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Optimal Labor-Market Policy in Recessions

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Abstract

We examine the optimal labor market-policy mix over the business cycle. In a search and matching model with risk-averse workers, endogenous hiring and separation, and unobservable search effort we first show how to decentralize the constrained-efficient allocation. This can be achieved by a combination of a production tax and three labor-market policy instruments, namely, a vacancy subsidy, a layoff tax and unemployment benefits. We derive analytical expressions for the optimal setting of each of these for the steady state and for the business cycle. Our propositions suggest that hiring subsidies, layoff taxes and the replacement rate of unemployment insurance should all rise in recessions. We find this confirmed in a calibration targeted to the U.S. economy.

JEL Classification System: E32, E24, J64

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1 Introduction

Unemployment in the U.S. has risen sharply in the wake of the Great Recession and remains at stubbornly high levels. Policymakers have reacted to this shock by substantially increasing the duration of unemployment benefits. In addition, instruments that are less standard, such as hiring subsidies, for example, are discussed intensively in the current environment and have been part of previous 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. Similarly, payroll subsidies have been used in other countries in the latest recession, a prominent example being the German short-time working scheme (Kurzarbeit).

Most of the related literature conducts a steady-state analysis and does not speak to the optimal labor-market policy in response to large business cycle shocks. The recent papers that are concerned with the business cycle in turn do not study the optimal labor-market policy mix, but restrict themselves to just one instrument, namely, unemployment benefits; see, for example, Landais, Michaillat, and Saez (2010) and Mitman and Rabinovich (2011). The current paper argues that this focus is restrictive in that it does not take into account that insurance and incentives can be provided by other means as well. We find that these other means are of first-order importance. Our main result is that non-standard instruments, namely, hiring subsidies and layoff taxes, should be actively used and should rise notably in a recession. Once this has been provided for, there may be little need to adjust unemployment benefits.

This paper studies the optimal labor-market policy mix in a real business cycle model with Mortensen and Pissarides-type matching frictions in the labor market. The model we use has the following features: first, workers in our model are risk-averse and do not have savings. Second, workers have to make a search effort to find a new job. This search effort is private information, so that unemployment benefits induce distortions and the government faces a trade-off between insurance and inducing search effort. Third, a frictional labor market as in Mortensen and Pissarides (1994) prevents the immediate reallocation of unemployed workers. In our framework, an increase in unemployment benefits affects wages, separations, search and hiring activity, all of which depend on the worker's outside option. Fourth, layoffs are privately efficient and affected by the amount of insurance granted to the worker. Fifth, and last, a closed-economy assumption realistically limits the government's ability to provide consumption insurance in the face of aggregate shocks.

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

We find that in reaction to a recessionary productivity shock, the government should simultaneously increase vacancy subsidies and layoff taxes. Vacancy subsidies rise because hiring can be induced at a lower cost in a recession: not only does the cost per hire fall but also the opportunity cost of not having an unemployed worker hired rises because the duration of unemployment rises in a recession. The resulting costs of unemployment insurance can be reduced if unemployed workers transit back into employment more rapidly. The subsidies stabilize the job-finding rate and provide search incentives to unemployed workers in the presence of positive unemployment benefits. Quantitatively, we find that in response to a negative 1 percent productivity shock, the government subsidizes an additional 8 percent of the cost of posting a vacancy.

Layoff taxes rise so as to make workers and firms internalize the higher social costs of unemployment in a recession: on the one hand, unemployment spells tend to last longer in recessions; on the other hand, this prompts the government to subsidize hiring more aggressively. Both of these activities are costly. In response to a 1 percent drop in productivity, the increase in layoff taxes amounts to almost 20 percent of a monthly unemployment benefit payment.

We also find that despite the fewer resources that are available, the government does not opt to reduce unemployment insurance in bad times. Instead, unemployment benefits rise to provide enhanced insurance at a time when search effort is not particularly elastic to benefits. Quantitatively, we find that the ratio of consumption when unemployed relative to consumption when employed (the "replacement rate") should rise by 0.2 percentage point in response to a negative 1 percent productivity shock. The increase in benefits is similar to the findings in Landais, Michaillat, and Saez (2010). The source of the result differs, however. Whereas they entertain wages that are exogenous to labor-market policy, in our paper, higher benefits alone would lead to higher wages and less employment. It is the optimal use of vacancy subsidies and layoff taxes that allows the government to maintain the generosity of the unemployment insurance system in bad economic times.

Our paper shows in detail the importance of the hiring subsidy and the layoff tax for our findings. First, we show numerically that if the government could use unemployment benefits only, not being able to vary layoff taxes or hiring subsidies in response to the recessionary shock, it would opt for steep cuts in benefits. Quantitatively, the replacement rate would fall by almost 1 percentage point in response to a fall in productivity by 1 percent. This cut reduces the worker's outside option and leads to more hiring and fewer separations at the cost of reduced insurance for the unemployed. This is reminiscent of the results in Mitman and Rabinovich (2011). However, the availability of the non-standard instruments renders such a reaction unnecessary: benefits can rise and still not make the recession worse.

Second, we look at a scenario in which the state uses only hiring subsidies and layoff taxes optimally but cannot alter benefits over the business cycle. Again, layoff taxes and hiring subsidies should rise in a recession. Indeed, the increase is quantitatively similar to the fully optimal plan. The resulting allocation closely resembles the constrained-efficient outcome.

The remainder of this paper is organized as follows. The next section relates our work to the existing literature. Section 2 introduces the model. Section 3 presents the planner's problem and 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 4 presents the calibration of the model economy. Section 5 discusses the optimal policy mix both in the steady state and over the business cycle. A final section concludes. The Appendix collects the proofs and derivations.

1.1 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 of the literature 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 studied the distortive effects of tax instruments on the wage-setting and hiring process, Mortensen and Pissarides (2003). This strand tends to focus on models that do not have a welfare-improving role for unemployment benefits. In contrast, in our framework the lack of insurance due to moral hazard endogenously induces distortions. The government therefore requires a rather rich set of instruments to 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, Hopenhayn and Nicolini (1997), Wang and Williamson (2002), and Shimer and Werning (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. Our approach assumes that consumption allocations are independent of durations for analytical tractability. In the optimum, workers who become unemployed turn out to be fully insured in the first period of their unemployment spell, because the incentive-constraint is not binding. Thereafter, however, benefits drop to a level that is characterized by a dynamic version of the Chetty (2006) formula.

The literature on optimal unemployment insurance has typically ignored the interaction of the design of unemployment benefits with matching frictions. A notable exception is Coles (2008), who studies the optimal unemployment benefit provision in a matching equilibrium with unobservable search effort and exogenous separation. Coles derives analytical expressions for the optimal duration dependence of unemployment benefits in a steady state without discounting, and when the government has 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. An insight that carries over to our environment is that 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. Due to the static frameworks, these papers do not deal with the effect of separations on the job-finding rate and the search incentives of unemployed workers. We extend their results in several dimensions: first, to the business cycle; second, to an environment with an endogenous hiring decision; and third, and most important, to a model with an unobservable search decision that interacts with the hiring and layoff decision. These extensions lead to an additional positive role for layoff taxes.[1]

[1] 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.

The fourth strand of the literature, which is most closely related to what we do, studies how to optimally set unemployment benefits over the business cycle when labor markets are frictional, workers are risk-averse, and search effort is not observable; see Mitman and Rabinovich (2011) and Landais, Michaillat, and Saez (2010).[2] These papers ignore the endogeneity of the separation margin that potentially further limits the amount of insurance that the government can provide. Landais, Michaillat, and Saez (2010) assume a closed economy in which real wages are exogenous to policy and partially sticky. As a result, real wages do not fall much in a recession, inducing too little hiring from a social perspective. The planner cannot confront this and, instead, lets benefits rise in a recession so as not to let workers inefficiently compete for the few jobs that are available. In contrast, Mitman and Rabinovich (2011) consider a setting where benefits do affect wages. The government's only instrument is unemployment benefits. It uses these to induce search effort and stimulate hiring activity. In numerical simulations they find that both the size and the duration of benefits should fall in recessions.

Our paper, instead, shifts the focus away from unemployment benefits and, realistically we would argue, toward a wider set of labor-market instruments. We find that both hiring subsidies and layoff taxes should rise in a recession and that these two features alone help track closely the optimal allocation. We find that benefits, too, should increase in recessions. While this is reminiscent of the findings in Landais, Michaillat, and Saez (2010), the reason why the government can and should provide more insurance in a recession differs. In our framework, an increase in unemployment benefits affects wages, hiring activity, and separations, all of which depend on the outside option of the worker. If unemployment benefits were the government's only instrument, in our setting these should fall. It is the availability of the other two labor-market instruments that mitigates the adverse effects of higher benefits and allows for providing better insurance in a recession.

2 Model

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. Time is discrete. The unemployment benefit system provides the only means of insuring against an unemployment spell. Search effort by the individual worker is not observ-

[2] For a more complete review of this literature, we refer the reader to the overview in Landais, Michaillat, and Saez (2010).

able. The unemployment insurance system therefore has to trade off insurance of the individual against providing incentives for job search. The insurance provided also affects the hiring and separation decision, since the unemployment insurance system determines the outside option of the worker when bargaining with the firm. The government taxes layoffs by $\tau_{\xi,t}$, and raises taxes on production income $\tau_{J,t}$. It subsidizes a fraction $\tau_{v,t}$ of the cost of posting a vacancy and pays unemployment insurance. We consider a closed economy: the government needs to balance its budget every period.

2.1 Value of the worker and consumption

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 do not work enjoy an additive utility of leisure $\overline{h}$.
Consumption of the worker is given by

$$c_{i,t} = \begin{cases} c_{e,t} & := & w_t + \Pi_t & \text{if} & \text{employed at the beginning of } t \text{ and working in } t, \\ c_{0,t} & := & w_{eu,t} + \Pi_t & \text{if} & \text{employed at the beginning of } t \text{ but laid off in } t, \\ c_{u,t} & := & B_t + \Pi_t & \text{if} & \text{unemployed at the beginning of } t. \end{cases} \tag{1}$$

Here w_t marks the wage. Firms are owned equally by all the workers. Π_t marks the dividends that the firms pay. $w_{eu,t}$ marks severance payments from the firm to a worker who has just been laid off. $c_{u,t}$ marks consumption when unemployed. B_t marks the level of unemployment benefits paid. For future reference, define the replacement rate as $b_t = c_{u,t}/c_{e,t}$.

2.1.1 Value of an employed worker

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

$$V_{e,t} = \quad (1 - \xi_t) \left[\mathtt{u}(c_{e,t}) + \beta \mathbb{E}_t V_{e,t+1} \right] + \xi_t V_{0,t}. \tag{2}$$

Here ξ_t marks the probability that the match separates in the course of the period, discussed below. $V_{0,t}$ is the *ex ante* value in t of a worker who has been laid off in t. Similarly, for future reference, let $V_{u,t}$ denote the *ex ante* value of a worker who enters the period unemployed.

