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ABSTRACT

This paper examines how optimal unemployment insurance (UI) responds to the state of the labor market. The theoretical framework is a matching model of the labor market with general production function, wage-setting mechanism, matching function, and preferences. We show that optimal UI is the sum of a conventional Baily-Chetty term, which captures the trade-off between insurance and job-search incentives, and a correction term, which is positive if UI brings labor market tightness closer to its efficient level. The state of the labor market determines whether tightness is inefficiently low or inefficiently high. The response of optimal UI to the state of the labor market therefore depends on the effect of UI on tightness. For instance, if the labor market is slack and tightness is inefficiently low, optimal UI is more generous than the Baily-Chetty level if UI raises tightness and less generous if UI lowers tightness. Depending on the production function and the wage-setting mechanism, UI could raise tightness, for example by alleviating the rat race for jobs, or lower tightness, for example by increasing wages through bargaining. To determine whether UI raises or lowers tightness in practice, we develop an empirical criterion. The criterion involves a comparison of the microelasticity and the macroelasticity of unemployment with respect to UI.

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1 Introduction

Unemployment insurance (UI) is a key component of social insurance because it provides relief to people who cannot find a job. The microeconomic theory of optimal UI is well understood: it is an insurance-incentive trade-off in the presence of moral hazard. UI helps workers smooth consumption when they are unemployed, but it also increases unemployment by discouraging job search. The Baily [1978]-Chetty [2006a] formula resolves this trade-off.

The macroeconomic theory of optimal UI is less well understood.[1] This becomes problematic in slumps, when unemployment is unusually high, because adjusting UI could improve welfare through macroeconomic channels. Some argue that UI should be decreased because it creates upward pressure on wages thereby discouraging job creation, which is particularly harmful when unemployment is already high. Others argue that UI should be increased because it cannot have much impact on the unemployment rate when unemployment is already high, since jobs are simply not available.

This paper proposes a framework to analyze how optimal UI responds to the state of the labor market. The framework encompasses the microeconomic insurance-incentive tradeoff and the macroeconomic influence of UI on firms' hiring decisions. We obtain a simple optimal UI formula showing the theoretical conditions under which it is desirable to increase UI when unemployment is high, and the conditions under which this would not be desirable. Our formula also identifies the empirical statistics needed to make policy recommendations. Our framework could help design UI system in which the generosity of UI is linked to the state of the labor market—such as in the US.[2]

To examine the response of optimal UI to the state of the labor market, we embed the Baily-Chetty framework into a matching model with general production function, wage-setting mechanism, and matching function.[3] The matching model is well suited for our purpose because it lends itself to an analysis of the state of the labor market. In our framework, the key variable linked to the state of the labor market is labor market tightness: the ratio of vacancies to aggregate search

[1]A few papers such as Mitman and Rabinovich [2011] and Jung and Kuester [2014] study the optimal response of UI to shocks by simulating calibrated macroeconomic models, but by nature the results are somewhat specific to the calibration and structural assumptions about the wage-setting mechanism or production function.

[2]US unemployment benefits have a duration of 26 weeks in normal times. The Extended Benefits program automatically extends duration by 13 weeks in states where the unemployment rate is above 6.5% and by 20 weeks in states where the unemployment rate is above 8%. Duration is often further extended by the government in severe recessions. For example, the Emergency Unemployment Compensation program enacted in 2008 extends durations by an additional 53 weeks in states where the unemployment rate is above 8.5%.

[3]Matching models have been used to study UI in other contexts. See for instance Cahuc and Lehmann [2000], Fredriksson and Holmlund [2001], Coles and Masters [2006], and Lehmann and Van Der Linden [2007].

effort, determined in equilibrium to equalize labor demand and labor supply. In general, UI affects tightness because labor supply and labor demand both respond to UI.

The state of the labor market is determined by the equilibrium level of tightness. The labor market is said to be efficient if equilibrium tightness maximizes welfare given the UI system. When the labor market is inefficient, it can be either tight or slack. The labor market is tight if equilibrium tightness is inefficiently high—that is, unemployment is inefficiently low and firms devote too much labor to recruit workers. The labor market is slack if equilibrium tightness is inefficiently low—that is, unemployment is inefficiently high and not enough jobseekers find a job.

When the labor market is efficient, as one might expect, optimal UI satisfies the Baily-Chetty formula. The reason is that when the labor market is efficient, the marginal effect of UI on tightness has no first-order effect on welfare. Hence, optimal UI is governed by the same principles as in the Baily-Chetty framework, in which tightness is fixed. Our theory uses the Baily-Chetty level as a baseline in the generosity scale. This is convenient because we have a good idea of the UI level implied by the Baily-Chetty formula. In fact, the Baily-Chetty formula has been extensively studied and the statistics that it involves have been estimated in many studies following Gruber [1997].

When the labor market is inefficient, an interesting result arises: optimal UI systematically departs from the Baily-Chetty level. There is a simple intuition for this result. Consider a slack market in which tightness is inefficiently low. If UI raises tightness, UI is desirable beyond the insurance-incentive trade-off, and optimal UI is higher than the Baily-Chetty level. Conversely, if UI lowers tightness, UI is not as desirable as what the insurance-incentive trade-off implies, and optimal UI is lower than the Baily-Chetty level. The same logic applies in a tight market.

Formally, we develop an optimal UI formula that is the sum of the Baily-Chetty formula plus a correction term. The correction term is equal to the effect of UI on tightness times the effect of tightness on welfare. The term is positive if UI brings tightness closer to efficiency, and negative otherwise. Hence, optimal UI is above the Baily-Chetty level if and only if UI brings the labor market closer to efficiency.

We then explore the mechanisms through which UI affects tightness by studying several matching models that differ by their wage-setting mechanism and production function. In these matching models, UI has two possible effects on tightness. The first effect is a *job-creation effect*: when UI rises, firms hire less because wages increase through bargaining, which reduces tightness. This effect operates in the standard model of Pissarides [2000], with bargaining and linear production function. The second effect is a *rat-race effect*: the number of jobs available is somewhat limited so by discouraging job search, UI alleviates the rat race for jobs and increases job-finding rate and labor market tightness. When workers search less, they mechanically increase others' probability of finding one of the few jobs available. This effect operates in the job-rationing model of Michaillat [2012], with a rigid wage that does not respond to UI and a concave production function.

Finally, we show how to implement our theoretical framework empirically. The optimal level of UI relies on two properties: whether UI raises or lowers tightness, and whether the labor market is slack or tight. Following Chetty [2006a], we express these properties in terms of statistics that can be estimated in the data. First, we develop an empirical criterion to determine whether UI raises or lowers tightness. The criterion involves a comparison of the microelasticity and macroelasticity of unemployment with respect to UI. The microelasticity measures the partial-equilibrium response of unemployment to UI, keeping tightness constant, whereas the macroelasticity measures its general-equilibrium response. The microelasticity accounts only for the response of job search to UI while the macroelasticity also accounts for the response of tightness. The criterion is that UI raises tightness if and only if the microelasticity of unemployment with respect to UI is larger than its macroelasticity. This criterion is simple to understand. Imagine that UI increases tightness. Then UI increases the job-finding rate, which dampens the negative effect of UI on job search. Therefore, the macroelasticity is smaller than the microelasticity.

Second, to be able to evaluate the state of the labor market using empirical evidence, we express the efficiency condition in terms of estimable statistics. Using data from the Current Employment Statistics (CES) program and the National Employment Survey (NES) of the Bureau of Labor Statistics (BLS), we construct a novel, monthly time series on the share of labor devoted to recruiting. This share is the key statistic in th efficiency condition. We find that in the US over the 1990–2014 period, the labor market is systematically slack in slumps and tight in booms. The labor market was the slackest in 2009 and the tightest in 2000.

Arguably, we need more estimates of the macroelasticity to reach a consensus on whether the macroelasticity is lower than the microelasticity, and thus whether optimal UI should be higher in slumps than in booms. Indeed, while the magnitude of the microelasticity is well established, estimates of the macroelasticity are still scattered. Nonetheless, we explain how one could use our framework to deliver concrete policy recommendations as further evidence on these elasticities becomes available. First, we explain how to use our formula to conduct a diagnostic of the current UI system. Second, we calibrate and simulate dynamic versions of the matching models. The calibration relies on available estimates of the microelasticity and the elasticity wedge. We simulate business cycles caused by standard macroeconomic shocks. For example, we find that optimal UI is procyclical in the standard model but countercyclical in the job-rationing model.

In our model optimal UI depends on the state of the labor market because UI influences tightness. Other mechanisms may also matter. Unemployed workers may be more likely to exhaust their savings or less able to borrow in slumps. It would then be desirable to provide more UI in slumps, when the consumption-smoothing value of UI is higher.[4] UI may also increase how long jobseekers can afford to wait before accepting a job, and longer search may lead to more productive matches upon reemployment.[5] If mismatch between workers and jobs is severe in slumps, providing more UI in slumps could be desirable. Adding these mechanisms to our model is left for future work.

2 A Matching Model of Unemployment Insurance

This section presents a static matching model of UI. The assumption that the model is static will be relaxed in Section 6. There is a measure 1 of identical workers and a measure 1 of identical firms.

The Labor Market. There are matching frictions on the labor market. Initially, all workers are unemployed and search for a job with effort e. Each firm posts o vacancies to recruit workers. The number l of workers who find a job is given by a matching function taking as argument aggregate search effort and vacancies: $l = m(e,o)$.[6] The function m has constant returns to scale, is differentiable and increasing in both arguments, and satisfies the restriction that $m(e,o) \leq 1$. Labor market tightness is defined as the ratio of vacancies to aggregate search effort: $\theta \equiv o/e$.

