# Optimal Labor-Market Policy in Recessions

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*Within a search and matching model with risk-averse workers, endogenous hiring and separation, and unobservable search effort, we show how to decentralize the constrained-efficient allocation by a combination of a production tax and three labor-market policy instruments: vacancy subsidies, layoff taxes and unemployment benefits. We derive analytical expressions for the optimal mix of these over the business cycle. Calibrating the model to the U.S. economy under the assumption that wages are rigid, we find that hiring subsidies and layoff taxes should rise considerably and persistently in recessions. The optimal variation in unemployment benefits, in contrast, is quantitatively small and short-lived.*
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Unemployment in the U.S. has risen sharply in the wake of the Great Recession and has been falling only slowly thereafter. Policymakers have reacted to this by increasing the generosity of unemployment insurance benefits. In addition, instruments that are less standard, for example, hiring subsidies, have been discussed intensively and have been enacted in stimulus packages. A case in point is the Hiring Incentives to Restore Employment (HIRE) Act that President Obama signed into law on March 18, 2010.[1] Little work exists, however, that actually quantifies the optimal labor-market policy mix over the business cycle.

This paper computes the optimal labor-market policy mix in a real business cycle model with Mortensen and Pissarides-type (1994) matching frictions in the labor market. The model features two potential reasons for the government to intervene in the labor market, both of which shape the optimal policy mix. First, we allow for deviations from the Hosios (1990) condition through a countercyclical bargaining power of firms. This yields a theory in which, from society's perspective, wages in recessions can be too high, causing too many separations and too

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[1] Similarly, payroll subsidies have been used in other countries in the latest recession, a prominent example being the German short-time working scheme (Kurzarbeit).

little hiring. As a consequence, unemployment rises to socially inefficient levels. Second, we assume that workers are risk-averse, do not have savings, and provide a search effort that is private information. The government, thus, has to trade off insurance and moral hazard. In a decentralized economy, the insurance also affects the employed workers' outside option and wages, meaning it can distort hiring and separation decisions. The optimal labor-market policy weighs these distortions and the government's role in helping to smooth income fluctuations.

We first characterize the planner's allocation when the planner cannot observe a worker's search effort. We then prove that an appropriate mix of vacancy subsidies, layoff taxes, and unemployment benefits along with a production tax can decentralize this constrained-efficient allocation. We provide analytical expressions for the optimal tax and benefit policies in the steady state and over the business cycle.

Next, we calibrate the model to the U.S. economy. The calibration entails considerable wage rigidity in order to match the amplitude of labor-market fluctuations observed in the data. The wage rigidity-induced fluctuations in unemployment are socially inefficient. This is so irrespective of the degree of risk aversion on the side of workers. According to the model, these rigidities are the dominant force in shaping the cyclical properties of the policy prescriptions. Optimal policy first and foremost reduces the fluctuations in unemployment. This is achieved by the vacancy subsidies and layoff taxes. Once unemployment has been stabilized, quantitatively there is little need for varying the generosity of unemployment insurance in response to fluctuations in output – even if workers are risk-averse.

Quantitatively, we find that in response to a negative 1 percent productivity shock the government should subsidize an additional 8 percent of the cost of posting a vacancy. At the same time, the optimal increase in layoff taxes amounts to almost 20 percent of a monthly unemployment benefit payment. Once these two policies are implemented, the government would want to adjust unemployment insurance in bad times only very little. We find that the ratio of consumption when unemployed relative to consumption when employed (which in our model is equal to the replacement rate given the restriction on saving) should rise by 0.2 percentage point in response to a negative 1 percent productivity shock. This increase is not only small, but also much more short-lived than the responses of the two aforementioned labor-market instruments.

In deriving these results, we make a number of simplifying assumptions. Specifically, the firm cannot insure the worker beyond a one-time severance payment. In addition, the government can condition its payments on a worker's current state of employment, but not his entire unemployment history. Last, we assume that the worker cannot save. These assumptions mean that, in the steady state, we overstate the insurance role of the unemployment benefit system; for example, see Shimer and Werning (2008). Our findings suggest, however, that the assumptions may be of lesser importance for the cyclical properties of the benefit system. In particular, our main result is that even with our stark assumptions there is little role for strongly countercyclical unemployment insurance once vacancy subsidies and layoff taxes are used appropriately in the optimal policy mix.

Two recent papers are also concerned with labor-market policy over the business cycle: Landais, Michaillat and Saez (2010) and Mitman and Rabinovich (2011). These two studies restrict themselves to just one instrument: unemployment benefits. In our setup, if unemployment benefits were the only instrument, the government not being able to vary layoff taxes or hiring subsidies in response to the recessionary shock, the government would use unemployment insurance to generate more flexibility in wages and thus less fluctuation in employment. We show numerically that, in this case, the government would opt for steep cuts in benefits in a recession: The replacement rate would then fall by almost 1 percentage point in response to a fall in productivity of 1 percent. This cut, which is reminiscent of the results in Mitman and Rabinovich (2011), reduces the workers' outside option and leads to more hiring and fewer separations at the cost of reduced insurance for the unemployed. The availability of the other instruments renders such a reaction unnecessary and inferior, the intuition being that hiring subsidies and layoff taxes are a cheaper way for the government to restore efficiency because they act directly on the probabilities of finding or losing a job, rather than varying the degree of insurance in economic downturns.

Landais, Michaillat and Saez (2010) find that unemployment benefits should rise considerably in recessions. The reason is as follows: wages in their model economy are not only rigid but, by assumption, they are also not affected by labor-market policy. Absent instruments other than unemployment benefits, the government cannot easily stimulate hiring. Regardless of what happens to benefits, workers have a hard time finding jobs. Moral hazard considerations thus lose importance, leading the government to provide more generous insurance. In our economy we also allow recessions to reduce the incidence of moral hazard. However, the government has instruments at hand to counteract the underlying frictions more directly, namely, vacancy subsidies and layoff taxes. Therefore, these instruments mirror the persistence of the recessionary shock. Once they have ensured that new jobs no longer are hard to come by, moral hazard remains an important concern for the government. As a result, the rise in benefits that we find is small and rather short-lived.

The remainder of this paper is organized as follows. The next section relates our work to the existing literature. Section I presents the model and the planner's problem. Section II provides the tax and benefit rules that decentralize the planner's allocation. We use these as a basis for providing intuition for the numerical simulations that follow in later sections. Section III presents the calibration of the model economy. Section IV discusses the optimal policy mix both in the steady state and over the business cycle. A final section concludes. The online appendix collects the proofs and derivations.

### A. Related literature

To the best of our knowledge, our paper is the first that focuses on the jointly optimal design of a wider set of labor-market policies over the business cycle in an environment with a genuine role for unemployment insurance. Various strands of the literature, though, have studied each of the instruments in isolation either in the steady state or in a business cycle context.

One strand has studied the impact of tax instruments on the congestion and thick-market externalities that can arise with matching frictions (Hosios, 1990 and Domeij, 2005), or has analyzed the distortive effects of tax instruments on the wage-setting and hiring process (Mortensen and Pissarides, 2003). We add to this a potentially welfare-improving role for unemployment benefits. In our framework the lack of insurance of risk-averse workers due to moral hazard induces further distortions. Therefore, the government requires a rather rich set of instruments to exactly restore the constrained-efficient allocation.

A second strand of the literature studies the optimal provision of unemployment insurance in the presence of moral hazard frictions, for example, Shavell and Weiss (1979), Hopenhayn and Nicolini (1997), Wang and Williamson (2002), and Shimer and Werning (2007, 2008), who present results in the steady state. This literature typically shows that the consumption profile of unemployed workers has to decline with the duration of unemployment. For analytical tractability, our approach abstracts from savings and assumes that consumption allocations are independent of durations. Benefits then are characterized by a dynamic version of the Chetty (2006) formula.

The literature has typically ignored the interaction of matching frictions with the design of optimal unemployment benefits. An exception is Coles (2008), who studies the optimal duration-dependent unemployment benefit provision in a matching equilibrium with unobservable search effort. Coles focuses on a steady state without discounting and gives the government access to vacancy subsidies. He finds, as we do, a positive role for vacancy subsidies in decentralizing the constrained-efficient allocation. We extend Coles' work by analytically characterizing the optimal tax rules over the business cycle in a general equilibrium labor-market search model that has an endogenous separation margin.

A third strand of the literature studies the role of layoff taxes. In a number of variants of a static model, Blanchard and Tirole (2008) and Cahuc and Zylberberg (2008) consider how layoff taxes can realign social and private costs. Without layoff taxes, firms do not take into account that their layoff decision affects the budget constraint of the government, so separations are typically larger than is socially optimal. They find that the first-best allocation can be achieved by unemployment benefits financed entirely by layoff taxes. We extend their results in several dimensions: first, to the business cycle; second, to an environment with an endogenous hiring decision; and third, to a model with an unobservable search decision that interacts with the hiring and layoff decision.[2]

## I. Model economy and the planner's problem

This section lays the groundwork for the optimal policy results in the paper. The section proceeds in small steps. First, we describe the technological constraints of the economy. Then, we formulate the planner's problem. Last, we describe the decentralized economy. In doing so, we focus on the government's instruments, the firms' hiring decisions and the bargaining between the firm and the worker.

Throughout, we impose two constraints on the information available to the government (and the planner). These constraints are reflected in the exposition of the model below. First, we assume that only the individual worker can observe his own search decision, giving rise to the moral hazard-insurance tradeoff. Second, we assume that the planner can condition consumption allocations only on a worker's state of employment in the current period, not on the worker's entire employment history. The same restriction applies to the government's ability to make payments to workers in the decentralized economy. While the latter assumption ensures analytical tractability, it is restrictive relative to earlier work in the literature, for example, Hopenhayn and Nicolini (1997) or Shimer and Werning (2008), and most likely biases the policy prescriptions toward too large a role of the state in providing unemployment insurance.

### *A. Technological constraints of the model economy*

The economy is populated by a continuum of workers with measure one and an infinite measure of potential one-worker firms. Workers are homogeneous in regard to their *ex ante* efficiency of working. Firms produce a homogeneous good that cannot be stored. We consider a closed economy. The last two assumptions combined limit the planner's ability to insure its population against aggregate shocks. Time is discrete.

Labor market flows. — We denote the measure of workers who are employed at the *beginning* of period $t$ by $e_t$ and the measure of workers who are unemployed at the beginning of the period by $u_t$, so that $u_t = 1 - e_t$. Employment at the beginning of the next period evolves according to

$$e_{t+1} = (1 - \xi_t)e_t + m_t, \tag{1}$$

[2]We find a welfare-improving role for layoff taxes. This differs from a large set of the literature that assesses the effects of labor market policies in environments in which – in contrast to our model – there is little scope for a welfare-improving government intervention. With regard to layoff taxes, see, for example, Hopenhayn and Rogerson (1993) and Ljungqvist (2002), who are concerned with the steady state, and Veracierto (2008), who considers the effects of employment protection on the business cycle.

where $m_t$ are new firm-worker matches formed in period $t$. $\xi_t$ is the rate of separation of existing firm-worker matches. A worker can be recruited only through the posting of a vacancy at a resource cost of $\kappa_v > 0$. Let $v_t$ be the number of vacancies. New matches are created according to the matching function

$$m_t = \chi\, v_t^{\gamma} \left([\xi_t e_t + u_t] s_t\right)^{1-\gamma}. \tag{2}$$

The term in parentheses is explained as follows. The mass of workers who are potentially searching during period $t$ equals $\xi_t e_t + u_t$. That mass comprises the workers laid off at the beginning of the period, $\xi_t e_t$, and the mass of workers who entered the period unemployed, $u_t$. $s_t$ is the share of these workers who search for a job. Parameter $\chi > 0$ governs the matching-efficiency, and $\gamma \in (0, 1)$ is the elasticity of matches with respect to vacancies.