2.1.2 Value of an unemployed worker, search and worker's surplus from working

Unemployed workers need to actively search in order to find a job. Workers are differentiated by their utility cost of search, $\iota_{i,t} \sim F_\iota(0, \sigma_\iota^2)$. For tractability, these costs are independently and identically distributed both across workers and across time and follow a logistic distribution with mean 0 and variance $\sigma_\iota^2 := \pi \frac{\psi_s^2}{3}$, where a lower case π refers to the mathematical constant. Search effort is not observable to the government. This generates the moral hazard on the side of the unemployed worker. All workers whose disutility of search falls below a certain cutoff value ι_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 gains from search:

$$\iota_t^s = f_t \, \beta \, \mathbb{E}_t \left[V_{e,t+1} - V_{u,t+1} \right]. \tag{3}$$

The gains from search are the discounted utility gain when employed 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, the share of non-employed workers who search is given by

$$s_t = Prob(\iota \leq \iota_t^s) = 1/\left(1 + \exp\left\{-\iota_t^s/\psi_s\right\}\right). \tag{4}$$

The *ex ante* value of an unemployed worker is given by

$$\begin{aligned} V_{u,t} \quad = \quad & \mathtt{u}(c_{u,t}) + \overline{h} \\ & + \int_{-\infty}^{\iota_t^s} \left[-\iota_i + f_t \, \beta \mathbb{E}_t V_{e,t+1} + (1 - f_t) \beta \mathbb{E}_t V_{u,t+1} \right] dF_\iota(\iota_i) \\ & + \int_{\iota_t^s}^{\infty} \beta \mathbb{E}_t V_{u,t+1} dF_\iota(\iota_i). \end{aligned} \tag{5}$$

Regardless of the 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 ι_i. Compensating for this, with probability f_t the worker will find a job. In that case, the worker's value in 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 in 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.
Apart from the consumption stream in the first period, the value of an unemployed worker who

has just been laid off is the same as that of a worker who enters the period unemployed:

$$V_{0,t} = V_{u,t} + \mathtt{u}(c_{0,t}) - \mathtt{u}(c_{u,t}). \tag{6}$$

For future reference we also need to define the surplus of the currently employed worker from employment as $\Delta^e_{u,t} := V_{e,t} - V_{u,t}$.

2.2 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

$$e_{t+1} = (1 - \xi_t)e_t + m_t, \tag{7}$$

where ξ_t is the rate of separation of existing matches in period t and m_t is the number of new matches formed in period t, which evolves according to

$$m_t = s_t f_t[\xi_t e_t + u_t]. \tag{8}$$

Here $\xi_t e_t + u_t$ is the mass of workers who are potentially searching during period 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. f_t is the probability with which a worker who looks for a job actually finds one.

2.3 Production and the value of the firm

Firms can be matched with exactly one worker and produce. If they do not have a worker, they can decide to create a vacancy. Firms are owned in an equal amount by all the workers in the economy and rebate their profits to all workers in the population. We assume that firms therefore discount the future using discount factor $Q_{t,t+s}$, where $Q_{t,t+s} := \beta \frac{\lambda_{t+s}}{\lambda_t}$, with λ_t is the weighted marginal utility of the firm's owners:

$$\lambda_t := \left(\frac{e_t(1 - \xi_t)}{\mathtt{u}'(c_{e,t})} + \frac{e_t \xi_t}{\mathtt{u}'(c_{0,t})} + \frac{u_t}{\mathtt{u}'(c_{u,t})} \right)^{-1}. \tag{9}$$

A firm j that is matched to a worker can produce an amount $\exp\{a_t\}$ of output. Aggregate productivity, a_t, evolves according to

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

Production entails a firm-specific cost $\epsilon_{j,t} \sim F_\epsilon(\mu_\epsilon, \sigma_\epsilon^2)$. For analytical tractability, we specify this shock as independently and identically distributed across both matches and time. $F_\epsilon(\cdot,\cdot)$ marks the logistic distribution with mean μ_ϵ and variance $\sigma_\epsilon^2 = \pi \frac{\psi_\epsilon^2}{3}$.
The *ex-ante* value of the firm, namely, before the idiosyncratic shock ϵ_j is realized, is given by

$$\begin{aligned} J_t \quad = \quad & - \int_{\epsilon_t^\xi}^{\infty} [\tau_{\xi,t} + w_{eu,t}] \, dF_\epsilon(\epsilon_j) \\ & + \int_{-\infty}^{\epsilon_t^\xi} [\exp\{a_t\} - \epsilon_j - w_t - \tau_{J,t} + \mathbb{E}_t Q_{t,t+1} J_{t+1}] \; dF_\epsilon(\epsilon_j). \end{aligned} \tag{10}$$

The firm separates from the worker (first line) whenever the idiosyncratic cost shock, ϵ_j, is larger than a state-dependent threshold ϵ_t^ξ, the determination of which will be discussed in Section 2.5. 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 ϵ_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 square brackets on the second line is the continuation value.

2.4 Matching and vacancy posting

Firms that do not have a worker can post a vacancy at cost $\kappa_v(1 - \tau_{v,t}) > 0$. Parameter κ_v is the resource cost of posting a vacancy and $\tau_{v,t}$ marks a *subsidy* that is proportional to that cost. New matches m_t are created according to

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

where $\chi > 0$ governs the matching-efficiency and $\alpha \in (0,1)$ is the elasticity of matches with respect to vacancies. The probability of filling a vacancy is given by $q_t := m_t/v_t$. The job-finding rate, f_t, is given by $f_t := m_t/([\xi_t e_t + u_t] s_t)$. Labor-market tightness is defined as $\theta_t = \frac{v_t}{u_t}$. In equilibrium, firms post vacancies until the after-tax cost of posting a vacancy equals the prospective gains from hiring:

$$\kappa_v(1-\tau_{v,t}) = q_t E_t \left[Q_{t,t+1} J_{t+1}\right]. \tag{11}$$

2.5 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 ϵ_j, firms and workers bargain about the wage and the severance payment as well as about a state-contingent plan for separation. They use generalized Nash bargaining:[3]

$$(w_t, w_{eu,t}, \epsilon_t^{\xi}) = \arg\max_{w_t,\epsilon_t^{\xi},w_{eu,t}} (\Delta_{u,t}^e)^{1-\eta_t} (J_t)^{\eta_t}, \tag{12}$$

where η measures the bargaining power of the firm. Note that, in principle, we allow this bargaining weight to vary with the state of the economy. Due to the bilateral bargaining, the separation decision will be privately efficient. Also observe that the firm's owners are insured against idiosyncratic risk associated with the cost shocks since they hold a well-diversified portfolio of individual firms. The firm will therefore insure the risk-averse worker against the idiosyncratic risk associated with ϵ_j so that the wage, w_t, and the severance payment $w_{eu,t}$ are independent of the realization of ϵ_j. The notation below 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

$$(1-\eta_t)J_t = \eta_t \frac{\Delta_{u,t}^e}{\mathtt{u}'(c_{e,t})}. \tag{13}$$

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

[3] 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 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 the fraction 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.

the wage $w_{eu,t} = w_t$.

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

$$\epsilon_t^{\xi} = [\exp\{a_t\} - \tau_{J,t} + \tau_{\xi,t} + E_t Q_{t,t+1} J_{t+1}] + \frac{\beta E_t \Delta^e_{u,t+1} + \psi_s \log(1-s_t) - \overline{h}}{\mathrm{u}'(c_{e,t})}. \tag{14}$$

Using the properties of the logistic distribution, the separation rate is given by

$$\xi_t = Prob(\epsilon_j \geq \epsilon_t^{\xi}) = 1/\left(1 + \exp\left\{(\epsilon_t^{\xi} - \mu_\epsilon)/\psi_\epsilon\right\}\right). \tag{15}$$

2.6 Dividends

Aggregate profits are given by

$$\begin{aligned} \Pi_t \quad = \quad & e_t \left(\int_{-\infty}^{\epsilon_t^{\xi}} [\exp\{a_t\} - \epsilon - w_t - \tau_{J,t}]\, dF_\epsilon(\epsilon) - \int_{\epsilon_t^{\xi}}^{\infty} [w_t + \tau_{\xi,t}]\, dF_\epsilon(\epsilon) \right) \\ & - \kappa_v (1 - \tau_{v,t}) v_t. \end{aligned} \tag{16}$$

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.

2.7 Government

The government's budget constraint is given by

$$e_t\,(1 - \xi_t)\,\tau_{J,t} + e_t\,\xi_t\,\tau_{\xi,t} = u_t B_t + \kappa_v \tau_{v,t} v_t, \tag{17}$$

reflecting revenue from the production and layoff tax on the left-hand side, as well as layouts 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 benefit payments, B_t. These are derived further below in a way that implements the constrained-efficient allocation.

2.8 Market clearing

Total production in the economy is given by

$$y_t = e_t (1 - \xi_t) \exp\{a_t\}.$$

Output is used for consumption, production costs and vacancy posting. Market-clearing requires

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

3 Tax and benefit policies

Before assessing the optimal policy mix quantitatively, we devote this section to building intuition. We first describe the planner's problem. We then characterize the tax and benefit rules that implement the resulting constrained-efficient allocation and discuss how the trade-offs inherent in the model shape the use of the instruments over the business cycle.

3.1 The planner's problem

The central friction in the current paper is that the planner cannot directly command or observe the search decision of an individual worker. Rather, the planner has to provide incentives for searching for a job and for retaining a job. Throughout, we consider a planner who can condition consumption allocations for the worker on the worker's current state of employment, but not on the worker's entire employment history. While this quite obviously is a restriction relative to some work in the literature, for example, Hopenhayn and Nicolini (1997) or Shimer and Werning (2008), we would argue that it is not without realism.

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, $\Delta_{u,t}^e$, that the planner had promised to the searching worker in the previous period.[4]

We consider a utilitarian planner who gives equal weight to all workers. Using the assumptions laid out above, the planner's objective can be written as

$$\mathtt{W}_t \;=\; \max_{\xi_t, \theta_t, c_{u,t}, c_{e,t}, \{\Delta_{u,t+1}^e\}} e_t \mathtt{u}(c_{e,t}) + u_t \mathtt{u}(c_{u,t}) + \;(e_t \xi_t + u_t)(\Psi_s(s_t) + \overline{h}) + \beta E_t \mathtt{W}_{t+1}, \qquad (18)$$

The first term on the right-hand side is the consumption-related utility of employed workers, and the second term is the consumption-related utility of unemployed workers. The third term

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

refers to the value of leisure and the utility costs of search.[5] The final term is the continuation value.

The planner faces four constraints: the aggregate resource constraint, the participation constraint of the worker, the promise-keeping constraint and the law of motion for employment. The planner maximizes over separations and market tightness for the current period, over consumption levels for the employed and unemployed for the current period, and over promised utility levels for the next period, $\{\Delta^e_{u,t+1}\}$, which are contingent on the future state of the economy.

In regard to the constraints, the aggregate resource constraint is given by

$$e_t(1-\xi_t)\exp\{a_t\} = e_t c_{e,t} + u_t c_{u,t} + e_t(1-\xi_t)\mu_\epsilon - e_t\Psi_\xi(\xi_t) + (e_t\xi_t + 1 - e_t)\kappa_v s_t\theta_t.$$

On the left-hand side there is aggregate output. On the right-hand side there appear aggregate consumption, the idiosyncratic production costs and the resource costs of posting vacancies. Next, the government has to induce search effort by the unemployed workers. Search effort is given by:

$$s_t \quad = \quad \left(1+\exp\left\{\frac{-f_t\beta\mathbb{E}_t\Delta^e_{u,t+1}}{\psi_\iota}\right\}\right)^{-1},$$

where the planner has to use the same matching technology as in the decentralized economy, namely, $f_t = \chi\theta_t^\gamma$. Key to inducing search effort is the government's promise of an increase in utility when a worker moves from unemployment to employment. This utility difference between work and unemployment evolves according to

$$\Delta^e_{u,t} \quad = \quad \mathtt{u}(c_{e,t}) - \overline{h}(1-\xi_t) - \mathtt{u}(c_{u,t}) + \beta\mathbb{E}_t(1-\xi_t)\Delta^e_{u,t+1} + (1-\xi_t)\psi_s\log(1-s_t).$$

Last, the planner is bound by the aggregate laws of motion of employment.

$$e_{t+1} = e_t(1-\xi_t) + (\xi_t e_t + u_t)s_t f_t.$$

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

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

3.2 Optimal policy mix in the steady state

We now discuss the decentralization of the constrained-efficient allocation by means of taxes and benefits. 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 already allows us to highlight the key tradeoffs. Having done this, in Section 3.3 we state our central Proposition 2 that describes in detail the optimal setting of the taxes and benefits over the business cycle.