Since the matching function has constant returns to scale, labor market tightness determines the

[4] Kroft and Notowidigdo [2011] analyze this issue.

[5] Acemoglu and Shimer [1999] and Marimon and Zilibotti [1999] propose models with this feature.

[6] As explained by Pissarides [2000, Chapter 5], search effort can be interpreted as a technical-change parameter in the matching function. Technical change in production functions is always defined as input augmenting. The matching literature follows the same convention in modeling matching with variable search effort. The standard assumption is that the matching function take as argument the efficiency units of searching workers—number of jobseekers u times effort per jobseeker e—and vacancies o. In our model, $u = 1$ so the efficiency units of searching workers is e.

probabilities that a unit of search effort is successful and a vacancy is filled. A jobseeker finds a job at a rate $f(\theta) \equiv m(e,o)/e = m(1,\theta)$ per unit of search effort. Thus, a jobseeker searching with effort e finds a job with probability $e \cdot f(\theta)$. A vacancy is filled with probability $q(\theta) \equiv m(e,o)/o = m(1/\theta,1) = f(\theta)/\theta$. The function f is increasing in θ and the function q is decreasing in θ; in other words, it is easier to find a job but harder to fill a vacancy when the labor market tightness is higher. We denote by $1-\eta$ and $-\eta$ the elasticities of f and q: $1-\eta \equiv \theta \cdot f'(\theta)/f(\theta) > 0$ and $\eta \equiv -\theta \cdot q'(\theta)/q(\theta) > 0$.

Firms. The representative firm hires l workers, paid a real wage w, to produce a consumption good. As in Michaillat and Saez [2013], we assume that some workers are engaged in production while others are engaged in recruiting. A number $n < l$ of workers are producing an amount $y(n)$ of good, where the production function y is differentiable, increasing, and concave. Posting a vacancy requires a fraction $r > 0$ of a worker's time. Thus, $l - n = r \cdot o = r \cdot l/q(\theta)$ workers are recruiting a total of l workers so that $l \cdot (1 - r/q(\theta)) = n$. Hence, workers and producers are related by

$$l = (1+\tau(\theta)) \cdot n, \tag{1}$$

where $\tau(\theta) \equiv r/(q(\theta)-r)$ is the recruiter-producer ratio. The function τ is positive and increasing when $q(\theta) > r$, which holds in equilibrium. It is easy to show that the elasticity of τ is $\theta \cdot \tau'(\theta)/\tau(\theta) = \eta \cdot (1+\tau(\theta))$.

The firm sells its output on a perfectly competitive market. Given θ and w, the firm chooses n to maximize profits $\pi = y(n) - (1+\tau(\theta)) \cdot w \cdot n$. The optimal number of producers satisfies

$$y'(n) = (1+\tau(\theta)) \cdot w. \tag{2}$$

At the optimum, the marginal revenue and marginal cost of hiring a producer are equal. The marginal revenue is the marginal product of labor, $y'(n)$. The marginal cost is the real wage, w, plus the marginal recruiting cost, $\tau(\theta) \cdot w$.

We implicitly define the labor demand $l^d(\theta,w)$ by

$$y'\left(\frac{l^d(\theta,w)}{1+\tau(\theta)}\right) = w \cdot (1+\tau(\theta)). \tag{3}$$

The labor demand gives the number of workers hired by firms when firms maximize profits given labor market tightness and real wage.

The UI System. Search effort is not observable, so the receipt of UI cannot be contingent on search. Hence, UI provides all employed workers with c^e consumption goods and all unemployed workers with $c^u < c^e$ consumption goods. We measure the generosity of UI in three different ways. UI is more generous if the consumption gain from work $\Delta c \equiv c^e - c^u$ decreases, the utility gain from work $\Delta v \equiv v(c^e) - v(c^u)$ decreases, or the replacement rate $R \equiv 1 - \Delta c / w$ increases. When a jobseeker finds work, she keeps a fraction $\Delta c / w = 1 - R$ of the wage and gives up a fraction R as UI benefits are lost. This is why we can interpret R as the replacement rate of the UI system.[7] The government must satisfy the budget constraint

$$y(n) = (1 - l) \cdot c^u + l \cdot c^e. \tag{4}$$

If firms' profits π are equally distributed, the UI system can be implemented with a UI benefit b funded by a tax on wages t so that $(1 - l) \cdot b = l \cdot t$ and $c^u = \pi + b$ and $c^e = \pi + w - t$. If profits are unequally distributed, a 100% tax on profits rebated lump sum implements the same allocation.

Workers. Workers cannot insure themselves against unemployment in any way, so they consume c^e if employed and c^u if unemployed. The utility from consumption is $v(c)$. The function v is differentiable, increasing, and concave. The disutility from job-search effort, e, is $k(e)$. The function k is differentiable, increasing, and convex. Given θ, c^e, and c^u, a representative worker chooses e to maximize expected utility

$$l \cdot v(c^e) + (1 - l) \cdot v(c^u) - k(e) \tag{5}$$

subject to the matching constraint

$$l = e \cdot f(\theta), \tag{6}$$

[7] Our definition of the replacement rate is not completely conventional. Consider a UI system that provides a benefit b funded by a tax t so that $\Delta c = w - t - b$. Our replacement rate is defined as $R = (t + b)/w$. The conventional replacement rate is b/w; it ignores the tax t and is not the same as R. However, unemployment is small relative to employment so $t \ll b$ and $R \approx b/w$.

where l is the probability to find a job and $1-l$ is the probability to remain unemployed. The optimal search effort satisfies

$$k'(e) = f(\theta) \cdot \Delta v. \tag{7}$$

At the optimum, the marginal utility cost and marginal utility gain of search are equal. The marginal utility cost is $k'(e)$. The marginal utility gain is the rate at which a unit of effort leads to a job, $f(\theta)$, times the utility gain from having a job, Δv. We implicitly define the effort supply $e^s(f(\theta), \Delta v)$ as the solution of (7). The function e^s increases with $f(\theta)$ and Δv.

We define the labor supply by

$$l^s(\theta, \Delta v) = e^s(f(\theta), \Delta v) \cdot f(\theta). \tag{8}$$

Labor supply gives the number of workers who find a job when workers search optimally for a given tightness and UI system. The labor supply increases with θ and with Δv. Labor supply is higher when UI is less generous because search efforts are higher. Labor supply is higher when the labor market is tighter because the job-finding rate per unit of effort is higher and search efforts are higher.

Equilibrium. An equilibrium is a collection of variables $\{e, l, n, \theta, w, c^e, c^u, \Delta v\}$ such that workers maximize utility given tightness and UI, firms maximize profits given tightness and wage, and the government satisfies a resource constraint. These variables satisfy equations (1), (2), (4), (6),(7), and $\Delta v = v(c^e) - v(c^u)$.

Since there are eight variables but only six equations, two variables are indeterminate. One variable is the generosity of UI, Δv. In the rest of the paper, Δv is determined by the government to maximize welfare. The other variable is the wage, w. As is well understood, the wage is indeterminate because of the matching frictions.[8] In Section 4, we assume that the wage follows a general wage schedule, which may be efficient or inefficient. In Section 5, we are more specific and study different wage-setting mechanisms.

Given Δv and w, the key to solving the equilibrium is to determine labor market tightness. In

[8] See for instance the discussions in Howitt and McAfee [1987], Hall [2005*a*], and Michaillat and Saez [2013].

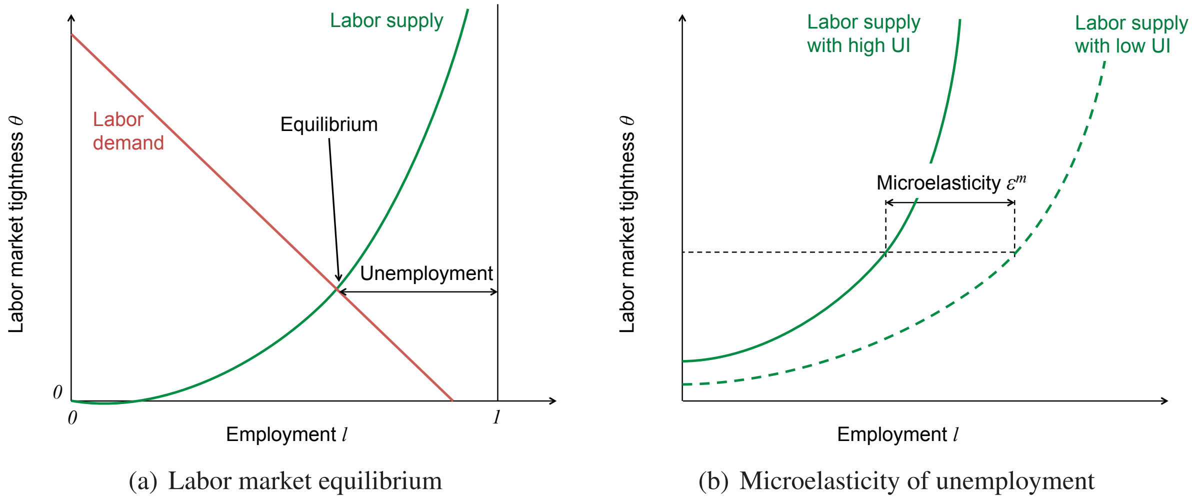


Figure 1: Equilibrium in an (employment, labor market tightness) plane

equilibrium, tightness equalizes labor supply to labor demand:[9]

$$l^s(\theta,\Delta v) = l^d(\theta,w). \tag{9}$$

Once θ is determined, l is determined from $l = l^s(\theta,\Delta v)$, e from $e = e^s(f(\theta),\Delta v)$, n from $n = l/(1+\tau(\theta))$, and c^e and c^u from the budget constraint (4) and $\Delta v = v(c^e) - v(c^u)$.