For subsequent use, we define labor-market tightness as $\theta_t := v_t/([\xi_t e_t + u_t] s_t)$, and the job-finding rate as $f_t := m_t/([\xi_t e_t + u_t] s_t)$.

CONSUMPTION, VALUE OF THE WORKER AND SEARCH. — Workers are risk-averse and have period utility functions $\mathtt{u} : \mathbb{R} \to \mathbb{R}$ that are twice continuously differentiable, strictly increasing and concave in the period's consumption level. $\beta \in (0, 1)$ is the time-discount factor. Workers who are not employed enjoy an additive utility of leisure $\overline{h}$. Workers employed throughout period $t$ consume $c_{e,t}$. Workers who are employed at the beginning of $t$ but whose match is severed in $t$ consume $c_{0,t}$. Workers who enter the period unemployed consume $c_{u,t}$.

*Value of an employed worker*

The value of an employed worker at the beginning of the period, before idiosyncratic shocks are realized, then is

$$V_{e,t} = \quad (1 - \xi_t)\left[\mathtt{u}(c_{e,t}) + \beta \mathbb{E}_t V_{e,t+1}\right] + \xi_t V_{0,t}. \tag{3}$$

Here $\xi_t$ marks the probability that the match separates in the course of the period. If the match does not separate, the worker consumes $c_{e,t}$ and the match continues into $t + 1$. $\mathbb{E}_t$ marks the expectation operator. $V_{0,t}$ is the value in $t$ of a worker who has just been laid off. Apart from the consumption stream in the first period, this value is the same as $V_{u,t}$, the value of a worker who enters the period unemployed: $V_{0,t} = V_{u,t} + \mathtt{u}(c_{0,t}) - \mathtt{u}(c_{u,t})$. The value $V_{u,t}$ will be explained in detail below. For now it suffices to define the surplus of the currently employed worker from employment, namely, $\Delta^{e}_{u,t} := V_{e,t} - V_{u,t}$.

*Value of an unemployed worker and search*

Unemployed workers need to actively search in order to find a job. Search is a 0-1 decision. Workers are differentiated by their utility cost of search, $\iota_i \sim F_\iota(0, \sigma_\iota^2)$. For tractability, these costs are independently and identically distributed both across workers and across time. $F_\iota(0, \sigma_\iota^2)$ marks the logistic distribution with mean 0 and variance $\sigma_\iota^2 := \pi \frac{\psi_s^2}{3}$, where a lower-case $\pi$ refers to the mathematical constant. All workers whose disutility of search falls below a certain cutoff value $\iota_t^s$ do search for a job. For the worker who is just at the cutoff value, the utility cost of search just balances with the expected gain from search:

$$\iota_t^s = f_t \, \beta \, \mathbb{E}_t \left[ \Delta_{u,t+1}^e \right]. \tag{4}$$

The gain from search is the discounted increase in utility when employed in the next period rather than unemployed multiplied by the probability, $f_t$, that a searching worker will find a job.

Using the properties of the logistic distribution, $s_t$, the share of unemployed workers who search is given by

$$s_t = Prob(\iota \leq \iota_t^s) = 1/\left(1 + \exp\left\{-\iota_t^s/\psi_s\right\}\right). \tag{5}$$

The value of an unemployed worker *ex ante*, that is, before the search preference shock has realized, is given by

$$\begin{aligned} V_{u,t} \quad = \quad & \mathrm{u}(c_{u,t}) + \overline{h} \\ & + \int_{-\infty}^{\iota_t^s} \left[ -\iota_i + f_t \, \beta \mathbb{E}_t V_{e,t+1} + (1 - f_t) \beta \mathbb{E}_t V_{u,t+1} \right] dF_\iota(\iota_i) \\ & + \int_{\iota_t^s}^{\infty} \beta \mathbb{E}_t V_{u,t+1} dF_\iota(\iota_i). \end{aligned} \tag{6}$$

Regardless of his own search decision, in the current period the unemployed worker receives consumption $c_{u,t}$ and enjoys utility of leisure $\overline{h}$. If the worker decides to search (second row), he suffers utility cost $\iota_i$. Compensating for this, with probability $f_t$ the worker will find a job. In that case, the worker's value at the beginning of the next period will be $V_{e,t+1}$. With probability $(1 - f_t)$ the worker remains unemployed, in which case the worker's value at the beginning of the next period will be $V_{u,t+1}$. If the worker does not search (third row), the worker will continue to be unemployed in the next period.

Production and separation. — Each firm $j$ that enters the period matched to a worker can either produce or separate from the worker. Production entails a firm-specific resource cost, $\epsilon_j$. For analytical tractability, we specify this as a shock that is independently and identically distributed across both matches and time, $\epsilon_j \sim F_\epsilon(\mu_\epsilon, \sigma_\epsilon^2)$. $F_\epsilon(\cdot, \cdot)$ marks the logistic distribution with mean $\mu_\epsilon$ and variance $\sigma_\epsilon^2 = \pi \frac{\psi_\epsilon^2}{3}$. The firm separates from the worker and avoids paying the resource cost whenever the idiosyncratic cost shock, $\epsilon_j$, is larger than a threshold $\epsilon_t^\xi$. Using the properties of the logistic distribution, conditional on the threshold, the separation rate can be expressed as

$$\xi_t = Prob(\epsilon_j \geq \epsilon_t^{\xi}) = 1/\left(1 + \exp\left\{(\epsilon_t^{\xi} - \mu_\epsilon)/\psi_\epsilon\right\}\right). \tag{7}$$

Each firm-worker match that does not separate, produces an amount $\exp\{a_t\}$ of output. Total production in the economy therefore is given by

$$y_t = e_t(1 - \xi_t)\exp\{a_t\}, \tag{8}$$

where $e_t(1 - \xi_t)$ is the mass of existing matches that are not separated in $t$. Aggregate productivity, $a_t$, evolves according to

$$a_t = \rho_a\, a_{t-1} + \varepsilon_{a,t}, \quad \rho_a \in [0, 1),\ \varepsilon_{a,t} \sim N(0, \sigma_a^2).$$

Output is used for consumption, production costs, and vacancy posting:

$$y_t = e_t c_{e,t} + u_t c_{u,t} + e_t \int_{-\infty}^{\epsilon_t^{\xi}} \epsilon\, dF_\epsilon(\epsilon) + \kappa_v v_t. \tag{9}$$

### B. *The planner's problem*

We consider a utilitarian planner who gives equal weight to all workers. Since consumption in the period of separation, $c_{0,t}$, does not affect the search incentives of a worker who was just laid off, the planner will provide such a worker with full insurance. In formulating the planner's problem, we anticipate this result and set $c_{0,t} = c_{e,t}$. There are three states in the planner's problem: aggregate technology, $a_t$, the stock of workers who are employed at the beginning of the period, $e_t$, and the (state-contingent) value of the utility difference from working, $\Delta_{u,t}^e$, that the planner had promised for $t$ to the worker who searched in $t - 1$.[3]

Using the assumptions laid out above, and using the properties of the logistic distribution, the planner's objective can be written as

(10)

$$\begin{aligned} \mathtt{W}_t = \max_{\xi_t, \theta_t, c_{e,t}, c_{u,t}, \{\Delta_{u,t+1}^e\}} \quad & e_t \mathtt{u}(c_{e,t}) + u_t \mathtt{u}(c_{u,t}) + (e_t \xi_t + u_t)(\Psi_s(s_t) + \overline{h}) \\ & + \beta E_t \mathtt{W}_{t+1} \end{aligned}$$

s.t.

[3]Recall from equation (4) that the expected utility difference governs the search decision.

$$
\begin{aligned}
e_{t+1} &= e_t(1-\xi_t) + (\xi_t e_t + u_t) s_t \chi \theta_t^{\gamma}, \\
e_t &= 1 - u_t, \\
s_t &= \left(1 + \exp\left\{\frac{-\chi\theta_t^{\gamma}\beta\mathbb{E}_t\Delta^e_{u,t+1}}{\psi_\iota}\right\}\right)^{-1}, \\
\Delta^e_{u,t} &= \mathtt{u}(c_{e,t}) - \overline{h}(1-\xi_t) - \mathtt{u}(c_{u,t}) + \beta\mathbb{E}_t(1-\xi_t)\Delta^e_{u,t+1} \\
&\quad + (1-\xi_t)\psi_s \log(1-s_t), \\
e_t(1-\xi_t)\exp\{a_t\} &= e_t c_{e,t} + u_t c_{u,t} + e_t(1-\xi_t)\mu_\epsilon - e_t \Psi_\xi(\xi_t) \\
&\quad + (e_t\xi_t + u_t) s_t \theta_t \kappa_v, \\
a_t &= \rho_a\, a_{t-1} + \varepsilon_{a,t},\ \varepsilon_{a,t} \sim N(0, \sigma_a^2).
\end{aligned}
$$

The first term on the right-hand side of the objective is the consumption-related utility of employed workers, and the second term is the consumption-related utility of unemployed workers. The third term refers to the value of leisure and the utility costs of search.[4] The final term is the continuation value.

The planner maximizes over separations, $\xi_t$ (understanding that this implicitly defines the separation cutoff $\epsilon_t^{\xi}$), market tightness, $\theta_t$, and consumption levels $c_{e,t}$ and $c_{u,t}$ for those who, respectively, are employed and unemployed at the beginning of the period. In addition, the planner maximizes over promised utility differences for the next period, $\{\Delta^e_{u,t+1}\}$. The latter are contingent on the future state of the economy.

The first two constraints are, respectively, the aggregate laws of motion of employment and unemployment. The third constraint is the incentive constraint that is formed by merging the search conditions (4) and (5). Here, we have replaced the job-finding rate by $\chi\theta_t^{\gamma}$, in line with the matching technology. Key to inducing search effort is the planner's promise of an increase in utility when a worker moves from unemployment to employment. The fourth constraint, interpretable as a promise-keeping constraint, describes the evolution of this utility difference. Last, the planner is bound by the aggregate resource constraint that equates the right-hand sides of (8) and (9), and by the law of motion of the aggregate productivity shock.

Appendix A provides the first-order conditions of the planner's problem that characterize the constrained-efficient allocation.

### C. *Decentralized economy*

Next, we turn to the decentralized economy in which employment-related decisions are taken by firms and workers. We make two additional simplifying assumptions. First, the firm lacks commitment and cannot insure the worker beyond a one-time severance payment. Second, we assume that the worker cannot save.

Unemployment benefits then provide the only means of insuring against a persistent unemployment spell.[5] At the same time, however, these benefits distort

[4]Here $\Psi_s(s_t) := -\psi_s\left[(1-s_t)\,\log(1-s_t) + s_t\log(s_t)\right]$. $\Psi_\xi(\xi_t)$, which is used further below, is defined in an analogous manner.

[5]These restrictions on the contracting and savings opportunities along with entertaining risk-averse

the workers' search decisions, and through their effect on the wage and the search intensity, they also affect the firms' employment decisions. The government has access to two other labor-market instruments that can address these distortions: it can tax layoffs by $\tau_{\xi,t}$, and subsidize a fraction $\tau_{v,t}$ of the cost of posting a vacancy. We assume that the government needs to balance its budget every period. A tax on production income $\tau_{J,t}$ is used to achieve this.[6] In Section II we will show how the government can set its four instruments optimally to replicate the allocations that emerge from the planner's problem.

Consumption and value of the worker. — In the decentralized economy, firms are owned equally by all of the workers. $\Pi_t$ marks the dividends that the firms pay. Consumption of the worker is given by

(11)
$$c_{i,t} = \begin{cases} c_{e,t} & := & w_t + \Pi_t & \text{if} & \text{employed at the beginning of } t \text{ and working in } t, \\ c_{0,t} & := & w_{eu,t} + \Pi_t & \text{if} & \text{employed at the beginning of } t \text{ but laid off in } t, \\ c_{u,t} & := & B_t + \Pi_t & \text{if} & \text{unemployed at the beginning of } t. \end{cases}$$

Here $w_t$ marks the wage, which the firm and the worker negotiate. $w_{eu,t}$ marks severance payments from the firm to a worker who has just been laid off. In every period that the worker enters unemployed, he receives an amount $B_t$ of unemployment benefits. Note that the government cannot condition the payment on the unemployed worker's actual search decision. For future reference, define the replacement rate as $b_t = c_{u,t}/c_{e,t}$.