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:*

$$\tau_v = [1-\Omega] + \frac{\eta}{(1-\eta)}\frac{\zeta}{\kappa_v \frac{\theta}{f}}, \tag{19}$$

$$\tau_\xi = \tau_J + \tau_v \kappa_v \frac{\theta}{f} + \zeta\,(1-sf)\,, \tag{20}$$

$$B + \Pi = e\frac{1-\beta}{\beta}\kappa_v \frac{\theta}{f} + \zeta\left[e\,\frac{1-\beta}{\beta} + sf\right], \tag{21}$$

$$\tau_J = \frac{1-e}{e}\left[c_u - \Pi\right] + \kappa_v \tau_v \theta\left[\frac{1-e}{e}s - \xi\frac{1-sf}{f}\right] - \xi(1-sf)\zeta. \tag{22}$$

Here

$$\zeta = \frac{\psi_s}{f(1-s)}\frac{(1-e)}{[\xi e + (1-e)]}\left[\frac{\mathrm{u}'(c_u) - \mathrm{u}'(c_e)}{\mathrm{u}'(c_e)\mathrm{u}'(c_u)}\right]. \tag{23}$$

Proof. This is the steady-state analogue of Proposition 2, the proof of which is in Appendix B.3. □

The interpretation is as follows. The key term for the tradeoffs in the economy is $\zeta \geq 0$, given by equation (23). It summarizes the tensions originating from the insurance motive and moral hazard. If there were a large family that provided insurance to individual household members and controlled search effort, the moral hazard friction would be absent and the marginal utilities when employed and unemployed would be equalized; ζ would be zero. Similarly, if workers were risk-neutral, marginal utilities would be constant, and the insurance motive would be absent; ζ would again be equal to zero. In that case, which was examined in Mortensen and Pissarides (2003) and many other papers, vacancy subsidies would take care only of the search externalities that arise from any violation of the Hosios (1990) condition, the term $1-\Omega$ in square brackets in equation (19). Unemployment benefits would be about zero (exactly zero if $\beta \to 1$). Our proposition extends the existing body of work to an environment with an endogenous, and unobservable, search decision by a risk-averse worker.

To the extent that workers are risk-averse, the government wants to provide unemployment benefits even if this negatively affects the search decision. The more risk-averse the worker is, the more insurance the government provides, even if this exacerbates the moral hazard problem; see equations (21) and (23). In that case, vacancy subsidies help to provide search incentives that alleviate the moral hazard problem. Layoff taxes in turn provide an incentive to hold on to a worker. An important element that shapes the tradeoff between insurance and moral hazard is the elasticity of the search margin with respect to earnings. If the margin is very elastic (ψ_s is large), the provision of unemployment benefits considerably reduces the search intensity. Even small vacancy subsidies can have a notable effect on the search effort in that case.

Next, in Corollary 1 we zoom in still further, on the case $\beta \to 1$.

Corollary 1. *Under the same conditions as in Proposition 1, assume further that $\beta \to 1$, then*

1. *Consumption when employed and unemployed follow a version of the Baily-Chetty formula:*

$$\mathtt{u}'(c_u) = \mathtt{u}'(c_e)\left[1 + D\,\epsilon_{D_2}\right]. \tag{24}$$

   Here $D = \frac{1}{sf}$ is the average duration of an unemployment spell. $D_2 = D - 1$ is the duration over which the government on average will need to pay 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 next period's consumption of an unemployed worker.

2. *Under the additional assumptions of log-utility, and with $\gamma = \eta$, we have that $\zeta = \frac{1-e}{\xi e + (1-e)}\frac{c_e(1-b)}{\epsilon_D}$, and that the optimal tax and benefit rules are*

$$\begin{aligned}
\tau_v &= \frac{\eta}{1-\eta}\frac{D\,c_u}{\kappa_v\frac{\theta}{f}}, &(25)\\
\tau_\xi &= \tau_J + \tau_v\kappa_v\theta/f + D_2\,c_u, &(26)\\
b &= \left(1 + \frac{1}{\psi_s}\frac{1-s}{s}\left[\frac{\xi e}{1-e} + 1\right]\right)^{-1} &(27)\\
\tau_J &= -\frac{1-e}{e}\Pi. &(28)
\end{aligned}$$

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

Proof. Item 1 is proved in Appendix C. Item 2 is a restricted version of Proposition 1. □

Item 1 of Corollary 1 shows that in the limit the planner sets 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.

In regard to Item 2 of the Corollary, we zoom in on a special case with log-utility. In addition, we assume $\gamma = \eta$ so that the Hosios condition would be satisfied if workers were risk-neutral. The only reason for non-zero values of the fiscal instruments in this case is the insurance-moral-hazard tradeoff. We see that typically all three labor-market instruments, namely, benefits, the vacancy subsidy and the layoff tax, will be positive. The higher the consumption of an unemployed worker and the longer the duration of unemployment, the more will the government subsidize hiring so as to provide incentives for firms to hire workers and for workers to search for work. In addition, the lower the costs per hire (the smaller $\kappa_v \theta_t / f_t$) the more recourse the government makes to vacancy subsidies. If a firm posts a vacancy, it increases an individual worker's incentives to search. This has two effects that are positive from a social of view. First, it allows the government to provide more insurance while retaining the incentives to search. Second, if it leads to recruitment, it reduces the costs of unemployment insurance to the government. In particular, randomly pick a worker who is unemployed. The expected duration of the worker's unemployment spell going forward is $D = 1/sf$. The vacancy subsidy condition (25) states that at the optimum, the cost per hire to the taxpayer, $\tau_v \kappa_v \theta / f$, equals the amount of unemployment benefits that the government would have paid out over that unemployment spell, Dc_u, weighted by a factor of proportionality given by the bargaining power of the firm: $(1-\eta)\tau_v \kappa_v \frac{\theta}{f} = \eta D c_u$. Intuitively, the larger the bargaining power of the firm, the larger is its share of the match surplus and the lower are wages. As a result, the larger η, the less does an additional vacancy create incentives to search. The government therefore needs to provide for more vacancies through larger subsidies. Note that vacancy subsidies are unambiguously positive, as in Coles (2008).

Layoff taxes are an integral part of the optimal tax and benefit system. As long as firms' steady-state profits are small enough and unemployment durations long enough, layoff taxes, too, will be positive; compare Blanchard and Tirole (2008), who use a static setting without an endogenous search decision. Layoff taxes, equation (30), make the worker and firm internalize more of the social costs of their private decisions. This is needed despite the fact that in our model economy, separations are privately efficient. That is, workers and firms do take into account the utility cost of unemployment to the worker and the forgone profit opportunities of the firm. Still, a separation means forgone revenue from production taxes, and it means that hiring subsidies are being paid to bring the worker back into employment. In addition, unemployment benefits have to be provided. A worker and firm who do separate do not take into account the effect of their actions on the search incentives of the already unemployed and on the government budget constraint. This result of full experience rating in the limit confirms findings in the literature, for example, Cahuc and Zylberberg (2008), who with an exogenous job-finding rate derive the optimal mix of layoff taxes, benefits and labor taxes in the steady state when the search decision is endogenous but observable to the government. Our results extend theirs to an unobservable search decision and to the business cycle, to which we turn next.

3.3 Tax and benefit responses over the business cycle

The discussion of the steady state above provides the intuition for the tradeoffs that arise if we consider business cycle fluctuations. For example, with log-utility, equation (27) of the corollary can be rewritten as

$$b = \frac{1}{1 + D\epsilon_{D_2}}.$$

This suggests that the business cycle has two opposing effects on the generosity of unemployment benefits provided, as measured by the replacement rate $b = c_u/c_e$. On the one hand, the evolution of benefits depends on the duration of an unemployment spell, D, which typically rises in a recession. In a closed economy a recessionary shock reduces the available resources. This makes financing unemployment benefits more demanding for the remaining employed workers. This scarcity or financing effect tends to reduce benefits in a recession. On the other hand, the elasticity to search $\epsilon_{D_2} := \frac{D}{D_2} \frac{f}{\psi_s}(1-s)$ is affected by the business cycle as well and typically falls in a recession. This is due to the typical decline in the aggregate hiring rate f in a recession. In essence, recessions are particularly bad times to provide search effort because, due to aggregate conditions outside the worker's control, the likelihood of finding a new job declines. In the extreme, if there were a complete "hiring freeze" so $f \to 0$, the elasticity ϵ_D would go to zero as well. Providing incentives to search would then be irrelevant. The government would provide as much insurance as possible. This effect tends to increase benefit payments in a recession and is, as we will show, quantitatively the dominant force at work.

Vacancy subsidies and layoff taxes are driven by the dynamics of ζ_t, which, staying with the assumptions of log-utility and $\beta \to 1$, is given by $\zeta = c_u D$. Focus first on the vacancy subsidies. Two forces are at work. First, recessions tend to increase the total costs of insuring an unemployment spell. While consumption when unemployed c_u will typically fall, this tends to be dwarfed by a strong increase in the average duration of unemployment.[6] As the costs to the government of not having a worker employed thereby increase, the government considers it worthwhile to raise hiring subsidies in a recession; see equation (25). Second, and working in the same direction, the cost per hire $\kappa_v \theta / f$ will typically fall in a recession, further tilting the environment toward an increase in vacancy subsidies.

Equation (26), which characterizes the layoff tax , suggests that these should rise in a recession. Keeping a worker at the margin employed is more valuable from a 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.

Having discussed the intuition that one can obtain using the steady-state relationships, we next state the central proposition of this paper. In particular, 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 Section 2. Consider CRRA preferences. Define* $\Omega_t := \frac{\eta_t}{\gamma}\frac{1-\gamma}{1-\eta_t}$. *Assume that the bargaining power* η_{t+1} *is measurable* 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 3.1. Suppose, in addition, that the government implements the following policies for all periods* $t \geq 0$:

$$\tau_{v,t} = \left[1 - \frac{\Omega_{t+1}}{1+\varsigma_t}\right] + \frac{\eta_{t+1}}{1-\eta_{t+1}} \frac{\zeta_t}{(1+\varsigma_t)\kappa_v \frac{\theta_t}{f_t}}, \tag{29}$$

$$\tau_{\xi,t} = \tau_{J,t} + \tau_{v,t}\kappa_v \frac{\theta_t}{f_t} + \zeta_t(1 - s_t f_t), \tag{30}$$

$$\begin{aligned} b_{t+1}\mathbb{E}_t\left[\beta \frac{\lambda_{t+1}}{\lambda_t}\frac{c_{e,t+1}}{e_{t+1}}\right] &= \tau_{v,t}\kappa_v \frac{\theta_t}{f_t} + \zeta_t - \mathbb{E}_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\zeta_{t+1}(1-s_{t+1}f_{t+1})(1-\xi_{t+1})\right] \\ &\quad -\mathbb{E}_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\tau_{v,t+1}\kappa_v\frac{\theta_{t+1}}{f_{t+1}}\frac{e_{t+2}}{e_{t+1}}\right] + \mathbb{E}_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\frac{\Pi_{t+1}}{e_{t+1}}\right], \end{aligned} \tag{31}$$

$$\begin{aligned} \tau_{J,t} &= \frac{1-e_t}{e_t}\left[b_t c_{e,t} - \Pi_t\right] + \kappa_v \tau_{v,t}\theta_t\left[\frac{1-e_t}{e_t}s_t - \xi_t\frac{1-s_t f_t}{f_t}\right] \\ &\quad -\zeta_t\xi_t(1-s_t f_t), \end{aligned} \tag{32}$$

where the two wedges ζ_t *and* ς_t *are given by* (33) *and* (34).