The equilibrium is represented in Figure 1(a) in a (l,θ) plane. This equilibrium diagram will be useful to understand our analysis.[10] The labor supply curve is upward sloping, and it shifts inward when UI increases. The labor demand curve may be horizontal or downward sloping, and it responds to UI when the wage responds to UI. The intersection of the labor supply and labor demand gives equilibrium labor market tightness, equilibrium employment, and equilibrium unemployment.

3 The States of the Labor Market

We describe social welfare as a function of two arguments—labor market tightness and UI. We express the derivatives of the welfare function in terms of estimable statistics. These expressions are key building blocks of the optimal UI formula derived in Section 4. Using the welfare function and

[9] Michaillat and Saez [2013] provide more details about the equilibrium concept and characterize the equilibrium and its properties in a model with exogenous search effort.

[10] More generally, Michaillat [2014] and Michaillat and Saez [2013, 2014] show that the equilibrium diagram is useful to study a number of fiscal and monetary policies.

its derivative, we formally define the possible states of the labor market: efficient, slack, or tight. These states will be important determinants of optimal UI.

We begin by defining the social welfare function. Consider an equilibrium parameterized by a utility gain from work, Δv, and a wage, w. For a given Δv, there is a one-to-one relationship between w and the labor market tightness, θ. This relationship is given by (9). Hence, we can equivalently parameterize the equilibrium by Δv and θ. Social welfare is thus a function of Δv and θ:

$$SW(\theta, \Delta v) = v(c^e(\theta, \Delta v)) - [1 - (e^s(\theta, \Delta v) \cdot f(\theta))] \cdot \Delta v - k(e^s(\theta, \Delta v)), \tag{10}$$

where $c^e(\theta, \Delta v)$ is the equilibrium level of consumption for employed workers. The consumption $c^e(\theta, \Delta v)$ is implicitly defined by

$$y\left(\frac{l^s(\theta, \Delta v)}{1+\tau(\theta)}\right) = l^s(\theta, \Delta v) \cdot c^e(\theta, \Delta v) + (1 - l^s(\theta, \Delta v)) \cdot v^{-1}\left(v(c^e(\theta, \Delta v)) - \Delta v\right), \tag{11}$$

This equation ensures that the government's budget constraint, given by (4), is satisfied when all the variables take their equilibrium values. The term $v^{-1}\left(v(c^e(\theta, \Delta v)) - \Delta v\right)$ is the equilibrium level of consumption for unemployed workers, $c^u(\theta, \Delta v)$, because $v(c^u) = v(c^e) - \Delta v$.

Next, we define two estimable elasticities that measure how search effort responds to UI and labor market conditions. We will use them to analyze the social welfare function.

DEFINITION 1. *The* microelasticity of unemployment with respect to UI *is*

$$\varepsilon^m = \frac{\Delta v}{1-l} \cdot \left.\frac{\partial l^s}{\partial \Delta v}\right|_{\theta}.$$

The microelasticity measures the percentage increase in unemployment when the utility gain from work decreases by 1%, taking into account jobseekers' reduction in search effort but ignoring the equilibrium adjustment of labor market tightness. The microelasticity can be estimated by measuring the reduction in the job-finding probability of an unemployed worker whose unemployment benefits are increased, keeping the benefits of all other workers constant. In Figure 1(b), a change in UI leads to a change in search effort, which shifts the labor supply curve. The microelasticity measures this shift.

The empirical literature does not typically estimate ε^m. Instead, this literature estimates the microelasticity ε_R^m of unemployment with respect to the replacement rate, R. This is not an issue, however, because the two elasticities are closely related. Usually ε_R^m is estimated by changing benefits c^u while keeping c^e constant. As $\Delta c = (1-R)\cdot w$, $\Delta v = v(c^e) - v(c^e - (1-R)\cdot w))$ and $\partial l^s/\partial R\big|_{\theta,c_e} = -w\cdot v'(c^u)\cdot\left(\partial l^s/\partial \Delta v\big|_\theta\right)$. The empirical elasticity ε_R^m is thus related to ε^m by

$$\varepsilon_R^m \equiv \frac{R}{1-l}\cdot\left.\frac{\partial(1-l^s)}{\partial R}\right|_{\theta,c_e} = \frac{R\cdot w\cdot v'(c^u)}{\Delta v}\cdot\varepsilon^m. \tag{12}$$

DEFINITION 2. *The* discouraged-worker elasticity *is*

$$\varepsilon^f = \frac{f(\theta)}{e}\cdot\left.\frac{\partial e^s}{\partial f}\right|_{\Delta v}.$$

The discouraged-worker elasticity measures the percentage increase in search effort when the job-finding rate per unit of effort increases by 1%, keeping UI constant. In our model, workers search less when the job-finding rate decreases and $\varepsilon^f > 0$; hence, ε^f captures jobseekers' discouragement when labor market conditions deteriorate. The discouraged-worker elasticity determines the elasticity of labor supply with respect to labor market tightness:

LEMMA 1. *The elasticity of labor supply with respect to tightness is related to the discouraged-worker elasticity by*

$$\frac{\theta}{l}\cdot\left.\frac{\partial l^s}{\partial\theta}\right|_{\Delta v} = (1-\eta)\cdot(1+\varepsilon^f)$$

Proof. Obvious because $l^s(\theta,\Delta v) = e^s(f(\theta),\Delta v)\cdot f(\theta)$, ε^f is the elasticity of e^s with respect to f, and $1-\eta$ is the elasticity of f with respect to θ. □

Equipped with these elasticities, we can differentiate the social welfare function:

LEMMA 2. *The social welfare function admits the following derivatives:*

$$\left.\frac{\partial SW}{\partial\theta}\right|_{\Delta v} = \frac{l}{\theta}\cdot(1-\eta)\cdot\phi\cdot w\cdot\left[\frac{\Delta v}{\phi\cdot w} + R\cdot\left(1+\varepsilon^f\right) - \frac{\eta}{1-\eta}\cdot\tau(\theta)\right] \tag{13}$$

$$\left.\frac{\partial SW}{\partial\Delta v}\right|_{\theta} = (1-l)\cdot\frac{\phi\cdot w}{\Delta v}\cdot\varepsilon^m\cdot\left[R - \frac{l}{\varepsilon^m}\cdot\frac{\Delta v}{w}\cdot\left(\frac{1}{v'(c^e)} - \frac{1}{v'(c^u)}\right)\right], \tag{14}$$

where ϕ is an harmonic mean of workers' marginal utilities:

$$\frac{1}{\phi} = \frac{l}{v'(c^e)} + \frac{1-l}{v'(c^u)}. \tag{15}$$

Proof. We first derive (13). Since workers choose effort to maximize expected utility, a standard application of the envelope theorem says changes in effort, $e^s(\theta, \Delta v)$, resulting from changes in θ have no impact on social welfare. The effect of θ on welfare therefore is

$$\frac{\partial SW}{\partial \theta} = \frac{l}{\theta} \cdot (1-\eta) \cdot \Delta v + v'(c^e) \cdot \frac{\partial c^e}{\partial \theta}. \tag{16}$$

The first term is the welfare gain from increasing employment by increasing tightness. It is obtained by noting that the elasticity of $f(\theta)$ is $1-\eta$ so $e \cdot f'(\theta) = (l/\theta) \cdot (1-\eta)$. This term accounts only for the change in employment resulting from a change in job-finding rate, and not for the change resulting from a change in effort. The second term is the welfare change arising from the consumption change following a change in θ.

The next step is to derive the consumption change, $\partial c^e / \partial \theta$. To do so, we implicitly differentiate $c^e(\theta, \Delta v)$ with respect to θ in (11). A few preliminary results are helpful. First, (2) implies that $y'(n)/(1+\tau(\theta)) = w$. Second, Lemma 1 implies that $\partial l^s / \partial \theta = (l/\theta) \cdot (1-\eta) \cdot (1+\varepsilon^f)$. Third, $v^{-1}(v(c^e(\theta, \Delta v)) - \Delta v) = c^u$ so $c^e - v^{-1}(v(c^e(\theta, \Delta v)) - \Delta v) = \Delta c$. Fourth, the elasticity of $1+\tau(\theta)$ is $\eta \cdot \tau(\theta)$ so the derivative of $1/(1+\tau(\theta))$ with respect to θ is $-\eta \cdot \tau(\theta)/[\theta \cdot (1+\tau(\theta))]$. Fifth, the derivative of $v^{-1}(v(c^e) - \Delta v)$ with respect to c^e is $v'(c^e)/v'(c^u)$. The implicit differentiation therefore yields

$$\frac{l}{\theta} \cdot (1-\eta) \cdot (1+\varepsilon^f) \cdot (w - \Delta c) - \frac{l}{\theta} \cdot \eta \cdot \tau(\theta) \cdot w = \left[\frac{l}{v'(c^e)} + \frac{1-l}{v'(c^u)} \cdot \right] \cdot v'(c^e) \cdot \frac{\partial c^e}{\partial \theta}.$$

The first term on the left-hand side is the budgetary gain from the new jobs created. Each new job increases government revenue by $w - \Delta c$. The increase in employment results both from a higher job-finding rate and from a higher search effort. The term $(1+\varepsilon^f)$ captures the combination of the two effects. The second term is the loss in resources due to a higher tightness. A higher tightness forces firms to devote more labor to recruiting and less to producing. Introducing the variable ϕ defined by (15) and plugging the resulting expression for $\partial c^e / \partial \theta$ into (16) yields (13).