The values of the worker take the same form as in Section I.A; the same holds for the worker's search decision.

Production and the value of the firm. — Firms are owned in an equal amount by all of the workers in the economy. Therefore, we assume that firms discount the future using discount factor $Q_{t,t+s} := \beta\frac{\lambda_{t+s}}{\lambda_t}$, where $\lambda_t$ is the weighted marginal utility of the firms' owners:

$$\lambda_t := \left( \frac{e_t(1-\xi_t)}{\mathtt{u}'(c_{e,t})} + \frac{e_t \xi_t}{\mathtt{u}'(c_{0,t})} + \frac{u_t}{\mathtt{u}'(c_{u,t})} \right)^{-1}. \tag{12}$$

workers overstate the role of the government in providing insurance. As discussed in the introduction and the next sections, these assumptions will invariably affect our theoretical results somewhat. As we will discuss further below, they seem to be less important for the quantitative findings, however.

[6]The balanced-budget assumption means that the government cannot engage in intertemporal tax smoothing. The government uses the taxes and subsidies to alleviate the distortions caused by wage rigidities and the insurance moral-hazard tradeoff. To the extent that these distortions remain present even if the government could smooth the tax burden intertemporally, we would expect that qualitatively our main results would not be affected. Note that the balanced-budget assumption follows directly from taking together three assumptions made previously: that the economy is closed (so that there cannot be any borrowing by citizens or the government from abroad), that goods are not storable (so the government cannot save on behalf of its citizens), and that there are also no other domestic savings opportunities (meaning, among others, no government IOUs).

The production technology is as described in Section I.A. *Ex ante*, namely, before the idiosyncratic shock $\epsilon_j$ is realized, the value of a firm that has a worker is given by

$$J_t = -\int_{\epsilon_t^\xi}^{\infty} [\tau_{\xi,t} + w_{eu,t}]\, dF_\epsilon(\epsilon_j) + \int_{-\infty}^{\epsilon_t^\xi} [\exp\{a_t\} - \epsilon_j - w_t - \tau_{J,t} + \mathbb{E}_t Q_{t,t+1} J_{t+1}]\, dF_\epsilon(\epsilon_j). \tag{13}$$

The firm separates from the worker (first line) whenever the idiosyncratic cost shock, $\epsilon_j$, is larger than the state-dependent threshold $\epsilon_t^\xi$, the determination of which will be discussed in Section I.C. Doing so, it is mandated to pay layoff tax $\tau_{\xi,t}$ to the government and a previously negotiated severance payment $w_{eu,t}$ to the worker. The match will produce (second line) if $\epsilon_j$ does not exceed the threshold. In that case, output of the firm is $\exp\{a_t\}$, and the firm will pay wage $w_t$ to the worker and a production tax $\tau_{J,t}$ to the government. A match that produces this period continues into the next. The last item in brackets on the second line is the continuation value of the firm.

Matching and vacancy posting. — A firm that does not have a worker can post a vacancy at cost $\kappa_v(1 - \tau_{v,t}) > 0$. $\kappa_v$ is the resource cost of posting a vacancy. $\tau_{v,t}$ marks a *subsidy* that is proportional to that cost.[7] New matches $m_t$ continue to be created according to matching function (2). In equilibrium, firms post vacancies until the after-tax cost of posting a vacancy equals the prospective gains from hiring:

$$\kappa_v(1 - \tau_{v,t}) = q_t E_t [Q_{t,t+1} J_{t+1}], \tag{14}$$

where $q_t := m_t/v_t$ is the probability of filling a vacancy.

Bargaining. — At the beginning of the period, matched workers and firms observe the aggregate shock, $a_t$. Conditional on this, and *prior* to observing the match-specific cost shock $\epsilon_j$, firms and workers bargain over the wage and the severance payment as well as over a state-contingent plan for separation. They use generalized Nash bargaining:[8]

[7] We abstract in this paper from job-to-job transitions. Our optimal policy results further below for the vacancy subsidies and the layoff taxes should therefore be interpreted as referring only to transitions that include an unemployment spell. That is, in practice hiring subsidies would need to be targeted toward workers who are hired out of the pool of unemployed workers. Similarly, layoff taxes should be levied only if, after a separation, a worker claims unemployment benefits. Both of these restrictions are common practice when it comes to the actual implementation of labor-market policies.

[8] The literature, for example, Ljungqvist (2002), entertains two different possibilities for how layoff taxes affect the worker's relative share of the match surplus. In one of these, indirect effects apart, the worker's relative share is not affected by the layoff tax. This is the setup we use here. We assume that the government can distinguish between a layoff and a breakdown in bargaining. Note that, *ex ante*, the joint surplus is always positive in our setup, so in any period every match will conclude the bargaining

$$(w_t, w_{eu,t}, \epsilon_t^{\xi}) = \arg\max_{w_t, \epsilon_t^{\xi}, w_{eu,t}} (\Delta_{u,t}^{e})^{1-\eta_t} (J_t)^{\eta_t}, \tag{15}$$

where $\eta$ measures the bargaining power of the firm. Note that this bargaining weight may vary with the state of the economy. Due to the bilateral bargaining, the separation decision will be privately efficient. The firm's owners are insured against idiosyncratic risk associated with the cost shocks since they hold a well-diversified portfolio of individual firms. In the current period, the firm will therefore insure the risk-averse worker against the idiosyncratic risk associated with $\epsilon_j$ so that the wage, $w_t$, and the severance payment $w_{eu,t}$ are independent of the realization of $\epsilon_j$. The notation used here anticipates this outcome.

The first-order condition for the wage states that after adjusting for the bargaining weights, the value of the firm equals the surplus of the worker from working expressed in units of consumption when employed

$$(1 - \eta_t) J_t = \eta_t \frac{\Delta_{u,t}^{e}}{\mathtt{u}'(c_{e,t})}. \tag{16}$$

The first-order condition for the severance payments is that consumption when employed equals consumption in the period of the layoff, $c_{e,t} = c_{0,t}$, that is, the severance payment equals the wage $w_{eu,t} = w_t$.

Once the idiosyncratic productivity shock has materialized, worker and firm will separate if the joint surplus of the match is negative. The first-order condition for the separation cutoff yields

$$\epsilon_t^{\xi} = [\exp\{a_t\} - \tau_{J,t} + \tau_{\xi,t} + E_t Q_{t,t+1} J_{t+1}] + \frac{\beta E_t \Delta_{u,t+1}^{e} + \psi_s \log(1 - s_t) - \overline{h}}{\mathtt{u}'(c_{e,t})}. \tag{17}$$

GOVERNMENT . — The government's budget constraint is given by

$$e_t\,(1 - \xi_t)\,\tau_{J,t} + e_t\,\xi_t\,\tau_{\xi,t} = u_t B_t + \kappa_v \tau_{v,t} v_t, \tag{18}$$

reflecting revenue from the production and layoff tax on the left-hand side, as well as outlays for unemployment benefits and the vacancy subsidy on the right-hand side. It remains to specify the tax and subsidy rules, $\tau_{J,t}$, $\tau_{\xi,t}$, $\tau_{v,t}$, and UI

successfully. An alternative arrangement assumes that the layoff tax would also be payable if merely the bargaining broke down. A layoff tax then would improve the worker's bargaining position. In order to decentralize the constrained-efficient allocation, another instrument would be needed: in the case where a worker who was employed last period claimed unemployment benefits in this period but cannot present a valid contract for employment for the current period, the government would pay out only a fraction of benefits in the first period. One could always choose this additional instrument such that the bargaining outcome is the same as in our main text. As a result, and since this affects only off-equilibrium outcomes, the setting of all other instruments would not be affected.

benefit payments, $B_t$. These are derived further below in a way that implements the constrained-efficient allocation.

DIVIDENDS AND MARKET CLEARING. — Aggregate profits are given by
(19)

$$\begin{aligned}\Pi_t \quad = \quad & e_t \left( \int_{-\infty}^{\epsilon_t^\xi} [\exp\{a_t\} - \epsilon - w_t - \tau_{J,t}]\, dF_\epsilon(\epsilon) - \int_{\epsilon_t^\xi}^{\infty} [w_t + \tau_{\xi,t}]\, dF_\epsilon(\epsilon) \right) \\ & - \kappa_v (1 - \tau_{v,t}) v_t.\end{aligned}$$

These are distributed as dividends to the mutual fund that the workers own. The mutual fund in turn directly distributes the firms' dividends in equal amount to all workers in the economy.

Market-clearing requires that the total supply of goods, given by (8) equal the demand for goods as given by (9). Appendix B collects the equilibrium conditions for the decentralized economy.

## II. Optimal policy

Before assessing the optimal policy mix quantitatively, we devote this section to building intuition. Both for the steady state and the dynamic economy, we characterize the tax and benefit rules that decentralize the constrained-efficient allocation emerging from the planner's problem. We use the resulting propositions to discuss how the tradeoffs inherent in the model shape the use of the instruments.

### A. *Optimal policy mix in the steady state*

We start by focusing on the steady state of the economy. This way we can compare our results with the literature, which has focused largely on steady states. In addition, it allows us to highlight the key tradeoffs. Proposition 1 below describes the optimal setting of the government's instruments in the non-stochastic steady state.

PROPOSITION 1: *Define* $\Omega := \frac{\eta}{\gamma}\frac{1-\gamma}{1-\eta}$. *Assume that the economy has converged to the non-stochastic steady state. Then the following set of taxes, subsidies and* *benefits implement the constrained-efficient steady-state allocation:*

$$\tau_v = [1-\Omega] + \frac{\eta}{(1-\eta)} \frac{\zeta}{\kappa_v \frac{\theta}{f}}, \tag{20}$$

$$\tau_\xi = \tau_J + \tau_v \kappa_v \frac{\theta}{f} + \zeta\,(1 - sf)\,, \tag{21}$$

$$B + \Pi = e\frac{1-\beta}{\beta}\kappa_v \frac{\theta}{f} + \zeta\left[e\,\frac{1-\beta}{\beta} + sf\right], \tag{22}$$

$$\tau_J = \frac{1-e}{e}\left[c_u - \Pi\right] + \kappa_v \tau_v \theta \left[\frac{1-e}{e}s - \xi\frac{1-sf}{f}\right] - \xi(1-sf)\zeta. \tag{23}$$

*Here*

$$\zeta = \frac{\psi_s}{f(1-s)} \frac{1-e}{[\xi e + (1-e)]} \left[\frac{\mathtt{u}'(c_u) - \mathtt{u}'(c_e)}{\mathtt{u}'(c_e)\mathtt{u}'(c_u)}\right]. \tag{24}$$

Proof: This is the steady-state analogue of Proposition 2, for which Appendix B.2 provides a sketch of the proof.

In our model, the government would intervene in the labor market for two reasons. The proposition captures these by the terms $\Omega$ and $\zeta$ which reflect, respectively, that the optimal policies are affected by search externalities arising due to a violation of the Hosios (1990) condition and tensions between moral hazard and insurance.

The literature, for example, Mortensen and Pissarides (2003), has examined the case that workers are risk-neutral. In this case, the insurance motive would be absent, the marginal utilities would be constant and $\zeta$ equal to zero, compare equation (24). The only reason for government intervention then would be to make firms and workers internalize the search externalities that arise when the Hosios-condition term $\Omega$ does not equal unity. This can be done with the use of vacancy subsidies, see equation (20). The layoff tax, equation (21), would balance most of the budget, the remainder being covered by the production tax, equation (23). Consumption when unemployed, $c_u = B + \Pi$, would be about zero, see equation (22). In the limit, as $\beta \to 1$, the consumption of the unemployed would be exactly equal to zero.