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

[6] In contrast to an open economy, the government cannot fully consumption-insure the society as a whole against aggregate fluctuations and will therefore, typically, reduce consumption of all workers, including the unemployed, due to the scarcity of aggregate resources. Note that the replacement rate, that is, the consumption levels of unemployed workers relative to employed workers, will typically increase nevertheless if consumption of the unemployed due to the curvature of the utility function falls by less than the consumption of the employed.

planner's problem and vice versa.

Proof. The proof is in Appendix B.3. □

A discussion of the proposition is in order. First, in regard to the conditions under which the proposition holds, note that these are not particularly stringent. The tax and benefit rules provided in the proposition hold exactly. If one were to relax the assumption that bargaining power η_{t+1} is measurable t, the tax and benefit rules would still remain valid up to a first-order approximation, with η_{t+1} then replaced by $\mathbb{E}_t\eta_{t+1}$.

In regard to content, the proposition shows that over the cycle additional intertemporal wedges show up in some places. Dynamically, wedge ζ_t is given by

$$\begin{aligned}\zeta_t \quad = \quad & \frac{\psi_s}{f_t(1-s_t)}\frac{1}{\lambda_t}\frac{1-e_t}{[\xi_t e_t+(1-e_t)]}\frac{1-\frac{\mathrm{u}'(c_{e,t})}{\mathrm{u}'(c_{u,t})}}{\frac{\mathrm{u}'(c_{e,t})}{\mathrm{u}'(c_{u,t})}(1-e_t)+e_t} \qquad (33)\\ & +\frac{\psi_s}{f_t(1-s_t)}\frac{1}{s_t f_t[\xi_t e_t+(1-e_t)]}\frac{1}{\lambda_t}e_{t+1}\left[\frac{1}{\frac{\mathrm{u}'(c_{e,t+1})}{\mathrm{u}'(c_{u,t+1})}(1-e_{t+1})+e_{t+1}}-\frac{1}{\frac{\mathrm{u}'(c_{e,t})}{\mathrm{u}'(c_{u,t})}(1-e_t)+e_t}\right].\end{aligned}$$

The first row resembles the results we discussed for the steady state. The second row is related to how the degree of insurance evolves over time. It is zero in the steady state. Similarly ς_t, given by

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

measures how the wedge between the planner's marginal utility of wealth and the employed workers' marginal utility evolves over time. ς is equal to zero in the steady state.

The previous discussions using the steady-state equations summarize the effects quite neatly for the vacancy subsidies, equation (29), and the layoff taxes, equation (30), which turn out to take the same form as in the steady state. The benefit rule is quite a bit more complex, however. From a technical point of view, it is worth mentioning that while the government cannot fully insure the worker's consumption, the utility promise for the future is such that it entails a time path of the replacement rate, b_{t+1}, that does not depend on tomorrow's state of the economy; see equation (31).

4 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 such that it matches key properties of the U.S. labor market. Subsequently, in Section 5, we treat these parameters as structural and ask what the labor market-policy mix *should* look like.

4.1 Data used for the calibration

We calibrate the model to data from 1976Q1 through 2011Q1.[7] 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.[8] 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, ξ_t, with the flow rate from employment to unemployment in the same data set. This rate, too, is adjusted for time-aggregation.[9] 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, ξ_t, is countercyclical and somewhat less responsive to the cycle than the finding rate. Wages are mildly procyclical

[7] 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.

[8] 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.

[9] 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	ξ	w	θ
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
	ξ	-	-	-	-	-	1.00	-0.42	-0.72
	w	-	-	-	-	-	-	1.00	0.31
	θ	-	-	-	-	-	-	–	1.00

Notes: 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.

and somewhat less volatile than output.

4.2 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

Table 2: Parameters for baseline

Preferences		
β	time-discount factor.	0.996
$\overline{h}$	disutility of work.	0.384
ψ_s	scaling parameter dispersion utility cost of search.	0.215
Vacancies, matching and bargaining		
κ_v	vacancy posting cost.	0.176
α	match elasticity with respect to vacancies.	0.300
χ	scaling parameter for match-efficiency.	0.297
η	steady-state bargaining power of firm.	0.300
γ_w	degree of cyclicality of bargaining power of worker.	13.97
Production and layoffs		
μ_ϵ	mean idiosyncratic cost.	0.063
ψ_ϵ	scaling parameter dispersion idiosyncratic cost shock.	0.659
ρ_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
τ_v	Vacancy posting subsidy.	0
τ_ξ	Layoff tax	0.680

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

leisure to $\overline{h} = 0.384$ such that in the steady state 7.5 percent of workers are unemployed ($\xi e + u$). As a result, the gap between the 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, that 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).[10] 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.[11] 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, the Hosios (1990) condition would be satisfied without any government intervention. We view this as a natural – and customary – choice. In order 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 may not 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 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). More in detail, we specify that the bargaining power follows

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

[10] 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

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

[11] 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.

Note that related assumptions are common in the literature.[12] We choose the value of γ_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 $\eta = 0.3$ 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.

In regard to policy variables, for the baseline we specify these directly and set them to constant values. 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 $\tau_{v,t} = 0$. 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.[13] Column "baseline" of 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. Unemployment and vacancies are considerably more volatile

[12] 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 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).

[13] 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."

Table 3: Business cycle properties of the model

		y	$Lprod$	$urate$	v	f	ξ	w	θ
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
	ξ	-	-	-	-	-	1.00	-0.99	-0.99
	w	-	-	-	-	-	-	1.00	0.99
	v/u	-	-	-	-	-	-	-	1.00

Notes: 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.

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.

5 The optimal labor-market policy mix

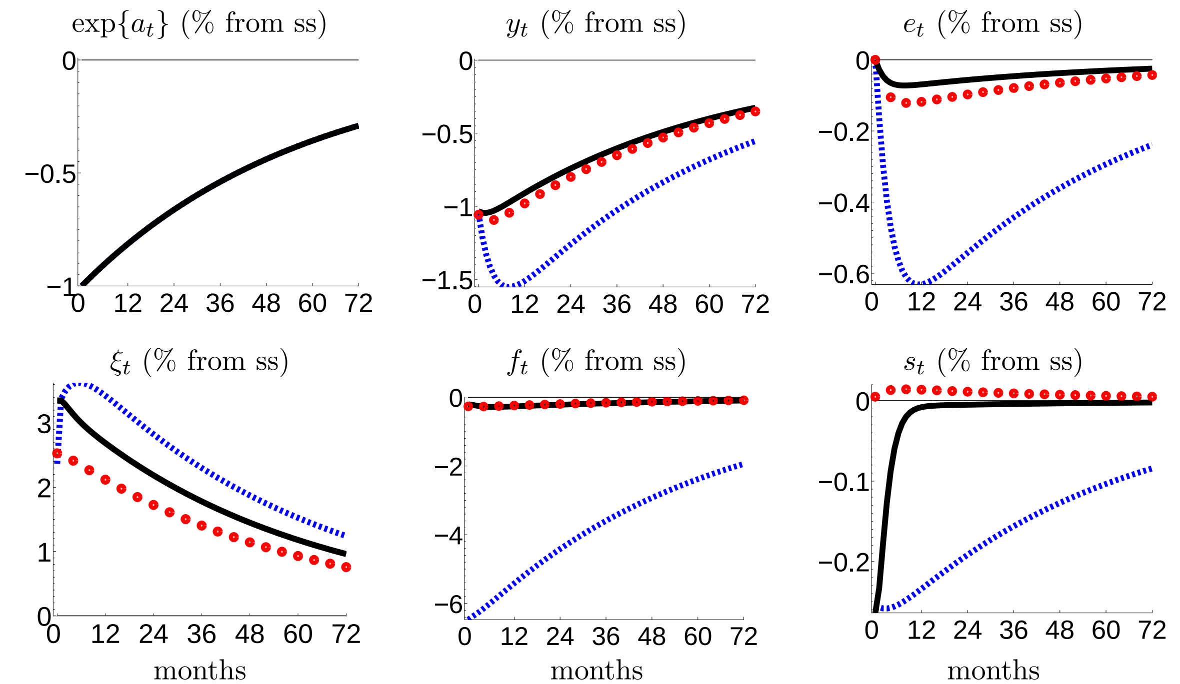
We now proceed to a quantitative exploration of the optimal labor-market policy mix over the business cycle. We first ask what the optimal mix of labor-market policies looks like in response to a recessionary shock and how closely the resulting allocations resemble the (unattainable) first-best in which search effort would be observable.[14] Thereafter, we link our results to the literature by restricting the planner 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 constrast, 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.

5.1 Optimal policy over the business cycle

Figure 1 shows the economy's response to a 1 percent shock to productivity. Red dots mark

[14] The steady state of this exercise is shown in Appendix D.

Figure 1: Impulse response to a technology shock - baseline, planner, and first-best



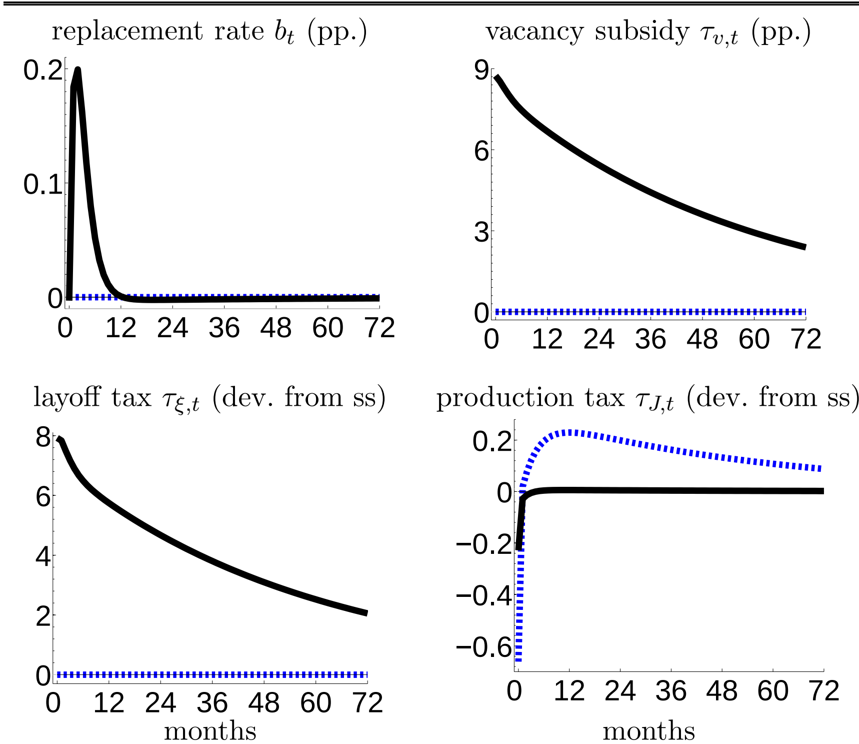
Notes: The figure shows responses of the monthly variables to a -1 percent shock to labor productivity (top left corner). The solid black line marks responses in the planner economy (constrained-efficient equilibrium). The blue dashed line marks responses in the calibrated baseline, the red dots the 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).