Next, we derive (14). Following the same logic as above, the effect of Δv on welfare is

$$\frac{\partial SW}{\partial \Delta v} = -(1-l) + v'(c^e)\cdot\frac{\partial c^e}{\partial \Delta v}. \tag{17}$$

The first term is the welfare loss suffered by unemployed workers after a reduction in UI benefits. The second term is the welfare change arising from the consumption change following a change in Δv. Next, we implicitly differentiate $c^e(\theta, \Delta v)$ with respect to Δv in (11). We need two preliminary results in addition to those above. First, the definition of the microelasticity implies that $\partial l^s/\partial \Delta v = [(1-l)/\Delta v]\cdot \varepsilon^m$. Second the derivative of $v^{-1}(v(c^e)-\Delta v)$ with respect to Δv is $-1/v'(c^u)$. The implicit differentiation yields

$$\frac{1-l}{\Delta v}\cdot\varepsilon^m\cdot(w-\Delta c)+\frac{1-l}{v'(c^u)} = \left[\frac{l}{v'(c^e)}+\frac{1-l}{v'(c^u)}\cdot\right]\cdot v'(c^e)\cdot\frac{\partial c^e}{\partial \Delta v}.$$

The first terms captures the budgetary gain from increasing employment by reducing the generosity of UI. This is a behavioral effect, coming from the response of job search to UI. The second term captures the budgetary gain from reducing the UI benefits paid to unemployed workers. This is a mechanical effect. As above, we plug the expression for $\partial c^e/\partial \Delta v$ into (17) and obtain

$$\frac{\partial SW}{\partial \Delta v} = (1-l)\cdot\phi\cdot\left[R\cdot\varepsilon^m\cdot\frac{w}{\Delta v}+\frac{1}{v'(c^u)}-\frac{1}{\phi}\right].$$

The definition of ϕ implies that $(1/v'(c^u))-(1/\phi) = -l\cdot[(1/v'(c^e))-(1/v'(c^u))]$. Combining this expression with the last equation yields (14). □

The idea of defining the state of the economy by comparing the equilibrium level of activity relative to an optimal level of activity has a long history in macroeconomics. For instance, in modern business-cycle theory, slumps and booms are defined as periods in which the output gap is negative or positive, and the output gap is defined as the gap between the equilibrium level of output and an optimal level of output. We use a similar idea to define the state of the labor market:

DEFINITION 3. *The labor market equilibrium is* efficient *if a marginal increase in tightness keeping constant the utility gain from work has no effect on welfare,* slack *if the increase enhances welfare, and* tight *if the increase reduces welfare. The equilibrium tightness is inefficiently low when the equilibrium is slack and inefficiently high when the equilibrium is tight.*

In a matching model the equilibrium may not be efficient because the wage is determined through bilateral bargaining.[11] When the equilibrium is slack, the wage is inefficiently high. When the equilibrium is tight, the wage is inefficiently low. The following proposition provides a simple condition to assess the state of the labor market:

PROPOSITION 1. *We define the* efficiency term *by*

$$\frac{\Delta v}{\phi \cdot w} + R \cdot \left(1 + \varepsilon^f\right) - \frac{\eta}{1-\eta} \cdot \tau(\theta), \tag{18}$$

where ϕ is given by (15)*. The labor market equilibrium is efficient if the efficiency term is zero, slack if the efficiency term is positive, and tight if the efficiency term is negative.*

Proof. The result directly follows from Lemma 2. □

Our analysis is closely related to the work of Hosios [1990] in that we study the efficiency of labor markets with matching frictions. One difference in that Hosios [1990] focuses on models with risk-neutral workers whereas workers are risk averse in our a model. Another difference is that the efficiency condition in Hosios [1990] takes the form of a condition on the wage-setting mechanism—the Hosios condition relates workers' bargaining power to the elasticity of the matching function—whereas our efficiency condition takes the form of a condition expressed with estimable statistics. As far as we know, the Hosios condition has never been implemented empirically, probably because of the difficulty in measuring workers' bargaining power. On the other hand, our efficiency condition is easy to implement empirically. In Section 6, it will allow us to evaluate the state of the labor market in the US over the 1990–2014 period using readily available data.

4 The Optimal Unemployment Insurance Formula

We derive the optimal UI formula. Following Chetty [2006a], we express the formula in terms of estimable statistics. Section 6 will provide estimates for these statistics and implement the formula.

The wage is determined by a general wage schedule that may depend on UI. The response of the wage to UI has important implications for optimal UI because it determines how labor demand

[11] See for instance the excellent discussion in Pissarides [2000, Chapter 8].

responds to UI. However, we do not need to give an explicit expression for the wage schedule. The only information needed is the response of employment to UI, measured by the following elasticity:

DEFINITION 4. *The* macroelasticity of unemployment with respect to UI *is*

$$\varepsilon^M = \frac{\Delta v}{1-l} \cdot \frac{dl}{d\Delta v}.$$

The macroelasticity measures the percentage increase in unemployment when the utility gain from work decreases by 1%, taking into account jobseekers' reduction in search effort and the equilibrium adjustment of labor market tightness. The macroelasticity can be estimated by measuring the increase in aggregate unemployment following a general increase in unemployment benefits.

Of course, the macroelasticity is endogenous. It may respond to the generosity of UI or the state of the labor market. We illustrate this property in Section 6 by simulating in several models the variations of the macroelasticity over the business cycle and in response to changes in UI.

We will show that the response of optimal UI to the state of the labor market depends on the response of tightness to UI. The following proposition is therefore important because it shows that the response of tightness to UI can be captured by the wedge between the microelasticity and the macroelasticity of unemployment with respect to UI.

DEFINITION 5. *The* elasticity wedge *is* $1-\varepsilon^M/\varepsilon^m$.

PROPOSITION 2. *The elasticity wedge measures the response of labor market tightness to UI:*

$$\frac{\Delta v}{\theta} \cdot \frac{d\theta}{d\Delta v} = -\frac{1-l}{l} \cdot \frac{1}{1-\eta} \cdot \frac{\varepsilon^m}{1+\varepsilon^f} \cdot \left(1-\frac{\varepsilon^M}{\varepsilon^m}\right). \tag{19}$$

The elasticity wedge is positive if tightness increases with the generosity of UI. The elasticity wedge is negative if tightness decreases with the generosity of UI. The elasticity wedge is zero if tightness does not depend on UI.

Proof. Since $l = l^s(\theta, \Delta v)$, we have:

$$\frac{\Delta v}{1-l} \cdot \frac{dl}{d\Delta v} = \left(\frac{\theta}{1-l} \cdot \frac{\partial l^s}{\partial \theta}\right) \cdot \left(\frac{\Delta v}{\theta} \cdot \frac{d\theta}{d\Delta v}\right) + \left(\frac{\Delta v}{1-l} \cdot \frac{\partial l^s}{\partial \Delta v}\right).$$

Using $(\theta/l)(\partial l^s/\partial\theta) = (1-\eta)(1+\varepsilon^f)$ from Lemma 1, we obtain

$$\varepsilon^M = \frac{l}{1-l} \cdot (1-\eta) \cdot \left(1+\varepsilon^f\right) \cdot \frac{\Delta v}{\theta} \cdot \frac{d\theta}{d\Delta v} + \varepsilon^m. \tag{20}$$

Dividing this equation by ε^m and rearranging the terms yields the desired result. □

The proposition shows that a wedge between microelasticity and macroelasticity appears when UI affects tightness, and that the elasticity wedge has the same sign as the effect of UI on tightness. Figure 2 illustrates this result. In Figures 2(a) and 2(b), the horizontal distance A–B measures the microelasticity and the horizontal distance A–C measures the macroelasticity. In Figure 2(a), the labor demand curve is downward sloping, and it does not shift with a change in UI. After a reduction in UI, the labor supply curve shifts outward (A–B) and tightness increases along the new labor supply curve (B–C). Tightness rises after an increase in UI and the macroelasticity is smaller than the microelasticity.

In Figure 2(b), the labor demand also shifts inward with an increase in UI (for example because higher UI leads to higher wages). Tightness falls along the new supply curve after the labor demand shift (C'–C). In sum, tightness can rise or fall. In Figure 2(b), tightness falls and the macroelasticity is larger than the microelasticity. In Section 5, we will specify several models that clarify the mechanisms through which UI affects tightness.