The novel element of the current paper's theory is the term $\zeta$, defined in equation (24): Our proposition extends the existing body of work to an environment with an endogenous, and unobservable, search decision by a risk-averse worker. Since workers are risk-averse, and by assumption cannot hold savings, the government seeks to help smooth the workers' consumption if they become unemployed. The very provision of unemployment benefits, however, affects the workers' outside option, and thereby all labor-market decisions. To see the implications of risk aversion for the optimal policy mix more clearly, Corollary 1 discusses the limiting case of no discounting, $\beta \to 1$.

COROLLARY 1: *Under the same conditions as in Proposition 1, assume furthermore that* $\beta \to 1$, *then*

1) *The moral-hazard insurance wedge is given by* $\zeta = c_u D$, *where* $D = \frac{1}{sf}$ *is the average duration of an unemployment spell.*

2) *Consumption when employed and unemployed follows a version of the Baily-Chetty formula:*

$$\mathtt{u}'(c_u) = \mathtt{u}'(c_e)\left[1 + D\,\epsilon_{D_2}\right]. \tag{25}$$

*Here* $D_2 = D - 1$ *is the duration over which the government on average pays unemployment benefits to an unemployed worker.* $\epsilon_{D_2} := \frac{D}{D_2}\frac{f}{\psi_s}(1-s)c_u\mathtt{u}'(c_u)$ *is the elasticity of duration* $D_2$ *with respect to an increase in consumption of an unemployed worker in the next period.*

3) *Under the additional assumptions of log-utility, and with* $\gamma = \eta$ *(that is,* $\Omega = 1$*), the optimal tax and benefit rules are*

$$\tau_v = \frac{\eta}{1-\eta}\frac{D\,c_u}{\kappa_v\frac{\theta}{f}}, \tag{26}$$

$$\tau_\xi = \tau_J + \tau_v\kappa_v\theta/f + D_2\,c_u, \tag{27}$$

$$b = \left(1 + \frac{1}{\psi_s}\frac{1-s}{s}\left[\frac{\xi e}{1-e} + 1\right]\right)^{-1} \tag{28}$$

$$\tau_J = -\frac{1-e}{e}\Pi. \tag{29}$$

*Here,* $b := c_u/c_e \in (0,1)$, $\tau_v > 0$, *and* $\tau_J < 0$. *If dividends* $\Pi$ *are sufficiently small* $\tau_\xi > 0$.

Proof: The first item follows from equation (22). Item 2 is proved in Appendix C. Item 3 is a restricted version of the entire Proposition 1.

The first item of the corollary shows that if $\beta \to 1$, $\zeta = c_u D$. $D$ is the average duration of an unemployment spell and $c_u$ is the consumption of an unemployed worker. In the steady state, the moral-hazard insurance wedge, $\zeta$, thus is given by the total resources that society spends on the average unemployed worker's consumption.

The second item of the corollary relates to the one instrument the literature has focused on most, namely, unemployment compensation. In the limit, the government should set unemployment compensation according to a version of the Baily-Chetty formula (Baily 1978, Chetty 2006). In particular, the planner equates the marginal utility of consumption of an unemployed worker to the marginal utility of consumption of an employed worker, correcting for the marginal impact that the insurance has on the search effort of the unemployed, see equation (25). This is so irrespective of any violation of the Hosios condition and suggests that it is left to the other instruments to neutralize such violations.

The third item of the corollary assesses the role that the moral-hazard insurance tradeoff plays for the entire policy mix, the novel dimension of this paper. In order to focus on this one aspect only, in this item we assume that the Hosios condition is satisfied ($\Omega = 1$). Furthermore, for tractability, we assume log-utility, as we will also do in our numerical simulations later on. In this case, vacancy subsidies are unambiguously positive as in Coles (2008), see equation (26). If a firm posts a vacancy, it increases the incentives to search, raising job-finding rates and reducing the social costs of allocating consumption to the unemployed. At the same time, the increased search incentives allow the government to provide more insurance. At the optimum the cost per hire to the taxpayer, $\tau_v \kappa_v \theta / f$, equals the amount of consumption provided to an unemployed worker over the average duration of an unemployment spell, $Dc_u$, the latter weighted by a factor involving the bargaining power of the firm. Intuitively, the larger the bargaining power of the firm, $\eta$, the larger is its share of the match surplus and the less, then, does an additional vacancy create incentives for unemployed workers to search. The government therefore needs to provide for more vacancies through larger subsidies.

Provided that firms' steady-state profits are small enough and unemployment durations long enough, layoff taxes, too, will be positive, see equation (27). We extend results in Blanchard and Tirole (2008), who use a static setting without an endogenous search decision, and in Cahuc and Zylberberg (2008), who assume the government government can observe the search decision. Layoff taxes are designed to make the worker and firm internalize the costs of their private separation decision. Next to the forgone production-tax revenue, these are the hiring subsidies the government pays to help bring the worker back into employment, and the unemployment benefits it provides over the course of the unemployment spell.

We will use the intuition that arises from the steady-state results when we discuss the optimal setting of the instruments over the business cycle, to which we turn next.

### B. *Tax and benefit responses over the business cycle*

Proposition 2 summarizes the tax and benefit rules that decentralize the constrained-efficient allocation over the business cycle.

PROPOSITION 2: *Consider the economy described in Sections I.A and I.C. Consider CRRA preferences. Define* $\Omega_t := \frac{\eta_t}{\gamma}\frac{1-\gamma}{1-\eta_t}$. *Also define the replacement rate as* $b_t := c_{u,t}/c_{e,t}$. *Assume that the bargaining power* $\eta_{t+1}$ *is known already in* *period $t$. Assume further that the values of the tuple of initial states $(b_0, a_0, e_0)$ is the same in the decentralized economy and in the planner's problem described in Section I.B. Suppose, in addition, that the government implements the following policies for all periods $t \geq 0$:*

$$\tau_{v,t} = \left[1 - \frac{\Omega_{t+1}}{1+\varsigma_t}\right] + \frac{\eta_{t+1}}{1-\eta_{t+1}} \frac{\zeta_t}{(1+\varsigma_t)\kappa_v \frac{\theta_t}{f_t}}, \tag{30}$$

$$\tau_{\xi,t} = \tau_{J,t} + \tau_{v,t}\kappa_v \frac{\theta_t}{f_t} + \zeta_t(1 - s_t f_t), \tag{31}$$

$$\begin{aligned} b_{t+1}\mathbb{E}_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\frac{c_{e,t+1}}{e_{t+1}}\right] = {} & \tau_{v,t}\kappa_v\frac{\theta_t}{f_t} + \zeta_t \\ & -\mathbb{E}_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\zeta_{t+1}(1 - s_{t+1}f_{t+1})(1-\xi_{t+1})\right] \\ & -\mathbb{E}_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\tau_{v,t+1}\kappa_v\frac{\theta_{t+1}}{f_{t+1}}\frac{e_{t+2}}{e_{t+1}}\right] + \mathbb{E}_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\frac{\Pi_{t+1}}{e_{t+1}}\right], \end{aligned} \tag{32}$$

$$\begin{aligned} \tau_{J,t} = {} & \frac{1-e_t}{e_t}\left[b_t c_{e,t} - \Pi_t\right] + \kappa_v \tau_{v,t}\theta_t\left[\frac{1-e_t}{e_t}s_t - \xi_t\frac{1-s_tf_t}{f_t}\right] \\ & -\zeta_t\xi_t(1-s_tf_t), \end{aligned} \tag{33}$$

*where the two wedges $\varsigma_t$ and $\zeta_t$ are given by*

$$\varsigma_t = \frac{e_t(1-\xi_t)}{[\xi_t e_t + (1-e_t)]f_t s_t}\left[1 - \frac{\frac{u'(c_{e,t+1})}{u'(c_{u,t+1})}(1-e_{t+1}) + e_{t+1}}{\frac{u'(c_{e,t})}{u'(c_{u,t})}(1-e_t)+e_t}\right], \tag{34}$$

$$\begin{aligned} \zeta_t = {} & \frac{\psi_s}{f_t(1-s_t)}\frac{1}{\lambda_t}\frac{1-e_t}{[\xi_t e_t + (1-e_t)]}\frac{1-\frac{u'(c_{e,t})}{u'(c_{u,t})}}{\frac{u'(c_{e,t})}{u'(c_{u,t})}(1-e_t)+e_t} \\ & + \frac{\psi_s}{f_t(1-s_t)}\frac{1}{s_t f_t[\xi_t e_t + (1-e_t)]}\frac{1}{\lambda_t}e_{t+1} \\ & \cdot\left[\frac{1}{\frac{u'(c_{e,t+1})}{u'(c_{u,t+1})}(1-e_{t+1})+e_{t+1}} - \frac{1}{\frac{u'(c_{e,t})}{u'(c_{u,t})}(1-e_t)+e_t}\right]. \end{aligned} \tag{35}$$

*Then these tax rules are consistent with the government's budget constraint. In addition, the equilibrium allocations in the decentralized equilibrium satisfy the first-order conditions in the planner's problem and* vice versa.

Proof: The proof is in Appendix B.2.

We discuss the proposition in turn. Mostly, the rules describing the optimal setting of the instruments are straightforward dynamic extensions of the steady-state results in the earlier proposition. The exception is that an additional term enters the considerations for the vacancy subsidy rule, term $\varsigma_t$ in equation (30). It measures the wedge between the planner's marginal utility of wealth and the employed workers' marginal utility. This term is zero in the steady state and, in the calibration adopted below, turns out to vary little over the business cycle.[9]

When discussing the optimal setting of the instruments over the business cycle, we will therefore abstract from this term. Rather, we discuss in detail how recessions affect the terms $\zeta_t$ and $\eta_t$ (and $\Omega_t = \frac{\eta_t}{\gamma}\frac{1-\gamma}{1-\eta_t}$) in Proposition 2, which relate to the moral hazard-insurance tradeoff and fluctuations of the bargaining power of firms, respectively.

Toward generating intuition for how the moral hazard-insurance term $\zeta_t$ moves over the business cycle, we resort to the steady-state relationships in Corollary 1. Recall that, under the conditions of the corollary, in the steady state the moral hazard-insurance term $\zeta$ is given by the total resources that an unemployed worker is expected to consume over his unemployment spell (item 1 of the corollary). This suggests that $\zeta_t$ tends to rise in recessions, when the average duration of an unemployment spell tends to increase steeply.[10] While, admittedly, there is nothing in the current paper that formally shows that one can, indeed, extrapolate from the steady state to the business cycle, it turns out that the intuition for the optimal setting of the instruments derived using the steady state is consistent with the numerical results shown later in the paper.

We turn to discussing how this shapes each of the instruments, starting with the vacancy subsidies. Focus first on the last term of equation (30). Following the above discussion, $\zeta_t$ would be expected to rise in a recession along with the cost of financing the unemployed. At the same time, the cost per hire, $\kappa_v\theta_t/f_t$, falls along with labor-market tightness. The optimal policy then is to raise vacancy subsidies in a recession so as to move unemployed workers into employment.

Another effect shapes the vacancy subsidies. Our simulations further below will assume that the firms' bargaining power, $\eta_t$, conforms with the Hosios condition in the steady state, but that it falls in recessions. The proposition shows that such fluctuations in the firms' bargaining power have two distinct effects. On the one hand, they reduce the importance of the moral hazard-insurance trade-off in determining vacancy subsidies (the term $\eta_{t+1}/(1-\eta_{t+1})$ falls in recessions).

[9] $\varsigma_t$ depends on the change of the ratio of marginal utilities and employment over time, but not on the levels of these. To the extent that the economy's response is sluggish, the cycle's effect on $\varsigma_t$ is small.