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 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. Employment falls considerably. The weakened prospects in the labor market along with the constant replacement rate reduce the search incentives for unemployed workers. This adds to the unfolding of the recession, since firms do not create jobs that would be desirable from the society's point of view. Output drops by considerably more than the movement in productivity alone would suggest (see the blue dashed line).

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 low idiosyncratic productivity 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.

The last set of results that we show in Figure 1 concerns the constrained-efficient 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 consumption insurance in the recession.

Figure 2: Policy responses to a technology shock



Notes: The figure shows the responses of the tax and benefit instruments that decentralize the constrained-efficient allocation (solid black line) and compares these 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. In the optimum, the replacement rate increases by about 0.2 percentage point relative to the steady-state value of 45 percent. That increase lasts for about a year. While the increase in unemployment benefits is reminiscent of the findings in Landais, Michaillat, and Saez (2010), the reason why the government can and should provide more insurance in a recession differs. 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 better 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 layoff taxes 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.

Table 4: Business cycle properties – baseline, constrained-efficient, first-best

	y	$Lprod$	$urate$	v	f	ξ	w	θ
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

Notes: 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.

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.

5.2 Restricted set of instruments

So far, we have worked under the assumption that the government makes use 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.

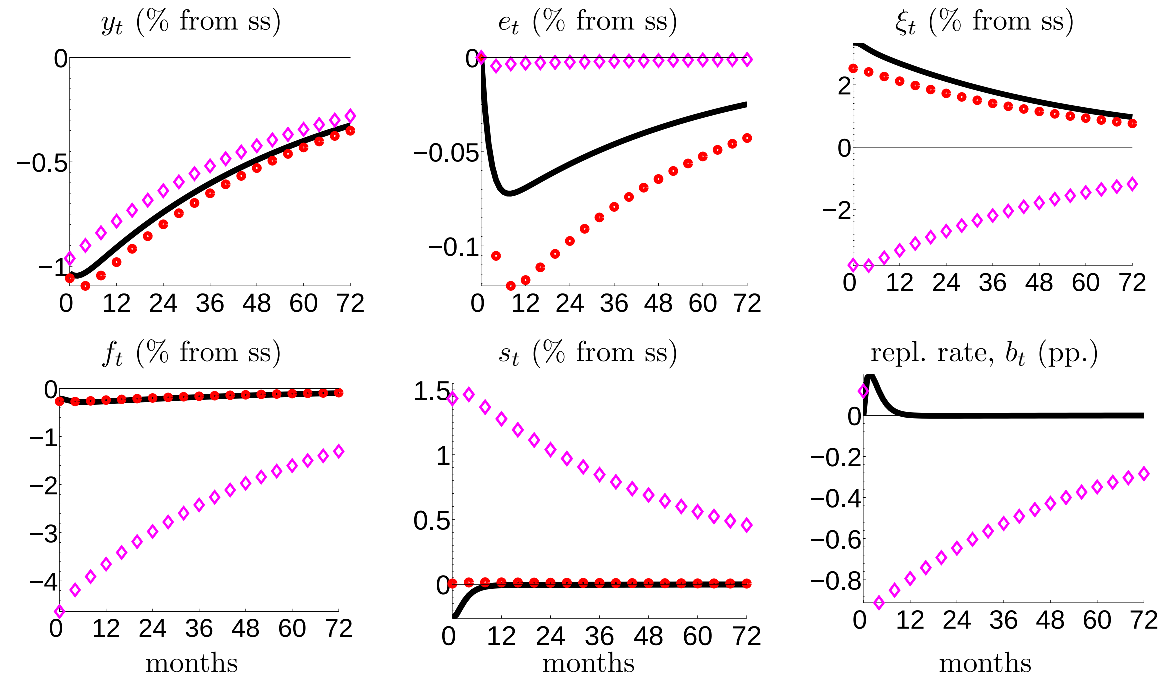
For comparison with the literature, for example, Landais, Michaillat, and Saez (2010) and Mitman and Rabinovich (2011), we first show the economy's response when the planner optimizes only the use of unemployment benefits (Figure 3). In order to highlight the effect of the additional two labor-market instruments that we allow for, in a second step we then report the responses if the government does optimally choose layoff taxes and hiring subsidies, but not unemployment benefits (Figure 4 and Figure 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.[15]

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 (magenta-colored diamonds), the results are reminiscent of Mitman and Rabinovich (2011). The government needs to trade off insurance through the job and insurance through unemployment benefits, and opts for reducing the replacement rate considerably. The replacement rate falls by almost 1 percentage point if labor productivity falls by 1 percent. The reduction in the replacement rate follows the persistence of the underlying shock. 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

[15] 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 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 4.

Figure 3: Impulse response to a technology shock - only unemployment benefits react

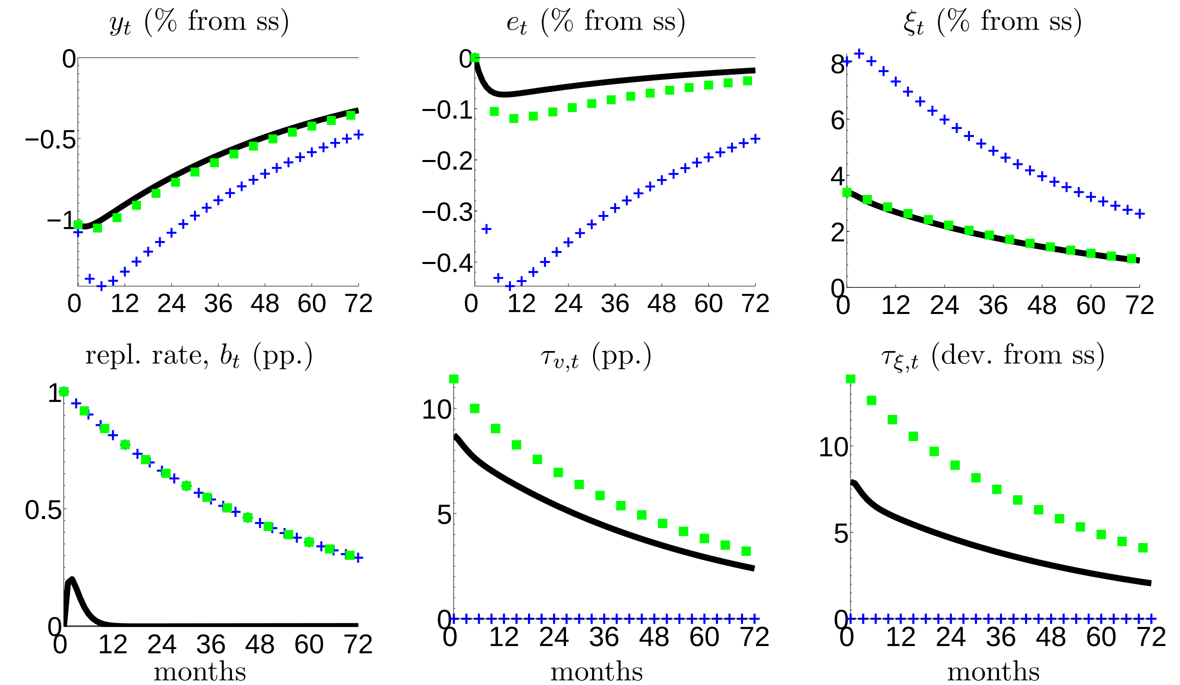


Notes: The figure shows responses of the monthly variables to a -1 percent shock to labor productivity. The solid black line marks responses in the planner economy (constrained-efficient equilibrium). The red dots mark responses in the first-best. The magenta diamonds mark the responses when, over the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

in the first-best, b) firms have more of an incentive to hire, but still much less so than in the first-best, and c) separations of existing matches fall, in contrast to the increase in separations witnessed in both the constrained-efficient and first-best equilibria. Indeed, 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 constrained-efficient equilibrium and more persistently (second line, left panel of Figure 4). For this scenario for unemployment benefits, the figure shows two alternative responses of the layoff

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

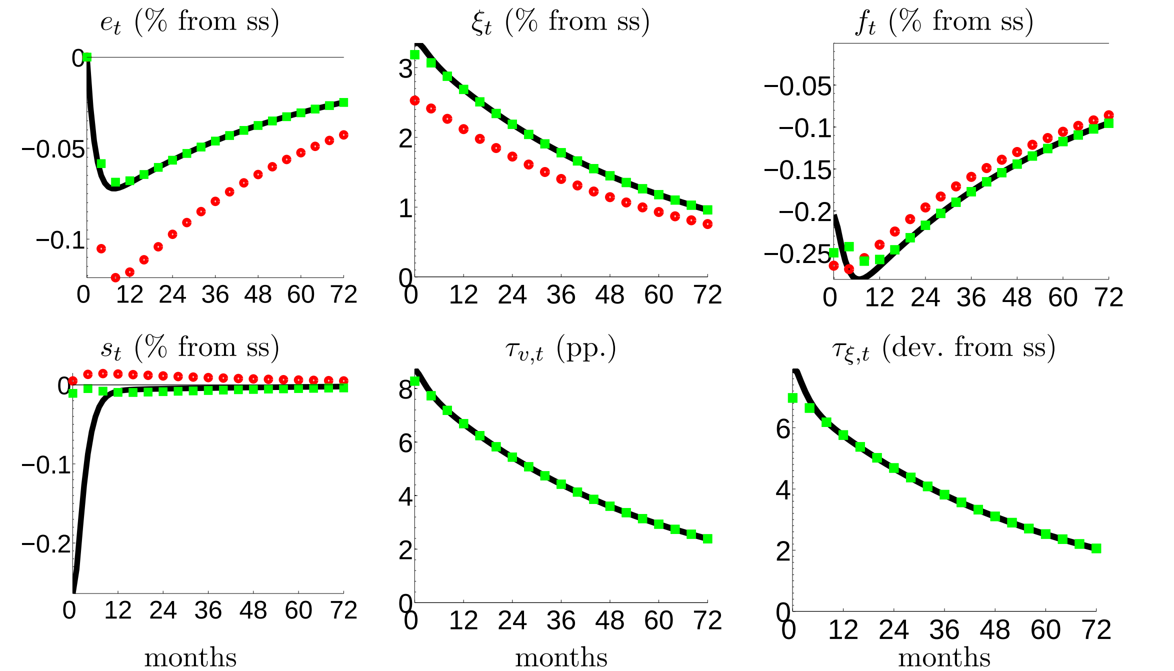


Notes: The figure shows responses of the monthly variables to a -1 percent shock to labor productivity. The solid black line marks responses in the planner economy (constrained-efficient equilibrium). The scenarios of the other two lines have the same steady state as the constrained-efficient equilibrium. 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.

