end{align*}
$$

This is equivalent to:

$$
\begin{align*}
& \left(\tau_{V, t}-\frac{\eta_{t}-\gamma}{1-\gamma}\right) \cdot \frac{1}{1-\eta_{t}} \cdot \frac{k_{v}}{q_{t}}=\beta \cdot E_{t}\left[b+\left(1-G\left(\epsilon_{s, t+1}\right)\right) \cdot \tau_{t+1}^{v, b}\right]  \tag{A.62}\\
& +\beta \cdot E_{t}\left[\left(1-G\left(\epsilon_{s, t+1}\right)\right) \cdot\left(\left(\left(1-\eta_{t+1} \cdot f_{t+1}\right) \cdot \tau_{V, t+1}-\left(1-f_{t+1}\right) \cdot \frac{\eta_{t}-\gamma}{1-\gamma}\right) \cdot \frac{1}{1-\eta_{t+1}} \cdot \frac{k_{v}}{q_{t+1}}\right)\right]
\end{align*}
$$

Assuming the system is in steady-state, we can rearrange the equation to:

$$
\begin{align*}
& \left(1-\beta \cdot\left(1-G\left(\epsilon_{s}\right) \cdot(1-\eta \cdot f)\right)\right) \cdot \tau_{V} \cdot \frac{k_{v}}{q}=  \tag{A.63}\\
& \beta \cdot(1-\eta) \cdot\left(\left(1-G\left(\epsilon_{s}\right)\right) \cdot \tau^{v, b}+b\right)+\left(1-\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-f)\right) \cdot \frac{\eta-\gamma}{1-\gamma} \cdot \frac{k_{v}}{q}
\end{align*}
$$

Solving for $\tau_{V}$ gives:

$$
\begin{align*}
\tau_{V} & =\frac{\beta \cdot(1-\eta)}{1-\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-\eta \cdot f)} \cdot\left(\left(1-G\left(\epsilon_{s}\right)\right) \cdot \tau^{v, b}+b\right) / \frac{k_{v}}{q}  \tag{A.64}\\
& +\frac{1-\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-f)}{1-\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-\eta \cdot f)} \cdot \frac{\eta-\gamma}{1-\gamma}
\end{align*}
$$

This is equivalent to equation 46.

## Net Benefits of STW:

Subtract the separation equation of the decentralized economy (equation 45) without hours
distortion $\left(h_{s t w, t}(\epsilon)=h_{t}(\epsilon)\right)$ from the equation of the planner economy (equation 30):

$$
\begin{align*}
& y_{t}\left(\epsilon_{s, t}\right)-v\left(h_{t}\left(\epsilon_{s, t}\right)\right)+F+\frac{1-\gamma \cdot f_{t}}{1-\gamma} \cdot \frac{k_{v}}{q_{t}}  \tag{A.65}\\
& -y_{t}\left(\epsilon_{s, t}\right)+v\left(h_{t}\left(\epsilon_{s, t}\right)\right)-F+\tau_{t}^{v, b}-\tau_{s t w, t}^{t o t a l}-\frac{1-\eta_{t} \cdot f_{t}}{1-\eta_{t}} \cdot\left(1-\tau_{V, t}\right) \cdot \frac{k_{v}}{q_{t}}=0
\end{align*}
$$

This is equivalent to:

$$
\begin{equation*}
\tau_{s t u, t}^{t o t a l}=\tau_{t}^{v, b}-\frac{\eta_{t}-\gamma}{(1-\gamma) \cdot\left(1-\eta_{t}\right)} \cdot\left(1-f_{t}\right) \cdot \frac{k_{v}}{q_{t}}+\frac{1-\eta_{t} \cdot f_{t}}{1-\eta_{t}} \cdot \tau_{V, t} \cdot \frac{k_{v}}{q_{t}} \tag{A.66}
\end{equation*}
$$

Assuming the system is in steady-state, we can insert the optimal vacancy subsidy:

$$
\begin{align*}
\tau_{s t w}^{\text {total }} & =\tau^{v, b}-\frac{1-f}{1-\eta} \cdot \frac{\eta-\gamma}{1-\gamma} \cdot \frac{k_{v}}{q}  \tag{А.67}\\
& +\frac{1-\eta \cdot f}{1-\eta} \cdot \frac{\beta \cdot(1-\eta)}{1-\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-\eta \cdot f)} \cdot\left(\left(1-G\left(\epsilon_{s}\right)\right) \cdot \tau^{v, b}+b\right) \\
& +\frac{1-\eta \cdot f}{1-\eta} \cdot \frac{1-\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-f)}{1-\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-\eta \cdot f)} \cdot \frac{\eta-\gamma}{1-\gamma} \cdot \frac{k_{v}}{q}
\end{align*}
$$

Rearranging gives:

$$
\begin{align*}
\tau_{s t w}^{\text {total }} & =\frac{1}{1-\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-\eta \cdot f)} \cdot \tau^{v, b}  \tag{A.68}\\
& +\frac{\beta \cdot(1-\eta \cdot f)}{1-\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-\eta \cdot f)} \cdot b \\
& +\frac{\eta}{1-\beta \cdot\left(1-G\left(\epsilon_{s}\right)\right) \cdot(1-\eta \cdot f)} \cdot \frac{\eta-\gamma}{1-\gamma} \cdot \frac{k_{v}}{q}
\end{align*}
$$

This is equivalent to equation 47.


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[^1]:    ${ }^{1}$ We use wages in the sense of monthly wages, that is, the wage-sum a worker gets for one month of work.
    ${ }^{2}$ This mirrors the fact that most OECD countries already provide UI benefits that might distort the economy.
    ${ }^{3}$ Wage-rigidities are empirically well documented (see, for instance, Taylor 1999, Barattieri 2014 or Durant et al. 2012) and often used to replicate the labor market volatility observed in the data (see, for instance, Shimer 2005, Hall 2005 or Costain and Reiter 2008).
    ${ }^{4}$ Both papers analyze, among others, the optimal provision of UI benefits over the business cycle. In incomplete markets, UI benefits insure workers against income fluctuations at the cost of distorting vacancy posting, search, and separation incentives. They find that UI benefits should be adjusted pro-cyclical.

[^2]:    ${ }^{5}$ Having persistent idiosyncratic shocks, we would need a state vector to keep track of the productivity distribution of the firms. This would make computing Ramsey policy very difficult.

[^3]:    ${ }^{6}$ Note that the cost shock of the firm is important, if we want to have a realistic impact of the UI system on unemployment, endogenous separations and feature time-independent idiosyncratic shocks for analytical tractability. It is a well-known problem that search and matching models overstate the importance of the UI system (see Costain and Reiter (2008)). To have a sensible impact of the UI system, we need a large surplus calibration. The bigger the surplus, the smaller the relative impact of a change of UI benefits. However, large surpluses lead to a small separation incentives. Since the cost shock has an expectation value of zero it allows for a large surplus calibration. At the same time, it affects the marginal firms the most, allowing for endogenous separations.

[^4]:    ${ }^{7}$ Derivations of the optimality conditions implied by the Nash-Bargaining can be found in the appendix in section A.2.

[^5]:    ${ }^{8}$ The derivations of the optimality conditions of the planner can be found in the appendix in section A.1.

[^6]:    ${ }^{9}$ Wesselbaum (2010) finds that separation costs in the US are around $30 \%$ of the quarterly wage. This is consistent with our parameter value.

[^7]:    ${ }^{10}$ The Derivation can be found in the Appendix under section A.5.