[10] The government of a closed economy like ours cannot fully consumption-insure the society as a whole against aggregate fluctuations. In a recession, it will therefore typically reduce consumption of all workers, including the unemployed, due to the scarcity of aggregate resources. However, moral hazard considerations apart, the curvature of the utility function means that consumption of the unemployed is cut by less than suggested by the fall in resources. The closed-economy assumption might make our economy look restrictive. We conjecture, however, that even in an open economy the optimal policy mix in a recession would ensure that the consumption level of unemployed workers falls less than the consumption of the employed.

The intuition is that a low bargaining power of firms in recessions means that wages do not fall by much. This gives unemployed workers incentives to search and thus mutes the role that the moral hazard-insurance tradeoff plays for the vacancy subsidies. On the other hand, and turning to the Hosios-condition term (in brackets in equation (30)), $\Omega_{t+1}$ falls in a recession. The low bargaining power of firms means that firms post too few vacancies. The government should thus increase the vacancy subsidies.[11]

For the layoff taxes, equation (31) suggests that they might need to rise in a recession as well. Making sure to keep a worker at the margin employed is more valuable from society's perspective in a recession because the expected duration of unemployment and the associated costs to the taxpayer increase. Working in the same direction, and as discussed above, the outlays for hiring subsidies also tend to increase in a recession so that the government wants to discourage layoffs. Recall that if layoff taxes do not rise, firms and workers do not internalize these costs.

Last, we discuss the behavior of the replacement rate, $b_t := c_{u,t}/c_{e,t}$, equation (32). For intuition of its cyclical behavior, we again resort to the steady state and, furthermore, to the case of log-utility. With log-utility, the steady-state replacement rate is given by $b = 1/(1 + D\epsilon_{D_2})$ (Corollary 1 item 2). Extrapolating to the business cycle, this is suggestive of two opposing effects. On the one hand, the average duration of an unemployment spell, $D$, tends to rise in recessions. This makes financing an unemployment spell more demanding and tends to reduce benefits in a recession. Working in the opposite direction, in a recession search effort is less likely to translate into a new job. The elasticity, $\epsilon_{D_2}$, of the average duration of an unemployment spell to search intensity thus tends to fall.[12] In our calibration below, quantitatively the second effect dominates so that benefits increase. However, the increase in benefits will be constrained quantitatively to the extent that in the optimal labor-market policy mix the government manages to stabilize the job-finding rate in the first place, so that jobs are no longer hard to come by. We show this next.

## III. Calibration

This section calibrates the model to the U.S. economy. Our strategy is as follows. For the baseline, we specify simple tax and benefit rules that are roughly in line with the current U.S. setup. We then calibrate the model's parameters

[11]The proposition assumes that already at the time of posting vacancies and searching for a job firms and workers, respectively, know the firms' bargaining power in the next period (when a new match can start producing). Then the tax and benefit rules provided in the proposition hold exactly. The condition does not seem particularly stringent, though. Namely, if one were to relax the assumption that the bargaining power $\eta_{t+1}$ is known to firms and workers already in period $t$, the tax and benefit rules would still remain valid up to a first-order approximation, with $\eta_{t+1}$ then replaced by $\mathbb{E}_t\eta_{t+1}$.

[12]The elasticity is $\epsilon_{D_2} = \frac{D}{D_2}\frac{f}{\psi_s}(1-s)$. See Corollary 1 for a definition of the terms. In the extreme, if there were a complete "hiring freeze" so $f \to 0$, the elasticity $\epsilon_{D_2}$ would go to zero. Providing incentives to search would then be irrelevant and the government would provide as much insurance as possible.

such that it matches key properties of the U.S. labor market. Subsequently, in Section IV, we treat these parameters as structural and ask what the labor market policy mix *should* look like.

### A. Data used for the calibration

We calibrate the model to data from 1976Q1 through 2011Q1.[13] Output $y$ is taken to be the real output in the nonfarm business sector. Labor productivity, $\frac{y}{e(1-\xi)}$, is measured as output per person in the nonfarm business sector. The unemployment rate is the Bureau of Labor Statistics' (BLS) civilian unemployment rate. In regard to vacancies, we rely on Barnichon's (2010) composite help-wanted index.[14] We equate the job-finding rate, $f_t$, with the monthly transition probability from unemployment to employment in the Current Population Survey (CPS). We adjust the data for time aggregation as in Shimer (2007). We equate the separation rate, $\xi_t$, with the flow rate from employment to unemployment in the same data set. This rate, too, is adjusted for time aggregation.[15] Our measure of the wage is real compensation per person employed in the nonfarm business sector, where nominal compensation has been deflated by the implicit price deflator for the nonfarm business sector. All series are seasonally adjusted.

The business cycle properties of the data are reported in Table 1. Whenever the frequency of the raw series is monthly, for assessing the fluctuations we take a quarterly average of the monthly data. Following Shimer (2005), the table reports the log deviations of these quarterly averages from an HP trend with a smoothing parameter of $10^5$. The business cycle properties of the data are well-known. Unemployment and vacancies, $u_t$ and $v_t$, are volatile and so is market tightness, $v_t/u_t$. The job-finding rate, $f_t$, is strongly procyclical. The separation rate, $\xi_t$, is countercyclical and somewhat less responsive to the cycle than the job-finding rate. Wages are mildly procyclical and somewhat less volatile than output.

### B. Calibrated parameters

We calibrate the model for log utility. One period in the model is a month. Table 2 summarizes the calibrated parameters. We set the time-discount factor to $\beta = 0.996$. We set the utility from leisure to $\overline{h} = 0.384$ such that in the steady state 7.5 percent of workers are unemployed $(\xi e + u)$. Not all of these search for a job. Rather, this value was chosen such that the gap between the

[13] This sample is dictated by the availability of the Current Population Survey. Unless noted otherwise, all but the CPS data are from the Federal Reserve Bank of St. Louis' FREDII database and were downloaded on 08/25/2011.

[14] Prior to 1995 the series is the conventional newspaper help-wanted advertising series. Afterward, the index links the Conference Board's print and help-wanted advertising indexes and accounts for the changing shares of these modes of advertising over time.

[15] In the sample, the average job-finding and separation rates are, respectively, 28 percent and 1.9 percent per month.

TABLE 1—BUSINESS CYCLE PROPERTIES OF THE DATA

| | | $y$ | $Lprod$ | $urate$ | $v$ | $f$ | $\xi$ | $w$ | $\theta$ |
|---|---|---|---|---|---|---|---|---|---|
| Standard deviation | | 3.34 | 1.85 | 17.46 | 18.55 | 12.29 | 8.52 | 1.94 | 34.85 |
| Autocorrelation | | 0.95 | 0.91 | 0.97 | 0.95 | 0.93 | 0.80 | 0.95 | 0.96 |
| | $y$ | 1.00 | 0.62 | -0.89 | 0.80 | 0.86 | -0.73 | 0.64 | 0.87 |
| | $Lprod$ | - | 1.00 | -0.29 | 0.28 | 0.25 | -0.61 | 0.72 | 0.29 |
| | $urate$ | - | - | 1.00 | -0.87 | -0.96 | 0.72 | -0.38 | -0.97 |
| Correlation | $v$ | - | - | - | 1.00 | 0.87 | -0.68 | 0.22 | 0.97 |
| | $f$ | - | - | - | - | 1.00 | -0.65 | 0.32 | 0.95 |
| | $\xi$ | - | - | - | - | - | 1.00 | -0.42 | -0.72 |
| | $w$ | - | - | - | - | - | - | 1.00 | 0.31 |
| | $\theta$ | - | - | - | - | - | - | – | 1.00 |

*Note:* The table reports second moments of the data. The sample is 1976Q1 to 2011Q1. *Lprod* is labor productivity per worker. *urate* is the unemployment rate. All data are quarterly aggregates, in logs, HP($10^5$) filtered and multiplied by 100 in order to express them in percent deviation from the steady state. The first row reports the standard deviation. The next row reports the autocorrelation. The following rows report the contemporaneous correlation matrix. See the text for details regarding the definition of the data.

unemployment rate, which is 6.4 percent in both the calibrated model and the data, and the share of unemployed workers replicates the typical gap between the "U3" measure of unemployment, which requires active search, and the BLS's "U5" measure, which includes workers who would take up work but who have not been actively searching for a job. We set $\psi_s = 0.215$ to replicate an elasticity of the average duration of unemployment with respect to UI benefits of 0.8, which is in line with the empirical literature, for example, Meyer (1990).[16] We set a vacancy posting cost of $\kappa_v = 0.176$ so as to obtain an average unemployment rate of 6.4 percent as in the data.[17] This results in an average cost per hire $\frac{v\kappa_v}{m}$ of 0.55 monthly wages – in line with a broader notion of recruiting costs; see Silva and Toledo (2009). We set the elasticity of the matching function with respect to vacancies to $\alpha = 0.3$ similar to Shimer (2005) and within the range of estimates deemed reasonable by Petrongolo and Pissarides (2001). We set the firm's bargaining power to $\eta = 0.3$ so that, absent risk aversion, in the steady state the Hosios (1990) condition would be satisfied without any government intervention. We view this as a natural – and customary – choice. In order

[16]The elasticity takes into account the effect of a *permanent* increase in UI benefits on an individual's search effort (and thus on the duration of unemployment) but not the general equilibrium effect of UI benefits on the job-finding rate and the separation margin. The elasticity can be shown to be

$$\epsilon_{D_u} = c_u \mathtt{u}'(c_u) \frac{1}{\psi_s} \frac{\beta f(1-s)}{1-\beta(1-\xi)(1-sf)}.$$

[17]The "unemployment rate" in the model is defined as $urate_t = (e_t\xi_t + u_t)s_t / [(e_t\xi_t + u_t)s_t + e_t(1-\xi_t)]$, and includes only those unemployed workers who did actively search for work.

Table 2—Parameters for baseline

| | | |
|---|---|---|
| Preferences | | |
| $\beta$ | time-discount factor. | 0.996 |
| $\overline{h}$ | disutility of work. | 0.384 |
| $\psi_s$ | scaling parameter dispersion utility cost of search. | 0.215 |
| Vacancies, matching and bargaining | | |
| $\kappa_v$ | vacancy posting cost. | 0.176 |
| $\alpha$ | match elasticity with respect to vacancies. | 0.300 |
| $\chi$ | scaling parameter for match-efficiency. | 0.297 |
| $\eta$ | steady-state bargaining power of firm. | 0.300 |
| $\gamma_w$ | degree of cyclicality of bargaining power of worker. | 13.97 |
| Production and layoffs | | |
| $\mu_\epsilon$ | mean idiosyncratic cost. | 0.063 |
| $\psi_\epsilon$ | scaling parameter dispersion idiosyncratic cost shock. | 0.659 |
| $\rho_a$ | AR(1) of aggregate productivity. | 0.983 |
| $\sigma_a \cdot 100$ | std. dev. of innovation to aggregate productivity. | 0.348 |
| Labor market policy | | |
| $b$ | Replacement rate | 0.451 |
| $\tau_v$ | Vacancy posting subsidy. | 0 |
| $\tau_\xi$ | Layoff tax | 0.680 |

*Note:* The table reports the calibrated parameter values in the baseline economy.

to determine the matching-efficiency parameter, we target a quarterly job-filling rate of 71 percent as in den Haan, Ramey and Watson (2000). This results in $\chi = 0.297$.

It is well-known that without wage rigidity the search and matching model cannot easily replicate the size of the cyclical fluctuations that one observes in the labor market; see Shimer (2005), Hall (2005), Hagedorn and Manovskii (2008), and Pissarides (2009). In our calibration, we make use of one particular mechanism that dampens wage fluctuations and that therefore increases fluctuations in the labor market: a procyclical bargaining power of firms (so in recessions, wages tend to be "too high" relative to productivity); compare Shimer (2005). In more detail, we specify that the bargaining power follows

$$\eta_t = \eta \exp\{\gamma_w a_{t-1}\}, \gamma_w \geq 0.$$

Note that related assumptions are common in the literature.[18] We choose the

[18]For example, Landais, Michaillat and Saez (2010) directly specify that $w_t = \overline{w}\exp\{\varrho a_t\}$, with $\varrho = 0.5$ as an exogenous wage rule. In our framework, workers and firms bargain about the wage. Due to the shifting bargaining powers, however, the resulting equilibrium wage will be less responsive to productivity than under a Nash-bargaining protocol with a constant bargaining power. As a point

value of $\gamma_w$ that generates an amount of volatility in the job-finding rate, $f_t$, that is comparable to the data summarized in Table 1. This implies $\gamma_w = 13.97$. As a result, for a 1 percent negative productivity shock the bargaining power of firms falls by about 14 percent, or, put differently, from $\eta_t = 0.3$ to a value of $\eta_t = 0.26$.