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 these non-standard instruments rise more strongly 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. 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 rise in the optimal policy mix of Figures 1 and 2 without adversely affecting economic outcomes.

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

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



Notes: 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.

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).

6 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 (2003)-type matching frictions in the labor market. The model features endogenous hiring and separations and endogenous search effort. Search effort by unemployed workers is private information. The government therefore cannot completely insure workers, who are risk-averse, against consumption fluctuations due to unemployment.

We have shown analytically that the constrained-efficient 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 insurance-moral-hazard tradeoff 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 should 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 because hiring can be induced at a lower cost in a recession: not only does the cost per hire fall in a recession but also the opportunity cost of not having an unemployed worker hired rises because the duration of unemployment rises in a recession. The resulting costs of unemployment insurance 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 have illustrated that vacancy subsidies and layoff taxes are essential for bringing the economy's response to a recessionary impulse close to first-best. In the absence of these instruments, the government would need to cut unemployment benefits quite dramatically – in the middle of a recession – so as to 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, but not all, of the current policy debate. 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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A Planner's Problem

We state the social planner's problem in recursive form. The planner enters the period facing the following state variables: aggregate productivity state a, e^p employed workers and a promised utility difference Δ^p. Here as in the following, a superscript ^{p} marks the allocation in the planner problem. The planner maximizes a utilitarian welfare function, choosing state-contingent promised utility $\Delta^{p\prime}_{a'}$ levels,[16] consumption choices c^p_e and c^p_u, separation decisions ξ^p and market tightness θ^p. Let $\Psi_x(x)$ denote the option value of having a choice with $\Psi_x(x) := -\psi_x[(1-x)\log(1-x) + x\log(x)]$, and with μ_ϵ the average cost.[17]
The planner's problem can be written as

$$\mathtt{W}(a, e^p, \Delta^p) = \max_{\xi^p, \theta^p, c^p_e, c^p_u, \{\Delta^{p\prime}_{a'}\}} e^p \mathtt{u}(c^p_e) + (1-e^p)\mathtt{u}(c^p_u) + [\xi^p e^p + (1-e^p)](\Psi_s(s^p) + \overline{h}) + \beta \mathbb{E}_a \mathtt{W}(a', e^{p\prime}, \Delta^{p\prime})$$

subject to the budget constraint

$$e^p(1-\xi^p)\exp\{a\} = c^p_e e^p + (1-e^p)c^p_u + \mu_\epsilon(1-\xi^p)e^p - e^p\Psi_\xi(\xi^p) + \kappa_v[\xi^p e^p + (1-e^p)]s^p\theta^p, \quad (35)$$

the participation constraint

$$s^p = \frac{1}{1 + e^{\frac{-f^p \beta \mathbb{E}_a \Delta^{p\prime}}{\psi_s}}} \quad (36)$$

the promise-keeping constraint

$$\Delta^p = \mathtt{u}(c^p_e) - \overline{h}(1-\xi^p) - \mathtt{u}(c^p_u) + \beta E_a \Delta^{p\prime}(1-\xi^p) + (1-\xi^p)\psi_s \log(1-s^p), \quad (37)$$

and the constraint on the law of motion for employment

$$e^{p\prime} = e^p(1-\xi^p) + [\xi^p e^p + (1-e^p)]s^p \chi(\theta^p)^\gamma. \quad (38)$$

In the last expression, the job-finding rate is defined as $f \equiv \chi(\theta^p)^\gamma$. Denoting by λ^p_Δ the Lagrange multiplier on the promise-keeping constraint and by λ^p_c the Lagrange multiplier on the budget constraint, the first-order conditions with respect to the two consumption levels c_e and c_u deliver:

$$\lambda^p_\Delta = \frac{[\mathtt{u}'(c^p_e) - \mathtt{u}'(c^p_u)]e^p(1-e^p)}{\mathtt{u}'(c^p_e)(1-e^p) + e^p\mathtt{u}'(c^p_u)}, \quad (39)$$

$$\lambda^p_c = \frac{\mathtt{u}'(c^p_e)\mathtt{u}'(c^p_u)}{\mathtt{u}'(c^p_e)(1-e^p) + e^p\mathtt{u}'(c^p_u)} = \left[\frac{e^p}{\mathtt{u}'(c_e)} + \frac{1-e^p}{\mathtt{u}'(c_u)}\right]^{-1}. \quad (40)$$

[16] In terms of notation, subindex $_{a'}$ here indicates that the level of future promised utility is chosen in a state-contingent way.

[17] In the following, we sketch the derivations skipping over a number of intermediate steps. A technical appendix that goes through all the derivations in much more detail is available from the authors upon request.

The first-order condition regarding separations, ξ^p, is given by

$$
\begin{aligned}
0 \quad = \quad & [\Psi_s(s) + \overline{h}] + \lambda_c^p[-\exp\{a\} + \mu_\epsilon + \Psi'_\xi(\xi^p) - \kappa_v s^p \theta^p] \\
& + \tfrac{\lambda_\Delta^p}{e^p}[\mathbb{E}_a \beta \Delta^{p\prime} - \overline{h}] + \tfrac{\lambda_\Delta^p}{e^p}\psi_s \log(1-s) + \beta \mathbb{E}_a \tfrac{\partial \mathtt{W}}{\partial e'}[-1 + s f^p].
\end{aligned} \tag{41}
$$

The first-order condition for market tightness θ delivers:

$$
\begin{aligned}
0 \quad = \quad & -\left[\kappa_v + \kappa_v \frac{\partial s^p}{\partial \theta^p}\frac{\theta^p}{s^p}\right] - \mathbb{E}_a \beta \frac{\Delta^{p\prime}}{\lambda_c^p}\frac{\partial s^p}{\partial \theta^p}\frac{f^p}{s^p} + \mathbb{E}_a \beta \frac{\lambda_c^{p\prime}}{\lambda_c^p}\frac{\frac{\partial \mathtt{W}}{\partial e^{p\prime}}}{\lambda_c^{p\prime}}\left[\gamma \frac{f^p}{\theta^p} + \frac{\partial s^p}{\partial \theta^p}\frac{f^p}{s^p}\right] \\
& + \frac{\lambda_\Delta^p}{\lambda_c^p}\psi_s \frac{1}{1-s^p}\frac{\partial s^p}{\partial \theta^p}\frac{1}{s^p}\frac{(1-\xi^p)}{[\xi^p e^p + (1-e^p)]}.
\end{aligned} \tag{42}
$$

The first-order conditions for state-contingent promised utility $\Delta^{p'}$ are:

$$
\begin{aligned}
\beta \frac{\lambda_\Delta^p}{\lambda_c^p}(1-\xi^p) \quad = \quad & \beta \frac{\lambda_c^{p\prime}}{\lambda_c^p}\frac{\frac{\partial \mathtt{W}}{\partial \Delta^{p\prime}}}{\lambda_c^{p\prime}} + \frac{\lambda_\Delta^p}{\lambda_c^p}\frac{\psi_s}{1-s^p}(1-\xi^p)\frac{\partial s^p}{\partial \Delta^{p\prime}} \\
& + [1-(1-\xi^p)e^p]\psi_s \log\left(\frac{1-s^p}{s^p}\right)\frac{\partial s^p}{\partial \Delta^{p\prime}} \\
& + \mathbb{E}_a \beta \frac{\lambda_c^{p\prime}}{\lambda_c^p}\frac{\frac{\partial \mathtt{W}}{\partial e^{p\prime}}}{\lambda_c^{p\prime}} f^p \frac{\partial s^p}{\partial \Delta^{p\prime}}[1-(1-\xi^p)e^p] - \kappa_v \frac{\partial s^p}{\partial \Delta^{p\prime}}\theta^p[1-(1-\xi^p)e^p].
\end{aligned} \tag{43}
$$

The envelope conditions are:

$$
\frac{\frac{\partial \mathtt{W}}{\partial \Delta^p}}{\lambda_c^p} \quad = \quad \frac{\lambda_\Delta^p}{\lambda_c^p}. \tag{44}
$$

$$
\begin{aligned}
\frac{\frac{\partial \mathtt{W}}{\partial e^p}}{\lambda_c^p} \quad = \quad & \frac{[\mathtt{u}(c_e^p) - \mathtt{u}(c_u^p)]}{\lambda_c^p} - \frac{(1-\xi^p)\left[\Psi(s^p) + \overline{h}\right]}{\lambda_c^p} + \mathbb{E}_a \beta \frac{\lambda_c^{p\prime}}{\lambda_c^p}\frac{\frac{\partial \mathtt{W}}{\partial e^{p\prime}}}{\lambda_c^{p\prime}}(1 - s^p f^p)(1-\xi^p) \\
& + (1-\xi^p)\left[\exp\{a\} - \mu_\epsilon\right] - c_e^p + c_u^p + \Psi_\xi(\xi^p) \\
& + \kappa_v s^p \theta^p (1-\xi^p).
\end{aligned} \tag{45}
$$

After a sequence of manipulations one can derive a "bargaining equation of the planner":

$$
\kappa_v \frac{\theta^p}{\gamma f^p} = \quad \mathbb{E}_a \beta \frac{\lambda_c^{p\prime}}{\lambda_c^p} J^{p\prime} + (1+\varsigma^p)\mathbb{E}_a \beta \frac{\lambda_c^{p\prime}}{\lambda_c^p}\frac{\Delta^{p\prime}}{\mathtt{u}'(c_e^{p\prime})}, \tag{46}
$$

where we have defined $J^p := \frac{\frac{\partial \mathtt{W}}{\partial e^p}}{\lambda_c^p} - \frac{\Delta^p}{\lambda_c^p}$, and the wedge ς^p as

$$
\varsigma^p = \frac{e^p(1-\xi^p)}{[\xi^p e^p + (1-e^p)] f^p s^p}\left[1 - \frac{\frac{\mathtt{u}'(c_e^{p\prime})}{\lambda_c^{p\prime}}}{\frac{\mathtt{u}'(c_e^p)}{\lambda_c^p}}\right]. \tag{47}
$$

Similarly, one can derive the "planner's free-entry condition":

$$\kappa_v \frac{\theta^p}{f^p} = E_a \beta \frac{\lambda_c^{p\prime}}{\lambda_c^p} J^{p\prime} - \zeta^p, \tag{48}$$

where we have defined the wedge ζ^p as

$$\begin{aligned}\zeta^p \quad = \quad & \frac{\psi_s}{f^p(1-s^p)} \frac{1}{[\xi^p e^p + (1-e^p)]} \frac{1}{\lambda_c^p} \left[\frac{\lambda_c^p}{\mathtt{u}'(c_e^p)} - 1\right] \\ & + \frac{\psi_s}{f^p(1-s^p)} \frac{1}{s^p f^p [\xi^p e^p + (1-e^p)]} \frac{1}{\lambda_c^p} e^{p\prime} \left[\frac{\lambda_c^{p\prime}}{\mathtt{u}'(c_e^{p\prime})} - \frac{\lambda_c^p}{\mathtt{u}'(c_e^p)}\right].\end{aligned} \tag{49}$$

An extensive derivation is available upon request.

A.1 The ratio of marginal utilities next period is measurable this period

This section shows that the planner promises marginal utilities of consumption in the next period such that the ratio of these, $\mathtt{u}'(c_u')/(\mathtt{u}'(c_e'))$, is measurable in this period. That is, next period's ratio of marginal utilities is known already today. As a special case, for CRRA utility, under the planner's allocations, the "replacement rate" next period, $b^{p\prime} := c_u^{p\prime}/c_e^{p\prime}$ therefore is known already this period.