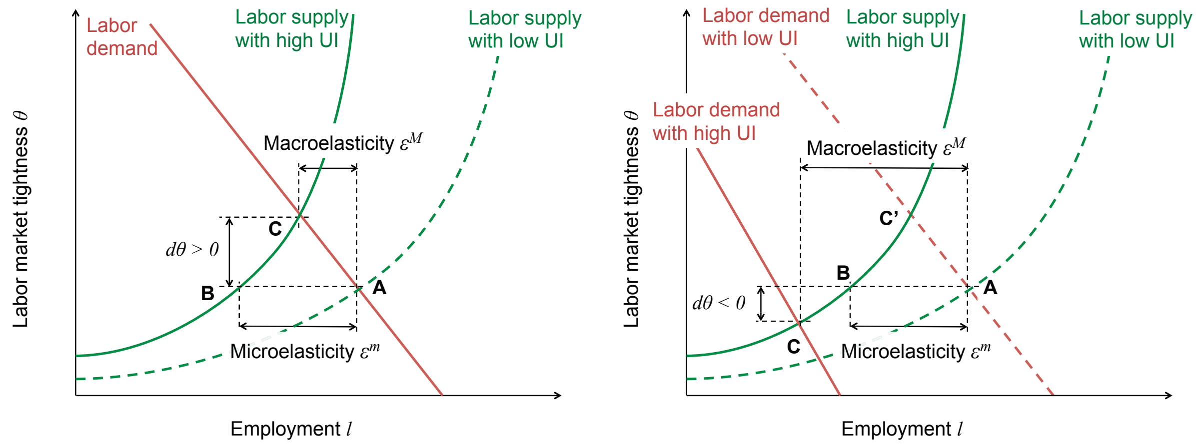
Having understood the properties of the social welfare function and the possible effects of UI on tightness, we are now equipped to derive the optimal UI formula. The problem of the government is to choose the utility gain from work to maximize social welfare, given by (10), subject to the equilibrium response of tightness, given by (9). The following proposition characterizes optimal UI:

PROPOSITION 3. *The optimal UI policy satisfies the formula*

$$R = \frac{l}{\varepsilon^m} \cdot \frac{\Delta v}{w} \cdot \left[\frac{1}{v'(c^e)} - \frac{1}{v'(c^u)}\right] + \frac{1}{1+\varepsilon^f}\left(1 - \frac{\varepsilon^M}{\varepsilon^m}\right)\left[\frac{\Delta v}{w \cdot \phi} + R \cdot \left(1+\varepsilon^f\right) - \frac{\eta}{1-\eta} \cdot \tau(\theta)\right], \tag{21}$$

where ϕ satisfies (15). *The first term in the right-hand side is the* Baily-Chetty term, *and the second term is the* correction term.

Proof. We define welfare $SW(\theta,\Delta v)$ by (10). The derivative of the social welfare with respect to Δv is $dSW/d\Delta v = \partial SW/\partial\Delta v + (\partial SW/\partial\theta) \cdot (d\theta/d\Delta v)$. Therefore, the first-order condition $dSW/d\Delta v =$



(a) Positive elasticity wedge

(b) Negative elasticity wedge

Figure 2: The effect of UI on tightness determines the sign of the elasticity wedge, $1-\varepsilon^M/\varepsilon^m$

Notes: This figure illustrates the results of Proposition 2. Panel (a) considers a downward-sloping labor demand that does not respond to UI. Panel (b) considers a downward-sloping labor demand that shifts inward when UI increases.

0 in the current problem is a linear combination of the first-order conditions $\partial SW/\partial\theta = 0$ and $\partial SW/\partial\Delta v = 0$. Hence, the optimal UI formula is a linear combination of the efficiency condition and the Baily-Chetty formula. Moreover, the efficiency condition is multiplied by the wedge $1-\varepsilon^M/\varepsilon^m$ because the factor $d\theta/d\Delta v$ is proportional to that wedge.

Equation (20) shows that the labor market tightness variation is given by

$$\frac{d\theta}{d\Delta v} = \frac{1-l}{l}\cdot\frac{1}{1-\eta}\cdot\frac{1}{1+\varepsilon^f}\cdot\frac{\theta}{\Delta v}\cdot\left(\varepsilon^M-\varepsilon^m\right).$$

We combine this equation with the derivatives provided by Lemma 2 to write the first-order condition $dSW/d\Delta v = 0$. Dividing the resulting equation by $(1-l)\cdot\phi\cdot w\cdot\varepsilon^m\cdot/\Delta v$ yields (21). □

COROLLARY 1. *If the labor market equilibrium is efficient, optimal UI satisfies the Baily-Chetty formula:*

$$R = \frac{l}{\varepsilon^m}\cdot\frac{\Delta v}{w}\cdot\left(\frac{1}{v'(c^e)}-\frac{1}{v'(c^u)}\right). \tag{22}$$

Proof. Equation (22) obtains from Propositions 1 and 3. It may not be immediately apparent that (22) is equivalent to the traditional Baily-Chetty formula. The equivalence becomes clear using

Table 1: Optimal replacement rate compared to Baily-Chetty replacement rate

	Elasticity wedge, $1-\varepsilon^M/\varepsilon^m$		
	$-$	0	$+$
Slack labor market	lower	same	higher
Efficient labor market	same	same	same
Tight labor market	higher	same	lower

Notes: The replacement rate is $R = 1-(c^e-c^u)/w$. The Baily-Chetty replacement rate is given by formula (22). The optimal replacement rate is higher than the Baily-Chetty rate if the correction term in formula (21) is positive, same as the Baily-Chetty rate if the correction term is zero, and lower than the Baily-Chetty rate if the correction term is negative.

(12), which allows us to rewrite formula (22) as

$$\varepsilon_R^m = l \cdot \left(\frac{v(c^u)}{v'(c^e)} - 1 \right).$$

This is the standard expression for the Baily-Chetty formula. □

Formula (21) shows that the optimal UI replacement rate, R, is the sum of the Baily-Chetty term and a correction term. The Baily-Chetty term captures the trade-off between the need for insurance, measured by $(1/v'(c^e)) - (1/v'(c^u))$, and the need for incentives to search, measured by ε^m, exactly as in the analysis of Baily [1978] and Chetty [2006a]. The correction term is the product of the effect of UI on tightness, measured by $1-\varepsilon^M/\varepsilon^m$, by the effect of tightness on welfare, measured by the efficiency term. The correction term is positive if and only if UI brings the labor market equilibrium toward efficiency.[12]

There are two situations where the optimal replacement rate is given by the Baily-Chetty formula: the two situations where the correction term is zero. The first situation is when the labor market equilibrium is efficient such that the efficiency term is zero. This is the situation described by the corollary. When the labor market equilibrium is efficient, the marginal effect of UI on tightness has no first-order effect on welfare; hence, optimal UI is governed by the same principles as in the Baily-Chetty framework in which tightness is fixed. The second situation is when UI has not effect on tightness such that $1-\varepsilon^M/\varepsilon^m = 0$, regardless of whether tightness is efficient or not.

[12] The response of tightness to UI can be interpreted as a pecuniary externality. The reason is that tightness can be interpreted as a price influenced by the search behavior of workers and influencing welfare when the labor market is inefficient. Under this interpretation, the additive structure of the formula—a standard term plus a correction term—is similar to the structure of many optimal taxation formulas in the presence of externalities.

When tightness is fixed, the matching model is isomorphic to the Baily-Chetty model, so optimal UI is guided by the same principles in the two models.

In all other situations, the correction term is nonzero and the optimal replacement rate departs from the Baily-Chetty rate. The main implication of (21) is that increasing UI above the Baily-Chetty rate is desirable if and only if UI brings the labor market closer to efficiency. UI brings the labor market closer to efficiency either if equilibrium tightness is inefficiently low and UI raises tightness or if equilibrium tightness is inefficiently high and UI lowers tightness. In concrete terms, UI brings the labor market closer to efficiency either if the labor market is slack and the microelasticity is larger than the macroelasticity or if the labor market is tight and the microelasticity is smaller than the macroelasticity. Table 1 summarizes all the possible situations depending on the state of the labor market and the sign of the elasticity wedge.

As is standard in optimal tax formulas, the right-hand-side of (21) is endogenous to UI. Even though the formula characterizes optimal UI only implicitly, it is useful. First, it transparently shows the economic forces at play. Second, it gives general conditions for optimal UI to be above or below the Baily-Chetty level. These conditions apply to a broad range of matching models, as we illustrate in Section 5. Third, the right-hand-side term is expressed with statistics that are estimable. Hence, the formula can be combined with empirical estimates to assess a UI system, as we illustrate in Section 6. This assessment is valid even if the right-hand-side term is endogenous to UI.

A key implication of formula (21) is that even in the presence of private provision of UI, the public provision of UI is justified. Indeed, small private insurers do not internalize tightness externalities and offer insurance according to the Baily-Chetty term. It is therefore optimal for the government to correct privately provided UI by a quantity equal to the correction term in (21). The correction is positive or negative depending on the state of the labor market.

Formula (21) reveals a few counterintuitive properties of optimal UI. First, even if UI has no adverse on unemployment and $\varepsilon^M = 0$, full insurance is not desirable. Consider a model in which the number of jobs is fixed. Increasing UI redistributes from employed workers to unemployed workers without destroying jobs, but, unlike what intuition suggests, the optimal replacement is strictly below 1. This can be seen by plugging $\varepsilon^M = 0$ and $\varepsilon^m > 0$ in (21). The reason is that increasing UI increases tightness and forces firms to allocate more workers to recruiting instead of producing, thus reducing output available to consumption. In fact, if the efficiency condition holds, UI is given by the standard Baily-Chetty formula and the magnitude of ε^M is irrelevant.

Second, even in the absence of any concern for insurance, some UI should be offered if UI brings the economy closer to efficiency.[13] Consider a model with with risk neutral workers. Formula (21) boils down to $\tau(\theta) = (1-\eta)/\eta$.[14] which is the condition on tightness to maximize output and hence restore efficiency.

Third, even though wages may respond to UI, the response of wages does not appear directly in the formula. It does not matter whether wages change or not because wages do not enter in the government's budget constraint or workers' search decisions. The wage does appear in firms' decisions, but this effect is measured by the macroelasticity. In other words, the elasticity wedge is the sufficient statistics that captures the effects of UI on wages.