We calibrate the location parameter for the idiosyncratic cost shock so that the average cost shock of a firm that decides to produce is zero. This yields $\mu_\epsilon = 0.063$. We calibrate the dispersion parameter for the idiosyncratic cost shock to $\psi_\epsilon = 0.659$. This ensures an average job-finding rate of $f = 0.28$ as in the data. In regard to aggregate productivity, we set the serial correlation of the productivity shock to $\rho_a = 0.983$ and the standard deviation of the shock to $\sigma_a = 0.00348$. With these values the model replicates the volatility and serial correlation of labor productivity in the data.

Next, we turn to calibrating the policy variables. These have been adjusted over the years, and also during the last recession. This applies to unemployment benefits as much as to hiring subsidies and taxes on firms. In addition, one could argue that layoff taxes have a cyclical component due to non-linearities inherent in the experience rating.[19] A detailed historical analysis of the implementation of each of the policy measures and their non-linearities is beyond the scope of the current paper, however. Lacking a better choice, for the baseline we thus specify the policies directly and set them to constant values. We conjecture that, at worst, if we accounted for changes in the policy variables in the baseline, we might need to adjust the calibrated degree of wage rigidity. Our main result then most likely would not be affected: namely, that changes in the policy instruments have to be assessed within the context of the overall policy mix, which prominently includes hiring subsidies and layoff taxes.

We set the replacement rate, $b = c_{u,t}/c_{e,t}$, such that in the steady state benefit payments by the government replace 45 percent of wages when employed, namely, $B/w = 0.45$. This follows Engen and Gruber (2001). We set vacancy subsidies to $\tau_{v,t} = 0$.[20]

of reference, a regression of wages on productivity would yield an elasticity of wages with respect to productivity of 0.94 in our model; compare Hagedorn and Manovskii (2008) and Haefke, Sonntag and van Rens (2008).

[19]Layoff taxes can have a procyclical element by construction of the experience rating schedules. In particular, statutory upper bounds for the unemployment insurance tax rate mean that for firms that experienced a lot of layoffs in the past the tax cost of an additional layoff becomes zero. This means that the average layoff tax falls in recessions, when more firms hit that bound. In the current paper we abstract from such non-linearities, implicitly assuming that the marginal firm that considers a layoff is at the upward-sloping part of the tax schedule. What the legislator may have in mind is a model where firms can become financially constrained in recessions. Such constraints could then mean that the average shadow value of the layoff tax could well stay constant in a recession, even if the face value of the tax burden falls. Needless to say, we abstract from such constraints in the current paper.

[20]Permanent programs of employment subsidies tend to restrict eligibility to workers with certain characteristics. The TANF (Temporary Assistance for Needy Families) program, for example, is restricted to members of needy families with children. This mixes traditional "welfare" considerations and the notion of subsidizing hiring. The expenditures for jobs and training of the major needs-tested benefit programs (including TANF) for fiscal year 2004 at the state and federal levels combined amounted to only roughly 0.06 percent of GDP (Spar, 2006, Table 1); Moffitt (2003) reports similar magnitudes for a longer range of time. This is an order of magnitude smaller than the optimal level of steady-state

Layoff taxes are set to a constant value of $\tau_{\xi,t} = 0.68$. This value is determined as follows. In our calibration, the average duration of unemployment is 4.2 months (a little bit above the average duration of 16.4 weeks in the data). The replacement rate of unemployment benefits in our calibration is 45 percent of wages. This implies that over the typical unemployment spell, the government pays unemployment benefits equivalent to about 1.45 monthly wages (recall that in the first period of unemployment the worker receives the severance payment, not unemployment benefits). We set the layoff tax such that it covers 50 percent of these payments.[21] The column labeled "baseline" in Table 5 in Appendix D reports the resulting steady-state values of the model.

In regard to the cyclical properties, the calibrated model does a good job of replicating the fluctuations in the data; see Table 3, which reports statistics based on a first-order approximation of the model. Unemployment and vacancies are

Table 3—Business cycle properties of the model

| | | $y$ | $Lprod$ | $urate$ | $v$ | $f$ | $\xi$ | $w$ | $\theta$ |
|---|---|---|---|---|---|---|---|---|---|
| Standard deviation | | 3.37 | 1.85 | 18.71 | 23.07 | 12.29 | 7.70 | 1.74 | 40.96 |
| Autocorrelation | | 0.97 | 0.96 | 0.98 | 0.93 | 0.96 | 0.97 | 0.97 | 0.96 |
| | $y$ | 1.00 | 0.99 | -0.99 | 0.97 | 0.99 | -0.99 | 1.00 | 0.99 |
| | $Lprod$ | - | 1.00 | -0.98 | 0.99 | 1.00 | -0.99 | 0.99 | 1.00 |
| | $urate$ | - | - | 1.00 | -0.94 | -0.98 | 0.99 | -0.99 | -0.98 |
| Correlation | $v$ | - | - | - | 1.00 | 0.98 | -0.98 | 0.97 | 0.98 |
| | $f$ | - | - | - | - | 1.00 | -0.99 | 0.99 | 1.00 |
| | $\xi$ | - | - | - | - | - | 1.00 | -0.99 | -0.99 |
| | $w$ | - | - | - | - | - | - | 1.00 | 0.99 |
| | $v/u$ | - | - | - | - | - | - | - | 1.00 |

*Note:* The table reports second moments in the model. *Lprod* is labor productivity per worker. *urate* is the unemployment rate. All data are quarterly aggregates, in logs and multiplied by 100 in order to express them in percent deviation from the steady state. We report unconditional standard deviations from the model. The first row reports the standard deviation. The next row reports the autocorrelation. The following rows report the contemporaneous correlation matrix. Table 1 reports the corresponding business cycle statistics in the data.

considerably more volatile than productivity and so are the job-finding and separation rates. Vacancies and unemployment are negatively correlated, thus preserving the Beveridge-curve relationship. The job-finding rate is procyclical, the separation rate countercyclical.

vacancy subsidies that we find.

[21] For the years 1988 through 2003, the Employment and Training Administration within the U.S. Department of Labor provides an experience-rating index. While the degree of *de facto* experience rating differs across states, the index suggests that experience rating is imperfect in the sense that individual firms typically pay for only about 50 percent of the costs of benefits for the unemployment spells that they "cause."

We wish to close this section by highlighting that our choice of resolution of the Shimer (2005) puzzle is important not only for bringing the model's second moments close to the ones in the data, but also for the normative prescriptions that we derive next. In particular, our calibration means that to a large degree unemployment fluctuations in the baseline economy are socially inefficient. The planner thus would implement much smoother employment than witnessed in the baseline. In the decentralized economy, the government will, therefore, choose the optimal policy mix to first and foremost stabilize employment. Vacancy subsidies and layoff taxes are the main vehicles for this. Once employment stability is ensured, quantitatively there is little need for varying the generosity of unemployment insurance in response to fluctuations in output.

## IV. The optimal labor-market policy mix

We now proceed to a quantitative exploration of the optimal labor-market policy mix over the business cycle. We first discuss the response of the baseline economy with constant labor-market policies to a recessionary shock. We show that employment in the baseline falls much more than in both the (unattainable) first-best in which search effort would be observable and the constrained-efficient allocation when the planner cannot observe search effort (see Section I.B). We then ask what the optimal mix of labor-market policies looks like that decentralizes the constrained-efficient allocation.[22]

Thereafter, we link our results to the literature by restricting the government to have access only to unemployment benefits financed by taxes on production. We demonstrate that the resulting allocations would differ starkly from those under the optimal policy mix. Then we show that, in contrast, the optimal use of vacancy subsidies and layoff taxes alone (that is, leaving the replacement rate constant) would bring the economy's responses very close to the constrained-efficient allocation.

### A. *Optimal policy over the business cycle*

Figure 1 shows the economy's response to a negative 1 percent shock to productivity. Red dots mark the responses in the (unattainable) first-best. A black solid line marks the responses under the constrained-efficient policy. The blue dashed line marks the responses in the calibrated baseline.

With its movements in bargaining power, and the suboptimal policies, in the baseline the drop in productivity induces a strong and persistent increase in the separation rate and a pronounced fall in the job-finding rate (see the blue dashed line). Employment falls considerably. The weakened prospects in the labor market along with the constant replacement rate reduce the search incentives for

[22]The steady state of these exercises is shown in Appendix D. The results shown in the following graphs are based on first-order approximations of the equilibrium conditions.

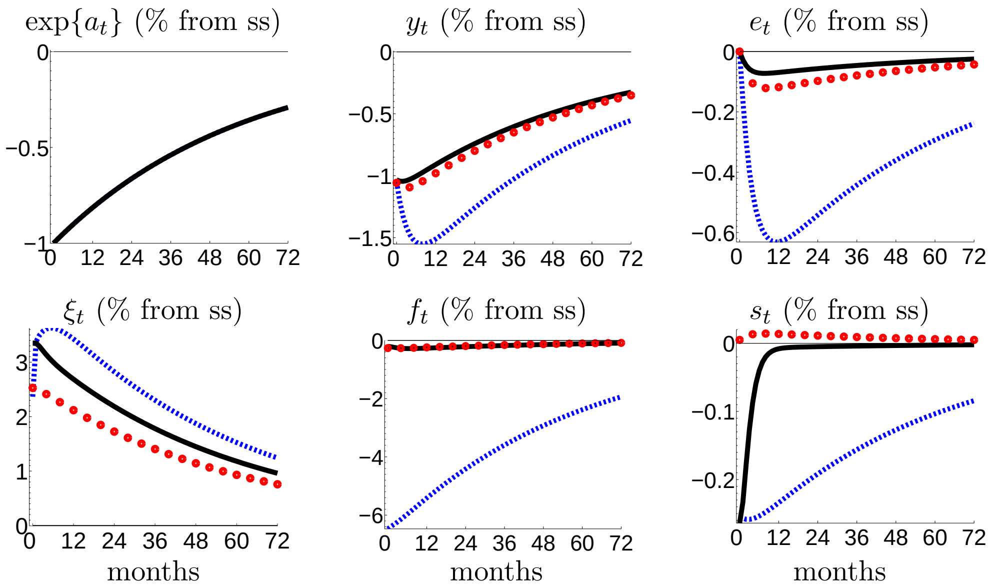


FIGURE 1. IMPULSE RESPONSE TO A TECHNOLOGY SHOCK - BASELINE, PLANNER, AND FIRST-BEST

*Note:* The figure shows responses of the monthly variables to a -1 percent shock to labor productivity (top left corner). The solid black line marks responses in the planner economy (constrained-efficient equilibrium). The blue dashed line marks responses in the calibrated baseline, the red dots the response in the first-best. All variables are expressed in percentage deviation from the steady state. The x-axes cover a time period of 72 months (6 years).

unemployed workers. This adds to the unfolding of the recession, since firms do not create jobs that would be desirable from society's point of view. Output drops by substantially more than the movement in productivity alone would suggest.

The second set of responses that we show in Figure 1 concerns the first-best response of the economy; see the red dots. The negative shock to aggregate productivity implies that jobs with high idiosyncratic production costs become socially undesirable (recall that workers do generate utility from leisure). As a result, the separation rate rises and with it unemployment. Moreover, the first-best allocation induces an increase in search effort. Aggregate resources are scarce; so absent incentive constraints, the planner wishes to increase the search effort of the unemployed. The first-best does not display the amplification of the aggregate productivity shock that we witnessed in the baseline economy. In particular, job offers would be plentiful. As a result, the rate $f_t$ at which searching workers find a job barely falls and employment falls much less than in the baseline.