The promise-keeping constraint, equation (43), can be rewritten as

$$\begin{aligned}\beta \frac{\lambda_\Delta^p}{\lambda_c^p}(1-\xi^p) \quad = \quad & \beta \frac{\lambda_c^{p\prime}}{\lambda_c^p} \frac{\frac{\partial \mathtt{W}}{\partial \Delta^{p\prime}}}{\lambda_c^{p\prime}} + \frac{\lambda_\Delta^p}{\lambda_c^p} \frac{\psi_s}{1-s^p}(1-\xi^p) \frac{\partial s^p}{\partial \Delta^{p\prime}} \\ & -[1-(1-\xi^p)e^p] f^p \beta \mathbb{E}_a \left\{\frac{\Delta^{p\prime}}{\lambda_c^p}\right\} \frac{\partial s^p}{\partial \Delta^{p\prime}} \\ & + \mathbb{E}_a \beta \frac{\lambda_c^{p\prime}}{\lambda_c^p} \frac{\frac{\partial \mathtt{W}}{\partial e^{p\prime}}}{\lambda_c^{p\prime}} f^p \frac{\partial s^p}{\partial \Delta^{p\prime}} [1-(1-\xi^p)e^p] - \kappa_v \frac{\partial s^p}{\partial \Delta^{p\prime}} \theta^p [1-(1-\xi^p)e^p].\end{aligned}$$

Observe that, by envelope condition (44),

$$\frac{\lambda_c^{p\prime}}{\lambda_c^p} \frac{\frac{\partial \mathtt{W}}{\partial \Delta^{p\prime}}}{\lambda_c^{p\prime}} = \frac{\lambda_c^{p\prime}}{\lambda_c^p} \frac{\lambda_\Delta'}{\lambda_c^{p\prime}} = \frac{\lambda_\Delta'}{\lambda_c^p.}$$

Then observe that $\partial s^p/(\partial \Delta^{p\prime})$ is measurable this period. As a result, all terms in the promise-keeping constraint apart from λ_Δ' are measurable this period. Therefore, λ_Δ' also needs to be measurable this period. λ_Δ' therefore is independent of the realization of the future shock.

Now, use the first-order conditions for consumption, which imply equation (39). Rearranging this, and moving it one period forward,

$$\lambda_\Delta^{p\prime} = \frac{\left[1 - \frac{\mathtt{u}'(c_u^{p\prime})}{\mathtt{u}'(c_e^{p\prime})}\right] e^{p\prime}(1-e^{p\prime})}{(1-e^{p\prime}) + e^{p\prime} \frac{\mathtt{u}'(c_u^{p\prime})}{\mathtt{u}'(c_e^{p\prime})}}.$$

Employment at the beginning of the next period is known as of this period; compare employment-flow equation (38). Therefore, if $\lambda_{\Delta}^{p\prime}$ is measurable this period, so must the ratio of next period's marginal utilities $\frac{\mathtt{u}'(c_u^{p\prime})}{\mathtt{u}'(c_e^{p\prime})}$. The claim regarding the replacement rate follows from the fact that for CRRA utility

$$\frac{\mathtt{u}'(c_u^{p\prime})}{\mathtt{u}'(c_e^{p\prime})} = \left(\frac{c_u^{p\prime}}{c_e^{p\prime}}\right)^{-\sigma},$$

where $\sigma > 0$ is the coefficient of relative risk aversion.

B Decentralization

This section decentralizes the equilibrium allocation in the planner's problem by means of a set of benefit and tax rules. First, we define a decentralized equilibrium. This definition collects all equilibrium conditions in the decentralized economy. Then, we state Proposition 3, which is a slightly more general version of Proposition 2 in the main text. The proposition states that certain tax rules decentralize the planner's allocation. We sketch the proof of the proposition.[18] In order to show the equivalence and save on notation, this section uses t-notation throughout.

B.1 Definition: decentralized equilibrium

A decentralized equilibrium is a sequence of job-finding rates f_t, vacancy-filling rates q_t, separation rates and separation cutoff levels ξ_t and ϵ_t^{ξ}, search intensities s_t, labor market tightness θ_t, matches m_t, vacancies v_t, consumption levels $c_{e,t}$, $c_{0,t}$, and $c_{u,t}$, aggregate levels of output y_t, and dividends Π_t, a discount factor $Q_{t,t+1}$, wage rates w_t, severance payments $w_{eu,t}$, employment rates e_t, firm values J_t, and surpluses of the worker Δ_t, and a sequence of government policies (a profit tax rate, $\tau_{J,t}$, a vacancy subsidy, $\tau_{v,t}$, a layoff tax $\tau_{\xi,t}$ and unemployment benefits B_t) such that the following are true:

1. The value of the firm is given by (10) and can be rearranged to:

$$\begin{aligned} J_t \quad = \quad & [\exp\{a_t\} - \mu_\epsilon - w_t - \tau_{J,t} + \mathbb{E}_t Q_{t,t+1} J_{t+1}] \\ & -\psi_\epsilon \log(1-\xi_t) + \xi_t \left[\frac{\beta \mathbb{E}_t \Delta_{u,t+1}^e + \psi_s \log(1-s_t) - \overline{h}}{\mathtt{u}'(c_{e,t})}\right]. \end{aligned} \tag{50}$$

2. The surplus of the worker is given by (2) and (5) and can be rearranged to:

$$\Delta_{u,t}^e = \mathtt{u}(c_{e,t}) - \overline{h}(1-\xi_{,t}) - \mathtt{u}(c_{u,t}) + \beta E_a \Delta_{u,t+1}^e (1-\xi_t) + (1-\xi_t)\psi_s \log(1-s_t). \tag{51}$$

[18] A detailed derivation is available from the authors upon request.

3. The search intensity is chosen optimally and is given by:

$$s_t = \frac{1}{1 + e^{\frac{-f_t \beta \mathbb{E}_t \Delta^e_{u,t+1}}{\psi_s}}}. \tag{52}$$

4. Firms choose the number of vacancies optimally, the free-entry condition equation (11) is repeated below:

$$\kappa_v \frac{\theta_t}{f_t}(1 - \tau_{v,t}) = \mathbb{E}_t Q_{t,t+1} J_{t+1}. \tag{53}$$

5. Wages w_t, severance payments, $w_{eu,t}$, and separation cutoffs, ϵ_t^ξ, are bargained according to Nash-bargaining protocol (12). The resulting first-order conditions are:

   (a) For the wage, equation (13) is repeated here:

$$(1 - \eta_t) J_t = \eta_t \frac{\Delta^e_{u,t}}{\mathrm{u}'(c_{e,t})}. \tag{54}$$

   (b) For the severance payments

$$w_{eu,t} = w_{e,t}. \tag{55}$$

   (c) For the separation cutoff, equation (14) is repeated here:

$$\begin{aligned} \epsilon_t^\xi \quad = \quad & [\exp\{a_t\} - \tau_{J,t} + \tau_{\xi,t} + \mathbb{E}_t Q_{t,t+1} J_{t+1} \\ & + \tfrac{\beta \mathbb{E}_t \Delta^e_{u,t+1} + \psi_s \log(1 - s_t) - \overline{h}}{\mathrm{u}'(c_{e,t})}. \end{aligned} \tag{56}$$

6. The separation cutoff implies a share of separations, ξ_t, that is in line with the logistic distribution. The corresponding equation (15) is repeated here:

$$\xi_t = 1/(1 + \exp\{(\epsilon_t^\xi - \mu_\epsilon)/\psi_\epsilon\}. \tag{57}$$

7. Matches link vacancies and workers who search for a job according to matching function (8), repeated here:

$$m_t = s_t f_t [\xi_t e_t + u_t]. \tag{58}$$

8. The job-finding rate is defined as

$$f_t = m_t / (s_t [\xi_t e_t + u_t]). \tag{59}$$

9. The vacancy-filling rate is defined as

$$q_t = m_t / v_t. \tag{60}$$

10. Labor-market tightness is defined as

$$\theta_t = v_t/u_t. \tag{61}$$

11. Employment evolves according to (7), or alternatively:

$$e_{t+1} = (1-\xi_t)e_t + s_t f_t[\xi_t e_t + u_t]. \tag{62}$$

12. Firms price future cash flow using discount factor $Q_{t,t+1} := \beta\frac{\lambda_{t+1}}{\lambda_t}$, where λ_t is given by equation (9):

$$\lambda_t = \frac{\mathtt{u}'(c_{e,t})\mathtt{u}'(c_{u,t})}{\mathtt{u}'(c_{e,t})(1-e_t) + e_t\mathtt{u}'(c_{u,t})}. \tag{63}$$

13. Dividends are given by equation (16), which can be rewritten as

$$\Pi_t = e_t(1-\xi_t)[\exp\{a_t\} - \mu_\epsilon - \tau_{J,t}] - e_t w_t - e_t\xi_t\tau_{\xi,t} + e_t\Psi(\xi_t) - \kappa_v(1-\tau_{v,t})v_t. \tag{64}$$

14. Consumption is given by (1), namely

    (a) Consumption when employed during the period:

$$c_{e,t} = w_t + \Pi_t. \tag{65}$$

    (b) Consumption when laid off at the beginning of the period:

$$c_{0,t} = w_t + \Pi_t. \tag{66}$$

    (c) Consumption when unemployed at the beginning of the period:

$$c_{u,t} = B_t + \Pi_t. \tag{67}$$

15. Production equals demand (goods markets clear, Section 2.8 in the text)

$$y_t = e_t(1-\xi_t)\exp\{a_t\}. \tag{68}$$

$$y_t = e_t c_{e,t} + u_t c_{u,t} + \mu_\epsilon(1-\xi_t)e_t - e_t\Psi_\epsilon(\xi_t) + \kappa_v v_t \tag{69}$$

16. The government budget constraint, equation (17), holds:

$$e_t(1-\xi_t)\tau_{J,t} + e_t\xi_t\tau_{\xi,t} = u_t B_t + \kappa_v\tau_v v_t. \tag{70}$$

B.2 Government policies that decentralize the planner's allocation

First, let us rearrange and restate in t-notation the two wedges defined earlier in equations (47) and (49):

$$\varsigma_t = \frac{e_t(1-\xi_t)}{[\xi_t e_t + (1-e_t)]f_t s_t}\left[1 - \frac{\frac{\mathrm{u}'(c_{e,t+1})}{\mathrm{u}'(c_{u,t+1})}(1-e_{t+1}) + e_{t+1}}{\frac{\mathrm{u}'(c_{e,t})}{\mathrm{u}'(c_{u,t})}(1-e_t) + e_t}\right], \tag{71}$$

and

$$\zeta_t = \frac{\psi_s}{f_t(1-s_t)}\frac{1}{\lambda_t}\frac{1-e_t}{[\xi_t e_t + (1-e_t)]}\frac{1 - \frac{\mathrm{u}'(c_{e,t})}{\mathrm{u}'(c_{u,t})}}{\frac{\mathrm{u}'(c_{e,t})}{\mathrm{u}'(c_{u,t})}(1-e_t) + e_t} \tag{72}$$

$$+\frac{\psi_s}{f_t(1-s_t)}\frac{1}{s_t f_t[\xi_t e_t + (1-e_t)]}\frac{1}{\lambda_t}e_{t+1}\left[\frac{1}{\frac{\mathrm{u}'(c_{e,t+1})}{\mathrm{u}'(c_{u,t+1})}(1-e_{t+1}) + e_{t+1}} - \frac{1}{\frac{\mathrm{u}'(c_{e,t})}{\mathrm{u}'(c_{u,t})}(1-e_t) + e_t}\right].$$

The following proposition summarizes the tax and benefit rules that support the social's planner allocation.