Finally, Formula (21) is quite robust: it would remain valid in a number of extensions. In the analysis, we assume that the utility of employed workers differs from that of unemployed worker only because employed workers consume more. In reality, they are many other differences between employed and unemployed workers that matter for their utility. For instance, it is well documented that the state of unemployment has high psychological and health costs [Clark and Oswald, 1994; Hawton and Platt, 2000; Sullivan and von Wachter, 2009]. To capture all the differences between employment and unemployment beyond consumption, we could assume that employed workers have utility $v_e(c^e)$ and unemployed workers have utility $v_u(c^u)$, where the functions v_e and v_u differ. In that case, formula (21) would carry over after adjusting the utility gain from work to $v_e(c^e) - v_u(c^u)$ and the marginal utilities to $v_u'(c^u)$ and $v_e'(c^e)$. In the analysis, we also assume that workers cannot insure themselves against unemployment. In reality, unemployed workers partially insure themselves [Gruber, 1997]. We could assume that workers self-insure partially against unemployment with home production.[15] In that case, formula (21) would carry over after adjusting the utility gain from work and the marginal utility of unemployed workers to account for home production.

[13] This result was noted by Rogerson, Shimer and Wright [2005].

[14] To see this, multiply the formula of Proposition 3 by $\varepsilon^m \cdot (1-R)$. With $\varepsilon^m = 0$ and hence $\varepsilon^f = 0$, and with $\Delta v = \Delta c$ due to risk neutrality, we have $\phi = 1$ and $\Delta v/w = 1-R$. Therefore, $-\varepsilon^M \cdot [(1-R) + R - \eta \cdot \tau(\theta)/(1-\eta)] = 0$. If UI has an influence on tightness, $\varepsilon^M > 0$ and $\tau(\theta) = (1-\eta)/\eta$.

[15] Home production is a reduced-form representation of all the means of self-insurance available to workers. In practice, workers self insure not only with home production but also with savings or spousal income. Analyzing savings or spousal income would be more complex.

Table 2: Effect of UI on labor market tightness in matching models

	Model			
	Standard	Rigid-wage	Job-rationing	Aggregate-demand
			A. Assumptions	
Production function	linear	linear	concave	linear
Wage setting	bargaining	rigid	rigid	rigid
			B. Properties	
Type of UI effect	job-creation	no effect	rat-race	rat-race
Effect of UI on tightness	−	0	+	+
Elasticity wedge, $1-\varepsilon^M/\varepsilon^m$	−	0	+	+

Notes: This table summarizes the results of Propositions 4, 6, 8, and 11. The job-creation and rat-race effects are depicted in Figure 3.

5 Application of the Formula to Four Matching Models

Section 4 showed that optimal UI may be above or below the conventional Baily-Chetty level depending on the state of the labor market and the effect of UI on tightness. However, Section 4 remained deliberately vague on the sources of labor market fluctuations and the mechanisms through which UI affects tightness. Here we specify four matching models to clarify the origins of labor market fluctuations and precise the mechanisms through which UI can affect tightness. Table 2 provides a description of the models and a summary of their properties.

5.1 The Standard Model

The standard model shares the main features of the model developed by Pissarides [1985, 2000] and Shimer [2005]. The production function is linear: $y(n) = n$. When they are matched, worker and firm bargain over the wage. The outcome of this bargaining is that the match surplus is shared, with the worker keeping a fraction $\beta \in (0,1)$ of the surplus.[16] The parameter β is the worker's bargaining power.[17] As in Jung and Kuester [2014], we model slumps as equilibria with high β and booms as equilibria with low β. Bargaining-power shocks ensure that the labor market is slack in slumps and

[16] In a seminal paper, Diamond [1982] also assumed a surplus-sharing solution to the bargaining problem. If workers and firms are risk neutral, the surplus-sharing solution coincides with the generalized Nash solution. Under risk aversion, these two solutions generally differ. We use the surplus-sharing solution for its simplicity.

[17] To obtain a positive wage, we impose that $\beta/(1-\beta) > \Delta v$.

tight in booms, as observed in the data (see Figure 5).

We need to derive the labor demand to analyze the model. We begin by determining the bargained wage. The worker's surplus from a match with a firm is $\mathscr{W} = \Delta v$. The firm's surplus from a match with a worker is $\mathscr{F} = 1 - w$ because once a worker is recruited, she produces 1 unit of good and receives a real wage w. Since worker and firm split the total surplus from the match, $\mathscr{W}/\beta = \mathscr{F}/(1-\beta)$. Hence, the bargained wage satisfies

$$w = 1 - \frac{1-\beta}{\beta} \cdot \Delta v.$$

Increasing UI raises the bargained wage. The reason is that the outside option of jobseekers increases after an increase in UI, so they are able to obtain a higher wage.

We combine the wage equation with equation (3) to obtain the labor demand:

$$\frac{\tau(\theta)}{1+\tau(\theta)} = \frac{1-\beta}{\beta} \cdot \Delta v. \tag{23}$$

This equation defines a perfectly elastic labor demand curve in a (l, θ) plane, as depicted in Figure 3(a). The labor demand shifts downward when UI increases. The reason is that when UI increases, wages rise so it becomes less profitable for firms to hire workers.

Having obtained the labor demand, we can describe the effect of UI on equilibrium tightness:

PROPOSITION 4. *Increasing UI lowers tightness: $d\theta/d\Delta v > 0$. The elasticity wedge is*

$$1 - \frac{\varepsilon^M}{\varepsilon^m} = -\frac{l}{1-l} \cdot \frac{1-\eta}{\eta} \cdot \frac{1+\varepsilon^f}{\varepsilon^m} < 0. \tag{24}$$

Proof. We differentiate (23) with respect to Δv. Since the elasticities of $\tau(\theta)$ and $1+\tau(\theta)$ with respect to θ are $\eta \cdot (1+\tau(\theta))$ and $\eta \cdot \tau(\theta)$, we obtain $(\Delta v/\theta) \cdot (d\theta/d\Delta v) = 1/\eta$. It follows that $d\theta/d\Delta v > 0$. Using (19) then immediately yields (24). □

Figure 3(a) illustrates the results of the proposition. After an augmentation in UI, jobseekers search less, shifting the labor supply curve inward by a distance A–B, and bargained wages increase, shifting the labor demand downward and further reducing employment by a distance B–C. The total reduction in employment is given by the distance A–C. Since the labor demand is horizontal and shifts downward, tightness necessarily falls. Since A–C is larger than A–B, the macroelasticity is larger than the microelasticity.

The standard model nicely captures two effects of UI: the moral-hazard effect and the job creation effect. The moral-hazard effect is the reduction in employment caused by the reduction in search effort, which is not observable and thus a source of moral hazard. The distance A–B measures this effect. The job-creation effect is the reduction in employment caused by the reduction in hiring following the increase in wages. The distance B–C measures this effect. The job-creation effect is the reason why tightness falls when UI increases and why the macroelasticity is larger than the microelasticity. It is not impossible that UI has additional effects on employment, however. Below, we present alternative models to illustrate these other effects.

The proposition implies that optimal UI is higher than the Baily-Chetty level in a tight labor market and lower in a slack labor market. For example, in a tight market, increasing UI raises wages and decreases tightness, which improves welfare beyond the insurance-incentive trade-off.

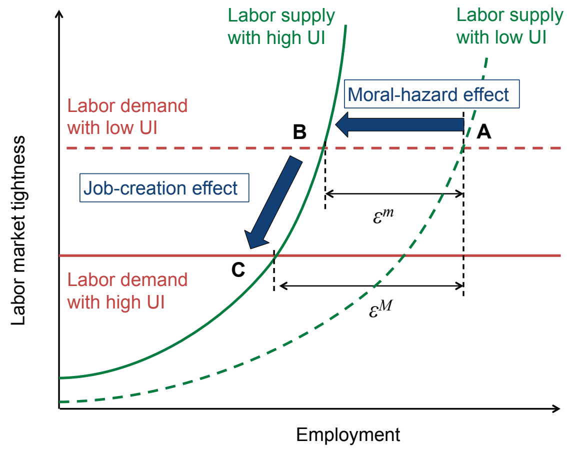
Of course, we would like to know the conditions under which the labor market is slack or tight. But in a general-equilibrium environment, this is complicated. As a first step, we provide conditions under which the labor market is in a slump or in a boom.

PROPOSITION 5. *For a given utility gain from work, an equilibrium in which workers have higher bargaining power has lower tightness and lower employment:* $\partial\theta/\partial\beta\big|_{\Delta v} < 0$ *and* $\partial l/\partial\beta\big|_{\Delta v} < 0$.

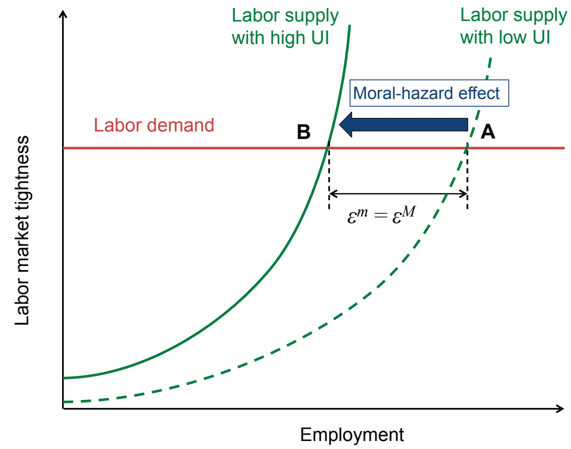
Proof. The comparative static for θ comes from (23), as $\tau'(\theta) > 0$. The comparative static for l follows as $l = l^s(\theta, \Delta v)$ and $\partial l^s/\partial\theta > 0$. □

The proposition says that in an equilibrium in which workers have high bargaining power, the economy is in a slump, and in an equilibrium in which they have low bargaining power, the economy is in a boom. The mechanism is that with high bargaining power, workers extract a high share of match surpluses so wages are high, which depresses labor demand and thus tightness and employment. In Figure 3(a), an increase in workers' bargaining power shifts the labor demand downward.