The last set of results that we show in Figure 1 concerns the constrained-efficient (planner) allocation; see the solid black line. The constrained-efficient allocation stabilizes the separation margin relative to the suboptimal baseline, if somewhat less so than in the first-best. The hiring margin is stabilized in a way comparable to the first-best. Indeed, while the constrained-efficient allocation features less search intensity than in the first-best, in percentage terms output and employment both fall by less than would be dictated in the first-best (compare the solid black line and the red dots). Intuitively, the constrained-efficient planner provides "over-employment" so as to be able to provide search incentives and consumption insurance at the same time in the recession.

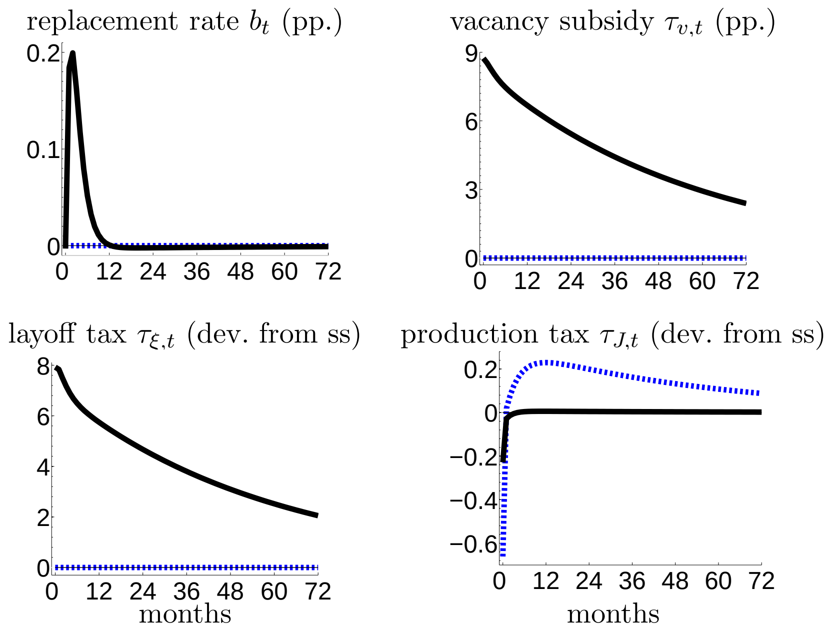


FIGURE 2. POLICY RESPONSES TO A TECHNOLOGY SHOCK

*Note:* The figure shows the responses of the tax and benefit instruments that decentralize the constrained-efficient allocation (solid black line) and compares them to the responses in the baseline (dashed blue). Shown is the response to a -1 percent labor productivity shock as in Figure 1. The replacement rate and the vacancy subsidy are expressed in percentage point deviation from the steady state. The layoff tax and production taxes are in deviation from the steady state (multiplied by 100). The x-axes cover a time period of 72 months (6 years).

Figure 2 reports the corresponding tax and benefit system that implements the constrained-efficient allocation in the decentralized economy. If the government cannot control the search effort, it will not provide full insurance. The government will, however, optimally use all of the tax instruments to influence economic activity. First and foremost it uses these to reduce the fluctuations in unemployment, thereby neutralizing the effect of the wage rigidity that is induced by the procyclical bargaining power of firms.

Once the job-finding rate and unemployment have been stabilized, there is no longer much need to alter unemployment benefits. In the optimum, the replacement rate increases by about 0.2 percentage point relative to the steady-state value of 45 percent. That increase is short-lived: it lasts for less than a year. The productivity shock that drives the recession and the wage rigidity, instead, has a half-life of about 40 months. This disconnect in persistence suggests that benefits are not used to counteract the wage rigidity. Instead, they rise initially only to the extent that the planner wants to reduce employment and search incentives.

While in its sign the initial increase in unemployment benefits is reminiscent of the findings in Landais, Michaillat and Saez (2010), in magnitude it is not. In the current paper, in the optimal policy mix the government opts to use the other instruments to ensure that jobs no longer are hard to come by. Moral hazard then remains a concern even in a recession. As a result, the rise in benefits is small and rather short-lived. Indeed, since wages in our model do respond to labor-market policies, the reason why the government can and should provide more insurance in a recession differs from that of Landais, Michaillat and Saez (2010). In our framework, an increase in unemployment benefits alone leads to higher wages, less hiring activity, and more separations. It is the availability of the other two labor-market instruments that mitigates the adverse effects of higher benefits and allows for providing insurance in a recession.

The planner uses vacancy subsidies to stimulate the hiring margin in line with our Proposition 2. The government subsidizes an additional 8.7 percent of the cost of posting a vacancy in the recession. Similarly, layoff taxes ensure a more favorable outcome than in the decentralized economy, counteracting the externalities that come with increased unemployment duration. At its peak, the increase in the layoff tax amounts to almost 20 percent of a monthly unemployment benefit payment. The increase in both the vacancy subsidy and the layoff tax is persistent, mirroring the distortions induced in the economy as the shock unfolds.[23]

The above responses under the different scenarios are also reflected in the properties of the business cycle in each of these; compare Table 4. Relative to the baseline, using the optimal policy mix over the business cycle considerably reduces business cycle fluctuations, particularly in regard to the unemployment rate and the job-finding rate. Under the first-best, the planner would cushion labor-market fluctuations still more.[24]

[23]Throughout the paper, we assume that the government cannot borrow abroad. In future work, it would be interesting to examine how the tax instruments would be used in a small open economy, the government of which has access to foreign lending. This may affect the responses. To the extent that the vacancy and layoff taxes are driven by violations of the Hosios condition, we conjecture that the results related to these would be similar, however.

[24]Our propositions indicate that fluctuations in the job-finding rate are a key determinant of the optimal labor-market policy. In inducing the baseline to yield a realistic amount of fluctuations, we generated violations of the Hosios condition. Unemployment fluctuations in the baseline thus were largely inefficient even absent the insurance motive. We have also entertained an alternative scenario that separates the role of violations of the Hosios condition from the importance of fluctuations in the job-finding rate. For this, we used the same calibration strategy as above but no longer held the elasticity of matches with respect to vacancies constant. Rather, we set $\gamma_t = \eta_t$. The Hosios condition thus held by construction. Regardless, there were strong fluctuations in the job-finding rate. While this amounts to a different description of what happens in a recession, more akin to a "hiring freeze," in which matches become harder to generate for firms, the optimal vacancy subsidy and layoff tax rose by similar amounts as in Figure 2. The optimal replacement rate rose by twice as much. Detailed results are available upon request.

TABLE 4—BUSINESS CYCLE PROPERTIES – BASELINE, CONSTRAINED-EFFICIENT, FIRST-BEST

| | $y$ | $Lprod$ | $urate$ | $v$ | $f$ | $\xi$ | $w$ | $\theta$ |
|---|---|---|---|---|---|---|---|---|
| Baseline | | | | | | | | |
| Standard deviation | 3.37 | 1.85 | 18.71 | 23.07 | 12.29 | 7.70 | 1.74 | 40.96 |
| Autocorrelation | 0.97 | 0.96 | 0.98 | 0.93 | 0.96 | 0.97 | 0.97 | 0.96 |
| Constrained-efficient | | | | | | | | |
| Standard deviation | 2.06 | 1.85 | 6.61 | 4.60 | 0.59 | 6.12 | 1.55 | 1.96 |
| Autocorrelation | 0.97 | 0.96 | 0.98 | 0.97 | 0.96 | 0.97 | 0.97 | 0.97 |
| First-best | | | | | | | | |
| Standard deviation | 2.21 | 1.85 | 5.10 | 3.28 | 0.54 | 4.80 | – | 1.81 |
| Autocorrelation | 0.96 | 0.96 | 0.98 | 0.98 | 0.96 | 0.97 | – | 0.96 |

*Note:* The table compares the model's second moments for three alternative assumptions: the baseline calibration, the constrained-efficient equilibrium and the first-best. *Lprod* is labor productivity. *urate* is the unemployment rate. All entries are quarterly aggregates, in logs and multiplied by 100 in order to express them in percent deviation from the steady state. The table reports unconditional standard deviations. For each block, the first row reports the standard deviation. The next row reports the autocorrelation.

### B. *Restricted set of instruments*

So far, we have worked under the assumption that the government makes use all of all the labor-market policy instruments. In this section, instead, we restrict the available set of instruments to illustrate the mechanisms that are at work.

For comparison with the literature, for example, Landais, Michaillat and Saez (2010) and Mitman and Rabinovich (2011), we first show the economy's response when the planner optimizes only the use of unemployment benefits (Figure 3). Thereafter, in order to highlight the effect of the additional two labor-market instruments that we allow for, we report the responses if the government optimally chooses layoff taxes and hiring subsidies, but not unemployment benefits (Figures 4 and 5).

Figure 3 reports as magenta-colored diamonds the economy's reaction to a recessionary shock if the government chooses the response of unemployment benefits optimally, leaving layoff taxes and vacancy subsidies at the steady-state values that decentralized the constrained-efficient allocation.[25]

As before, the figure compares this to the responses in the first-best (red dots) and the constrained-efficient equilibrium (solid black line). If variations in unemployment benefits are the only means of inducing search effort in a recession

[25]In the figures shown, we restrict the values of the instruments that are not optimized to the constant values that would support the constrained-efficient equilibrium in the steady state. For example, when allowing the planner to optimize only benefits, we set $\tau_{v,t} = 0.588$ and $\tau_{\xi,t} = 1.499$. As a result, all of the scenarios with restrictions on the instruments that we discuss in this section have the same steady state as the constrained-efficient equilibrium. In any case, the responses measured in deviation from the steady state would have been quite similar if we had instead restricted the instruments that are not being optimized to the values that we calibrated in Section III.

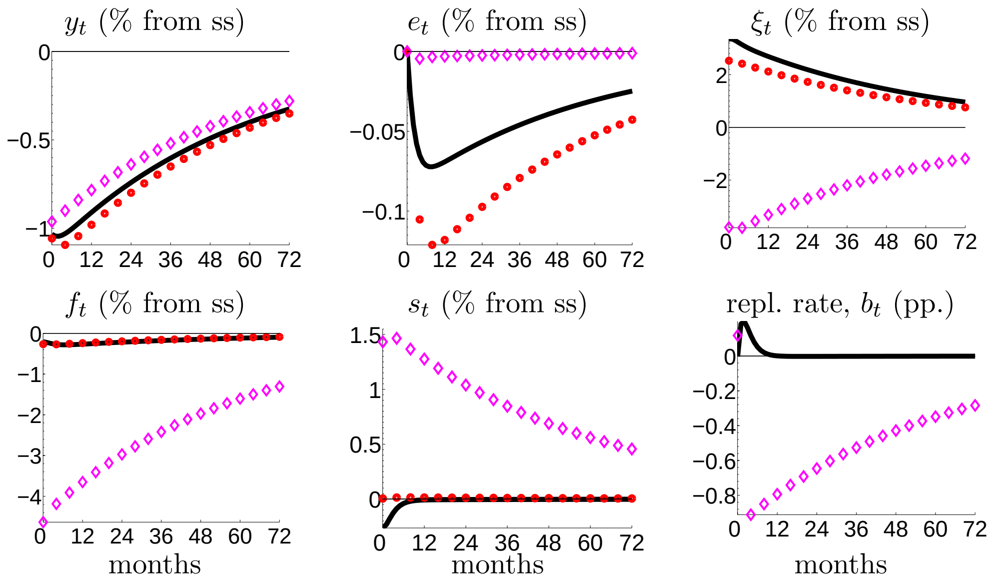


FIGURE 3. IMPULSE RESPONSE TO A TECHNOLOGY SHOCK - ONLY UNEMPLOYMENT BENEFITS REACT

*Note:* The figure shows responses of the monthly variables to a -1 percent shock to labor productivity. The solid black line marks responses in the planner economy (constrained-efficient equilibrium). The red dots mark responses in the first-best. The magenta diamonds mark the responses when, over the business cycle, the government optimizes only unemployment benefits. The x-axes cover a time period of 72 months (6 years).