Proposition 3. *Consider the economy described in Section 2. Consider preferences for which the ratio of marginal utilities in the two states of employment can be expressed as some function g, the sole argument of which is the replacement rate $b_t := c_{u,t}/c_{e,t}$. Namely, $\frac{\mathrm{u}'(c_{e,t})}{\mathrm{u}'(c_{u,t})} = g(b_t)$. Define $\Omega_t := \frac{\eta_t}{\gamma}\frac{1-\gamma}{1-\eta_t}$. In addition, assume that the bargaining power η_t is measurable $t-1$. Assume 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 Appendix A. Suppose, in addition, that the government implements the following policies for all periods $t \geq 0$:*

$$\tau_{v,t} = \left[1 - \frac{\Omega_{t+1}}{1+\varsigma_t}\right] + \frac{\eta_{t+1}}{1-\eta_{t+1}}\frac{\zeta_t}{(1+\varsigma_t)\kappa_v\frac{\theta_t}{f_t}}, \tag{73}$$

$$\tau_{\xi,t} = \tau_{J,t} + \tau_{v,t}\kappa_v\frac{\theta_t}{f_t} + \zeta_t(1-s_t f_t), \tag{74}$$

$$b_{t+1}\mathbb{E}_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\frac{c_{e,t+1}}{e_{t+1}}\right] = \tau_{v,t}\kappa_v\frac{\theta_t}{f_t} + \zeta_t - \mathbb{E}_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\zeta_{t+1}(1-s_{t+1}f_{t+1})(1-\xi_{t+1})\right]$$
$$-\mathbb{E}_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\tau_{v,t+1}\kappa_v\frac{\theta_{t+1}}{f_{t+1}}\frac{e_{t+2}}{e_{t+1}}\right] + \mathbb{E}_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\frac{\Pi_{t+1}}{e_{t+1}}\right], \tag{75}$$

$$\tau_{J,t} = \frac{1-e_t}{e_t}[b_t c_{e,t} - \Pi_t] + \kappa_v\tau_{v,t}\theta_t\left[\frac{1-e_t}{e_t}s_t - \xi_t\frac{1-s_t f_t}{f_t}\right]$$
$$-\zeta_t\xi_t(1-s_t f_t), \tag{76}$$

where the two wedges, ς_t and ζ_t, are given by equations (71) and (72).
Then these tax rules are consistent with the government's budget constraint in the decentralized economy. In addition, the equilibrium allocations in the decentralized equilibrium satisfy the first-order conditions in the planner's problem and vice versa.

B.3 Proof of Proposition 3

A detailed proof is available from the authors as part of the longer technical appendix. In the interest of space, here we limit ourselves to sketching the steps. The planner's allocation is characterized by five first-order conditions:

1. With respect to separations: equation (41),
2. With respect to market tightness (hiring): equation (48),
3. With respect to future promised utility: equation (46),
4. With respect to consumption when employed: equation (40),
5. With respect to consumption when unemployed: equation (39),

and four constraints

1. The budget constraint: equation (35),
2. The participation constraint: equation (36),
3. The promise-keeping constraint: equation (37),
4. The law of motion for employment: equation (38).

The proof proceeds by guessing that the allocations in the planner's problem satisfy the equilibrium conditions of the decentralized economy if the tax and benefit rules stated in Proposition 3 are used. This guess is then verified. Next, the proof shows that with these allocations and the resulting values for taxes and benefits the government's budget is balanced. Then, the proof argues that doing the steps sketched above in reverse order, the opposite would be true as well: the equilibrium allocations that result when the tax rules described in Proposition 3 are used in the decentralized economy satisfy the equilibrium conditions of the planner's problem.

C Relation to the Baily-Chetty formula

In this Appendix, we show how our formula for optimal UI benefits relates to the Baily-Chetty formula, compare Baily (1978) and Chetty (2006). We do so in the steady state and for the limiting case of $\beta \to 1$.

The average duration of unemployment is given by $D := 1/(sf)$. The average duration over which the government pays unemployment benefits is given by $D_2 := D - 1$. Note that D_2 is one period shorter than D. The reason is that in the first period of an unemployment spell the worker still consumes c_e (financed by a severance payment by the firm), not a state-financed c_u.

Define the elasticity of the duration of unemployment with respect to an increase in next period's consumption of an unemployed worker as

$$\epsilon_D := \left. \frac{\partial \log D}{\partial \log c_u'} \right|_{f,\Delta''}.$$

This elasticity treats the continuation value next period, Δ'', and aggregate variables (such as the aggregate job-finding rate) now and in the future as constant. Evaluating for $\beta \to 1$, we have that

$$\epsilon_D = \frac{f}{\psi_s}(1-s)\mathtt{u}'(c_u')c_u'. \tag{77}$$

Evaluating this at steady-state values gives

$$\epsilon_D = \frac{f}{\psi_s}(1-s)\mathtt{u}'(c_u)c_u.$$

Also define the elasticity of the duration of unemployment benefit payments with respect to an increase in next period's consumption of an unemployed worker as

$$\epsilon_{D_2} := \left. \frac{\partial \log D_2}{\partial \log c_u'} \right|_{f,\Delta''} = \frac{D}{D_2}\,\epsilon_D.$$

Next, from equations (40) and (72), observe that

$$\zeta \quad = \quad \frac{\psi_s}{f(1-s)} \frac{1-e}{\xi e + (1-e)} \frac{\mathtt{u}'(c_u) - \mathtt{u}'(c_e)}{\mathtt{u}'(c_e)\mathtt{u}'(c_u)} = \frac{1-e}{\xi e + (1-e)}\, c_u \frac{\frac{\mathtt{u}'(c_u)-\mathtt{u}'(c_e)}{\mathtt{u}'(c_e)}}{\epsilon_D}.$$

From equation (21), we have that as $\beta \to 1$:

$$c_u = \zeta s f.$$

Substitute for ζ from above to obtain

$$c_u = sf \frac{1-e}{\xi e + (1-e)}\, c_u \frac{\frac{\mathtt{u}'(c_u)-\mathtt{u}'(c_e)}{\mathtt{u}'(c_e)}}{\epsilon_D},$$

or

$$\mathtt{u}'(c_u) = \mathtt{u}'(c_e)\left[1 + \epsilon_D D \frac{\xi e + (1-e)}{1-e}\right]. \tag{78}$$

Express this in terms of ϵ_{D_2}:

$$\mathtt{u}'(c_u) = \mathtt{u}'(c_e)\left[1 + \epsilon_{D_2} D_2 \frac{\xi e + (1-e)}{1-e}\right].$$

To simplify this further, note that from the employment-flow equation we have that

$$sf = \frac{\xi e}{\xi e + 1 - e},$$

and that

$$1 - sf = \frac{1 - e}{\xi e + 1 - e}.$$

Also, $D_2 = (1 - sf)/sf = D(1 - sf)$. So

$$D_2 \frac{\xi e + (1 - e)}{1 - e} = D(1 - sf)\frac{\xi e + (1 - e)}{1 - e} = D.$$

We can therefore rewrite the optimal UI benefit formula (78) as

$$\mathtt{u}'(c_u) = \mathtt{u}'(c_e)\left[1 + D\,\epsilon_{D_2}\right]. \tag{79}$$

An increase in UI payments for an unemployed worker reduces consumption of an employed worker one by one. It also changes the duration of unemployment by ϵ_{D_2}. Since unemployment spells last on average paid for D periods, we have that the total indirect effect on consumption of an employed worker is $D\,\epsilon_{D_2}$.

D Steady-state properties under the optimal policy mix

This Appendix presents the steady states in the calibrated baseline, the constrained-efficient economy and the first-best; see Table 5. This complements the analysis in Sections 4 and 5.1.

Table 5: Steady state – baseline, constrained-efficient planner, first-best

	planner	baseline	first-best		planner	baseline	first-best
B	0.427	[0.424]	–	u	0.021	[0.057]	(0.046)
b	0.453	[0.451]	–	$urate$	0.026	[0.064]	(0.064)
c_e	0.945	[0.945]	(0.924)	e	0.978	[0.943]	(0.953)
c_0	0.945	[0.945]	(0.924)	s	0.845	[0.843]	(0.947)
c_u	0.428	[0.426]	(0.924)	f	0.369	[0.282]	(0.329)
Δ_u^e	0.996	[1.291]	–	ξ	0.010	[0.018]	(0.022)
w	0.943	[0.943]	–	q	0.180	[0.338]	(0.235)
w_{eu}	0.943	[0.943]	–	θ	2.049	[0.834]	(1.405)
J	0.403	[0.523]	–	v	0.053	[0.052]	(0.089)
Π	.0015	[0.002]	–	y	0.968	[0.925]	(0.932)
τ_ξ	1.499	[0.680]	–	τ_J	0.000	[0.013]	–
τ_v	0.588	[0.000]	–	ζ	1.343	[1.929]	(0.000)

Notes: The table compares the steady-state values of the planner's problem (constrained-efficient) with those of the baseline calibration of Section 4 (in square brackets), and the first-best allocation (in round brackets).

We discuss these briefly. If the planner could directly control the search effort (and thus attain the first-best), the planner would perfectly insure the consumption of all workers regardless of their labor-market state. At the same time, the vast majority of unemployed workers would have to search for a job. More vacancies would be posted so that the steady-state job-finding rate would be higher than in the baseline economy. Out of efficiency considerations, the rate of separation would be higher as well, so that only the lowest-cost matches produce. Output would rise 0.7 percent above the steady-state level of output in the baseline economy. Note that due to perfect consumption insurance in the first-best the tensions summarized by ζ_t are zero. This is a major difference to the constrained-efficient allocation. If search effort cannot be commanded or observed, the planner has to trade off the utility benefits from insurance and the distortions in behavior that insurance generates. The planner does this by providing some – but at a 45 percent replacement rate less than perfect – unemployment insurance. In addition, the planner makes sure that those workers who do search have a reasonably high chance of first finding a job and then a much lower probability of losing the job than in the baseline calibration. As a result of this – and with the search intensity affected little – the unemployment rate falls from 6.4 percent in the baseline to 2.6 percent, and steady-state employment rises. Note that the increase in output and employment is stronger than in the first-best. This is due to the fact that, for reasons of incentive-compatibility, the planner seeks to provide insurance primarily through opportunities to work and job security rather than by means of unemployment benefits.[19]

As suggested by Proposition 1, the tax, subsidy and benefit system that supports the constrained-efficient allocation features positive unemployment benefits. The government would use positive vacancy subsidies and positive layoff taxes to ameliorate the resulting distortions. The size of both of these instruments is quantitatively significant. The vacancy subsidy is worth about 59 percent of the cost of posting a vacancy. Layoff taxes amount to about 1.6 monthly wages. The production tax is close to zero in the steady state.

[19] Our paper restricts the set of contracts that firms and workers can write to one-period contracts. In some sense, the result of "insurance through the job" on behalf of the government is related to the results that the implicit-contract literature stresses for privately optimal contracts in the absence of social insurance; see, for example, Azariadis (1975), and Akerlof and Miyazaki (1980).