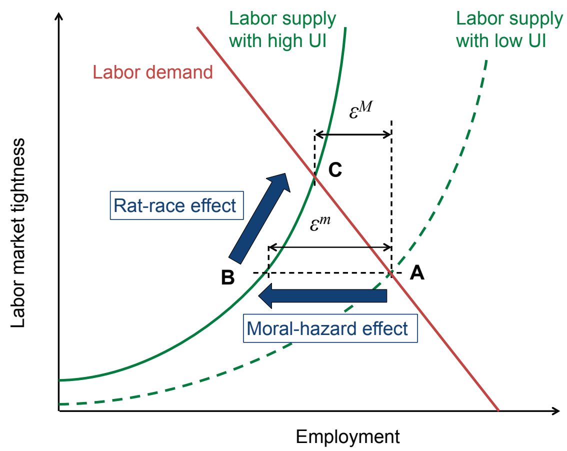
As we expect the labor market to be slack in slumps and tight in booms, we expect the labor market to be slack when workers have high bargaining power and tight when they have low bargaining power. We cannot prove this result, but we will show that it holds in the simulations of Section 6.



(a) The standard model



(b) The rigid-wage model



(c) The job-rationing and aggregate-demand models

Figure 3: Effect of UI on labor market tightness and employment in matching models

5.2 The Rigid-Wage Model

The rigid-wage model shares the main features of the model developed by Hall [2005*a*]. The production function is linear: $y(n) = a \cdot n$, where a is the technology level. The wage is partially rigid with respect to technology and completely rigid with respect to UI: $w = \omega \cdot a^{\gamma}$, where $\gamma \in [0,1)$ parameterizes the rigidity of wages with respect to technology. If $\gamma = 0$, wages are completely rigid: they do not respond to technology. If $\gamma = 1$, wages are fully flexible: they are proportional to technology. Slumps are equilibria with low technology, and booms are equilibria with high technology.

We combine the wage schedule with equation (3) to obtain the labor demand:

$$1 = \omega \cdot a^{\gamma-1} \cdot (1+\tau(\theta)). \tag{25}$$

Equation (25) defines a perfectly elastic labor demand in a (l,θ) plan, as depicted in Figure 3(b). The labor demand is unaffected by UI because the wage does not respond to UI.

Having obtained the labor demand, we can describe the effect of UI on equilibrium tightness:

PROPOSITION 6. *Increasing UI has no effect on tightness: $d\theta/d\Delta v = 0$.*

Proof. Equilibrium tightness is determined by (25). This equation is independent of Δv. □

Figure 3(b) illustrates the result. Since the labor demand is horizontal and independent of UI, UI has no effect on tightness. The only effect at play is the moral-hazard effect, as in the original Baily-Chetty framework. The rigidity of wages with respect to UI eliminates the job-creation effect that was present in the standard model. The proposition implies that optimal UI is always given by the Baily-Chetty formula even if the efficiency condition does not hold. Tightness may be inefficient but this inefficiency does not affect optimal UI because UI has no effect on tightness.

For completeness, we show that when technology is low, the labor market is in a slump, and when technology is high, the labor market is in a boom.

PROPOSITION 7. *For a given utility gain from work, an equilibrium in which technology is lower has lower tightness and lower employment: $\partial\theta/\partial a\big|_{\Delta v} > 0$ and $\partial l/\partial a\big|_{\Delta v} > 0$.*

Proof. The comparative static for θ comes from (25), as $\gamma < 1$ and $\tau'(\theta) > 0$. The comparative static for l follows as $l = l^s(\theta, \Delta v)$ and $\partial l^s/\partial\theta > 0$. □

When technology is low, the wage-technology ratio is high by wage rigidity, which depresses labor demand, tightness, and employment. In Figure 3(b), an fall in technology shifts the labor demand downward.

5.3 The Job-Rationing Model

The job-rationing model shares the main features of the model developed by Michaillat [2012]. The production function is concave: $y(n) = a \cdot n^{\alpha}$, where a is technology and $\alpha \in (0,1)$ parameterizes diminishing marginal returns to labor. As in the rigid-wage model, the wage is partially rigid with respect to technology and completely rigid with respect to UI: $w = \omega \cdot a^{\gamma}$ with $\gamma \in (0,1)$. Slumps are equilibria with low technology, and booms are equilibria with high technology.

We combine the wage schedule with equation (3) to obtain the labor demand:

$$l^d(\theta, a) = \left(\frac{\omega}{\alpha} \cdot a^{\gamma-1}\right)^{-\frac{1}{1-\alpha}} \cdot (1+\tau(\theta))^{-\frac{\alpha}{1-\alpha}}. \tag{26}$$

The labor demand is unaffected by UI because the wage does not respond to UI. The labor demand is decreasing with θ. When the labor market is tighter, hiring workers is less profitable as it requires a higher share of recruiters, $\tau(\theta)$. Hence, firms choose a lower level of employment. The labor demand is also increasing in a. When technology is lower, the wage-technology ratio, $w/a = \omega \cdot a^{\gamma-1}$, is higher as wages are somewhat rigid, and hiring workers is less profitable. Hence, firms choose a lower level of employment. In the (l, θ) plane of Figure 3(c), the labor demand curve is downward sloping, and it shifts inward when technology falls.

The properties of the labor demand imply that jobs are rationed in slumps. When technology is low enough ($a < (\alpha/\omega)^{\frac{1}{\gamma-1}}$), then $l^d(\theta = 0, a) < 1$ and jobs are rationed: firms would not hire all the workers even if workers searched infinitely hard and tightness was zero. In Figure 3(c), the labor demand crosses the x-axis at $l < 1$.

Having characterized the labor demand, we describe the effect of UI on equilibrium tightness:

PROPOSITION 8. *Increasing UI raises tightness: $d\theta/d\Delta v < 0$. The elasticity wedge is*

$$1 - \frac{\varepsilon^M}{\varepsilon^m} = \left(1 + \frac{\eta}{1-\eta} \cdot \frac{\alpha}{1-\alpha} \cdot \frac{1}{1+\varepsilon^f} \cdot \tau(\theta)\right)^{-1} > 0. \tag{27}$$

Proof. The elasticity of $1+\tau(\theta)$ with respect to θ is $\eta \cdot \tau(\theta)$. From (26), we infer that the elasticity of $l^d(\theta, a)$ with respect to θ is $-\eta \cdot \tau(\theta) \cdot \alpha/(1-\alpha)$. By definition, ε^M is $l/(1-l)$ times the elasticity of l with respect to Δv. Since $l = l^d(\theta, a)$ in equilibrium, we infer that

$$\varepsilon^M = -\frac{l}{1-l} \cdot \eta \cdot \frac{\alpha}{1-\alpha} \cdot \tau(\theta) \cdot \frac{\Delta v}{\theta} \cdot \frac{d\theta}{d\Delta v}$$

We plug the expression for $(\Delta v/\theta)\cdot(d\theta/d\Delta v)$ given by (19) into this equation and obtain

$$\varepsilon^M = \frac{\eta}{1-\eta}\cdot\frac{\alpha}{1-\alpha}\cdot\frac{1}{1+\varepsilon^f}\cdot\tau(\theta)\cdot\left(\varepsilon^m-\varepsilon^M\right).$$

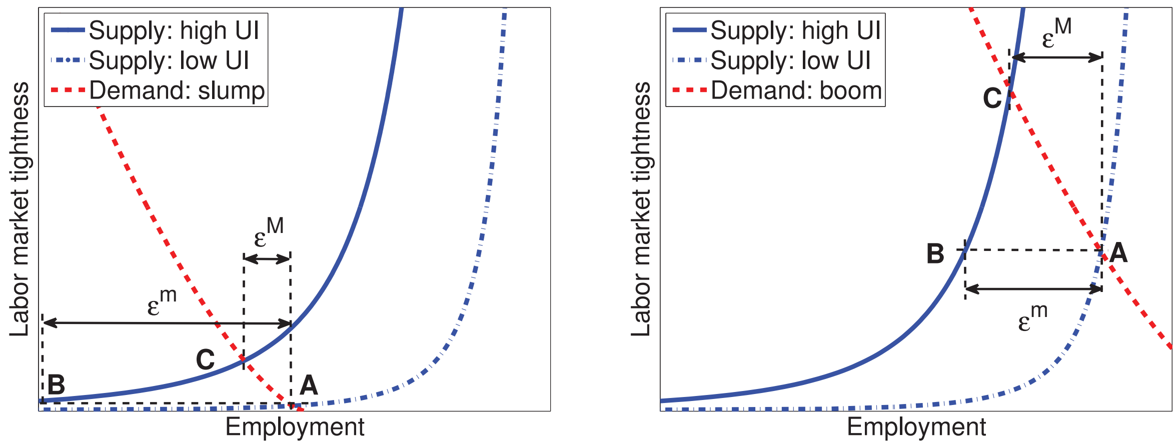
Dividing this equation by ε^m and re-arranging yields (27). □

Figure 3(c) illustrates the results of the proposition. After an augmentation in UI, jobseekers search less, shifting the labor supply curve inward by a distance A–B. Since the labor demand is downward sloping, the initial reduction in employment is attenuated by a distance B–C. The total reduction in employment is given by the distance A–C. Since the labor demand is downward sloping and does not respond to UI, tightness necessarily increases. Since A–C is smaller than A–B, the macroelasticity is smaller than the microelasticity.