(magenta-colored diamonds), the results are reminiscent of Mitman and Rabinovich (2011). Workers can be insured through being employed, which is more likely if the outside option of the worker is low, or through unemployment benefits. The government weighs these options, and opts for reducing the replacement rate considerably. The replacement rate falls by almost 1 percentage point if labor productivity falls by 1 percent. This reduction in the replacement rate follows the persistence of the underlying shock and contrasts sharply with the short-lived response in benefits witnessed in the optimal policy mix discussed earlier. The lower replacement rate reduces the outside option of the worker, with the effect that a) unemployed workers provide considerably more search effort, indeed much more so than in the first-best (panel "$s_t$"), b) firms have more of an incentive to hire, but still much less so than in the first-best (panel "$f_t$"), and c) separations of existing matches fall, in contrast to the increase in separations witnessed in both the constrained-efficient and first-best equilibria (panel "$\xi_t$"). The result of all this – in the simulations shown – is that there would be too much output and employment relative to both the first-best and the constrained-efficient allocation.

Conversely, the responses can be seen as showing that any increase in the replacement rate that would not be accompanied by an increase in vacancy subsidies and layoff taxes would be bound to deepen the recession. This highlights the importance of the additional labor-market instruments for the optimal response. Figure 4 explores this further. Next to the response in the constrained-efficient equilibrium (as before, the solid black line), the figure shows a scenario in which, starting from the same steady-state value as before, the replacement rate rises exogenously in a recession. The precise scenario features an increase in the replacement rate by 1 percentage point for any 1 percent fall in productivity. Benefits, therefore, rise about five times as much as in the optimal policy mix that implements the constrained-efficient equilibrium and more persistently so (second line, left panel of Figure 4).

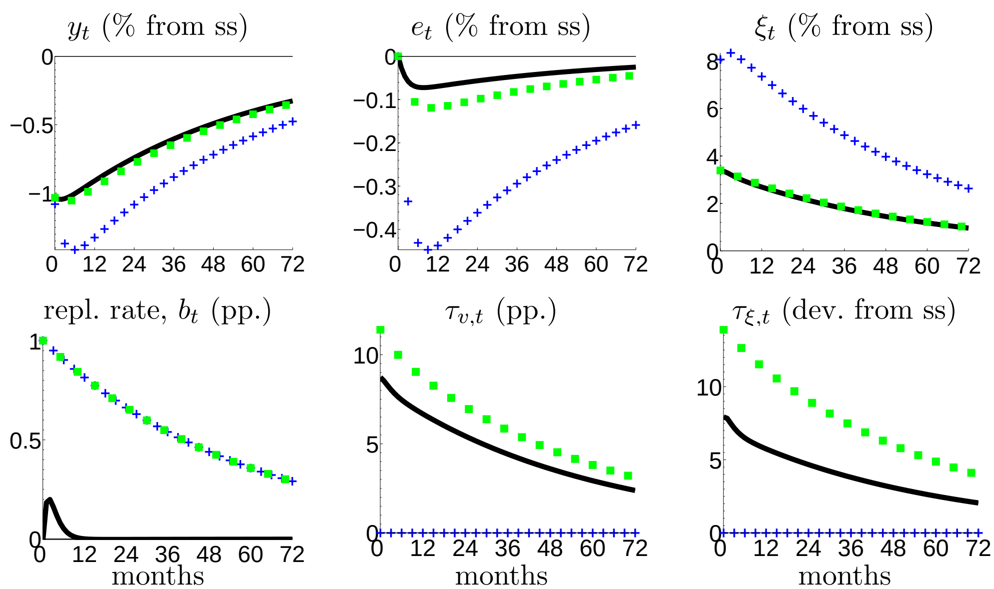


Figure 4. Impulse response to a technology shock - UI benefits rise exogenously

*Note:* The figure shows responses of the monthly variables to a -1 percent shock to labor productivity. The solid black line marks responses in the planner economy (constrained-efficient equilibrium). The scenarios of the other two lines have the same steady state as the constrained-efficient equilibrium. Blue crosses mark the responses when the replacement rate rises in lockstep with a fall in productivity while vacancy subsidies and the layoff tax are kept at their steady-state level. The green squares mark the responses when the replacement rate rises with a fall in productivity but the government optimizes the vacancy subsidy and the layoff tax.

The figure shows two alternative responses of the layoff taxes and vacancy subsidies. Blue crosses mark the case when vacancy subsidies and layoff taxes remain constant over the business cycle despite the increase in benefits. The result is a deep recession with more layoffs and considerably less employment than in the constrained-efficient equilibrium. The green squares, instead, show the case when this increase in benefits is accompanied by a response of vacancy subsidies and layoff taxes that is chosen optimally. Both of the latter instruments rise more notably still than in the constrained-efficient equilibrium. Vacancy subsidies and layoff taxes have a strong bearing on labor-market activity. As a result, layoffs are contained and hiring is stabilized. For the same increase in the replacement rate, output and employment fall much less steeply than would be suggested by the increase in the benefits alone. We conclude that it is the presence of vacancy subsidies and layoff taxes, and their optimal use, that allows unemployment benefits to stay constant, or even to initially rise slightly, in the optimal policy mix of Figures 1 and 2 without adversely affecting economic outcomes.

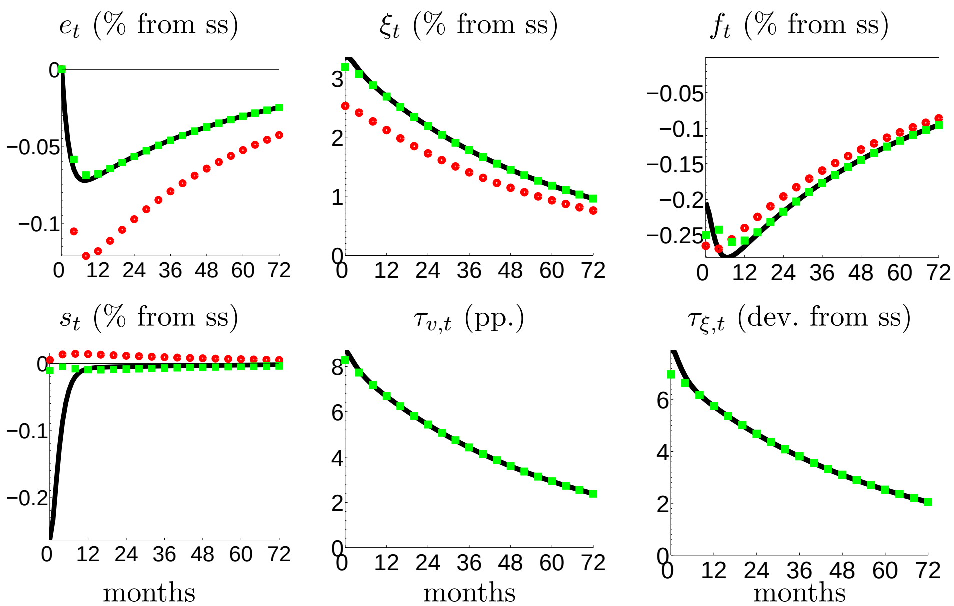


Figure 5. Impulse response to a technology shock - vacancy subsidy and layoff tax only

*Note:* The figure shows responses of the monthly variables to a -1 percent shock to labor productivity. The solid black line marks responses in the planner economy (constrained-efficient equilibrium). The red dots mark responses in the first-best. The green squares mark the responses when, over the business cycle, the government optimizes only the vacancy subsidy and the layoff tax, but not benefits.

Last, we analyze the role of the vacancy subsidy and the layoff tax alone. Toward that end, Figure 5 shows as green squares the evolution of the economy if the government optimizes the response of vacancy subsidies and layoff taxes, but not of unemployment benefits. The latter remain at their level in the constrained-efficient steady state. When only vacancy subsidies and layoff taxes are optimized, the government steers the economy in a way that quite closely resembles the constrained-efficient allocation, that is, an allocation that could have been implemented by using all three labor-market instruments at the same time. This contrasts sharply with the case when only unemployment benefits are optimized in response to the recession (see Figure 3). In sum, if one takes seriously the view that wage rigidities account for the lion's share of unemployment fluctuations, then asking how unemployment insurance should optimally vary over the cycle seems largely beside the point. Optimal policy should, instead, aim to eliminate the unemployment fluctuations.

## V. Conclusions

In this paper, we have assessed the optimal cyclical mix of labor-market instruments in a real business cycle model with Mortensen and Pissarides-type (1994) matching frictions in the labor market. The model features endogenous hiring and separations and endogenous search effort. We have allowed for two competing reasons for the government to intervene in the labor market. On the one hand, a countercyclical bargaining power of firms induces wage rigidity and means that the Hosios (1990) condition is violated over the business cycle. This gives a role to the government in stabilizing employment. On the other hand, we give a role to labor-market policies in helping to smooth income and consumption fluctuations of risk-averse workers. Since search effort by the unemployed is private information, the government cannot provide complete insurance against unemployment. This insurance-moral hazard tradeoff is affected by the business cycle.

We have shown analytically that the constrained-efficient planner allocation can be decentralized using, next to a production tax, three labor-market instruments: a layoff tax, a vacancy subsidy and unemployment benefits. Analytical expressions for the optimal evolution of these instruments, which we present, illustrate how the government optimally resolves the tradeoffs both in the steady state and over the business cycle. These expressions suggest that not only are all three instruments positive in the steady state but also that these instruments might need to increase further in response to a recessionary shock. Unemployment benefits rise to provide enhanced insurance at a time when search is not particularly elastic. Hiring subsidies rise in order to neutralize the effect of wage rigidity on the firms' hiring incentives. In addition, hiring subsidies rise because hiring can be induced at a lower cost in a recession: the cost per hire falls in a recession and the duration of unemployment rises. The resulting costs to society can be reduced if unemployed workers transit back into employment more rapidly. Last, layoff taxes rise so as to make workers and firms internalize the costs of separations regarding unemployment benefits and hiring subsidies to the fiscal authority.

We then calibrated the model to the U.S. economy, which required considerable wage rigidity. The wage rigidity greatly amplifies unemployment fluctuations, rendering a large extent of these socially inefficient. We have demonstrated that vacancy subsidies and layoff taxes are essential for bringing this model economy's response to a recessionary impulse close to first-best, whereas there is little need for unemployment benefits to be cyclical. The intuition behind these policy implications is simple. To the extent that unemployment fluctuations are inefficient, labor-market policy should first and foremost eliminate these fluctuations. This can be achieved by vacancy subsidies and layoff taxes. Once this is taken care of, there is little need for varying the generosity of unemployment insurance in response to fluctuations in output. In the absence of these instruments, instead, the government would need to cut unemployment benefits quite dramatically and persistently – in the middle of a recession – so as to reduce wages and induce search effort. Such a response runs counter to the optimal behavior of benefits that we find in the optimal policy mix. It is precisely the availability of the other two labor-market instruments that allows the government to maintain the generosity of the unemployment insurance system in a recession.

Our work provides analytical and quantitative results. We have derived our results in a search and matching model that does speak to some policy issues, but not all. For example, the model does not capture the notion that there may be something inherently valuable in keeping one's job in a recession over and above the short-run consumption insurance that the job provides. It has by now been rather well documented that there are scarring effects of unemployment, for example, Jacobson, LaLonde and Sullivan (1993), and that these tend to be more pronounced in recessions; see Davis and von Wachter (2011). It would seem important to analyze the resulting tradeoffs and optimal government policies in a richer environment that allows for such effects, for example, one with loss of human capital during unemployment along the lines of Ljungqvist and Sargent (2008).

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