In addition to the moral-hazard effect, the job-rationing model captures the rat-race effect, which is not present in the standard model. The rat-race effect is the increase in employment caused by the increase in tightness following the increase in UI. Intuitively, the number of jobs available is somewhat limited because of diminishing marginal returns to labor. Hence, when workers searching less, they reduce their own probability of finding a job but mechanically increases others' probability of finding one of the few jobs available. By discouraging job search, UI alleviates the rat race for jobs and increases the job-finding rate per unit of effort and labor market tightness.[18] The distance B–C measures employment gained through the rat-race effect. The rat-race effect is the reason why tightness rises when UI increases and why the macroelasticity is smaller than the microelasticity.

Proposition 8 implies that optimal UI is lower than the Baily-Chetty level in a tight labor market and higher than the Baily-Chetty level in a slack labor market. For instance, in a slack market, increasing UI raises tightness by alleviating the rat-race for jobs, which improves welfare beyond the insurance-incentive trade-off. The proposition also shows that the sign of the elasticity wedge does not depend at all on the rigidity of wages with respect to technology. Even if the wage were completely flexible with respect to technology ($\gamma = 1$), the job-rationing model would feature a

[18]The formal argument is as follows. Consider an increase in UI. Imagine that tightness, θ, remained constant. Then the marginal recruiting cost, $\tau(\theta)$, would remain constant. As the wage, w, remains constant, the marginal cost of labor, $w\cdot(1+\tau(\theta))$, would remain constant. Simultaneously, firms would employ fewer workers because workers search less. Hence, the marginal product of labor would be higher because of the diminishing marginal returns to labor. Firms would face the same marginal cost but a higher marginal product of labor, which would not be optimal. Thus, firms post more vacancies and the new equilibrium has higher labor market tightness.



(a) High elasticity wedge in a slump

(b) Low elasticity wedge in a boom

Figure 4: Countercyclicality of the elasticity wedge, $1-\varepsilon^M/\varepsilon^m$, in the job-rationing model

Notes: This figure illustrates the results of Proposition 10. A slump corresponds to an equilibrium with low technology. A boom corresponds to an equilibrium with high technology.

positive elasticity wedge and thus a rat-race effect. In a way this is obvious because the response of tightness to UI is independent of the response of tightness to technology. What is critical to obtain a positive elasticity wedge is the rigidity of wages with respect to UI.

As in the standard model, it is complicated to determine the conditions under which the labor market is slack or tight. But we can show that the economy is in a slump when technology is low and in a boom when technology is high.

PROPOSITION 9. *For a given utility gain from work, an equilibrium with lower technology has lower tightness and lower employment:* $\partial\theta/\partial a|_{\Delta v} > 0$ *and* $\partial l/\partial a|_{\Delta v} > 0$.

Proof. The equilibrium condition is $l^d(\theta,a) = l^s(\theta,\Delta v)$, where l^d is given by (26) and l^s by (8). Implicit differentiation of the equilibrium condition yields $\partial\theta/\partial a = \left(\partial l^d/\partial a\right)\cdot\left(\partial l^s/\partial\theta - \partial l^d/\partial\theta\right)^{-1}$. We have seen that $\partial l^d/\partial a > 0$, $\partial l^s/\partial\theta > 0$, and $\partial l^d/\partial\theta < 0$. Thus $\partial\theta/\partial a > 0$. The other result follows since $l = l^s(\theta,\Delta v)$ and $\partial l^s/\partial\theta > 0$. □

The proposition says that when technology is low, tightness and employment are low, as in a slump. Conversely, tightness and employment are high when technology is high, as in a boom. When technology is low, the wage-technology ratio is high by wage rigidity, which depresses labor demand and therefore tightness and employment. Figure 4(a) plots the labor demand curve for a low technology, which represents a slump, and Figure 4(b) plots it for a high technology, which represents a boom. As we expect the labor market to be slack in slumps and tight in booms, we expect the labor market to be slack when technology is low and tight when technology is high. We cannot prove this result, but we will show that it holds in the simulations of Section 6.

To explore further how the correction term varies in slumps and booms, we describe the comparative static effect of technology on the elasticity wedge.

ASSUMPTION 1. *The matching function and the marginal disutility of search effort are isoelastic:* $m(e,v) = \omega_h \cdot e^{\eta} \cdot v^{1-\eta}$ *and* $k'(e) = \omega_k \cdot e^{\kappa}$ *for* $\eta \in (0,1)$, $\kappa > 0$, $\omega_h > 0$, *and* $\omega_k > 0$.

PROPOSITION 10. *Suppose that Assumption 1 holds. An equilibrium with lower technology has a higher elasticity wedge:* $\partial \left[1 - \varepsilon^M / \varepsilon^m\right] / \partial a \big|_{\Delta v} < 0$.

Proof. This result follows from combining Proposition 9 with (27), the fact that $\tau(\theta)$ is increasing with θ, and the fact that $\varepsilon^f = 1/\kappa$ and η are constant under Assumption 1. □

Proposition 10 shows that the elasticity wedge is higher when technology is lower. It makes clear that the elasticity wedge is endogenous; it is not necessarily a parameter of the model.[19]

This result is illustrated by comparing a boom in Figure 4(b) to a slump in Figure 4(a). The wedge between ε^M and ε^m is driven by the slope of the labor supply relative to that of the labor demand. In a boom, the labor supply is steep at the equilibrium point because the matching process is congested by the large number of vacancies. Hence, ε^M is close to ε^m. Conversely, in a slump, the labor supply is flat at the equilibrium point because the matching process is congested by search efforts. Hence, ε^M is much lower than ε^m. Formally, let $\varepsilon^{ls} \equiv (\theta/l) \cdot (\partial l^s / \partial \theta)$ and $\varepsilon^{ld} \equiv -(\theta/l) \cdot \left(\partial l^d / \partial \theta\right)$ be the elasticities of labor supply and labor demand with respect to tightness (ε^{ld} is normalized to be positive). We could rewrite the elasticity wedge as $1 - \varepsilon^M / \varepsilon^m = 1/\left[1 + (\varepsilon^{ld}/\varepsilon^{ls})\right]$. The elasticity wedge is countercyclical because $\varepsilon^{ld}/\varepsilon^{ls}$ is procyclical.[20]

[19] The result that the elasticity wedge is endogenous is not true in the standard and rigid-wage models. Of course, the wedge is always zero in the rigid-wage model. In the standard model, the wedge is a constant. The proof is simple. Under Assumption 1, equation (7) implies that $\varepsilon^f = 1/\kappa$ and $(1-l) \cdot \varepsilon^m / l = 1/\kappa$. Hence, (24) becomes $1 - \varepsilon^M/\varepsilon^m = (1+\kappa) \cdot (1-\eta)/\eta$, which is a constant.

[20] The cyclicality of the elasticity wedge is closely connected to the cyclicality of the public-employment multiplier in Michaillat [2014]. Both results rely on the cyclicality of the ratio $\varepsilon^{ld}/\varepsilon^{ls}$. The main difference is that the wedge describes the response to a shift in labor supply whereas the multiplier describes the response to a shift in labor demand.

5.4 The Aggregate-Demand Model

The aggregate-demand model does not appear elsewhere in the literature, but it is useful to establish the robustness of the rat-race effect. This model shows that diminishing marginal returns to labor are not required to obtain a rat-race effect. Here the rat-race effect is present even though the marginal returns to labor are constant. We will see that this effect is present because the general-equilibrium labor demand is downward sloping in a (l, θ) plane, such that the number of jobs is limited for a given tightness. This model also shows that technology shocks combined with real wage rigidity is not the only mechanism that can generate slumps and booms. In this model, slumps and booms are generated by money-supply shocks and nominal wage rigidity.

We make the following assumptions on the production function and wage schedule. The production function is linear: $y(n) = n$. The nominal wage is partially rigid with respect to the price level, P, and completely rigid with respect to UI: $W = \mu \cdot P^{\zeta}$, where $\zeta \in [0, 1)$ parameterizes the rigidity of the nominal wage with respect to the price level. The real wage is $w = W/P = \mu \cdot P^{\zeta - 1}$.

Because of nominal wage rigidity, it is necessary to define the price-setting mechanism. As in Mankiw and Weinzierl [2011], we assume that workers are required to hold money to purchase consumption goods and that the money market is described by a quantity equation: $M = P \cdot y$. The parameter $M > 0$ is the money supply. The quantity equation says that nominal consumer spending is equal to the money supply.[21] Since $y = n$, the quantity equation implies that $P = M/n$. A high number of producers implies high output and, for a given money supply, a low price. In general equilibrium, the real wage is therefore related to the number of producers by

$$w = \mu \cdot \left(\frac{n}{M}\right)^{1-\zeta}. \tag{28}$$

When money supply falls or the number of producers rises, the price falls and the real wage rises.

The product market is perfectly competitive; hence, firms take the price as given and (3) remains valid. We combine the wage equation (28) with (3) to obtain the general-equilibrium labor demand:

$$l^d(\theta, M) = M \cdot \mu^{-\frac{1}{1-\zeta}} \cdot (1 + \tau(\theta))^{-\frac{\zeta}{1-\zeta}}. \tag{29}$$

This is a general-equilibrium demand because it takes into account the quantity equation describ-

[21] We implicitly assume that the velocity of money is constant and normalized to 1.

ing the money market. Labor demand decreases with θ, as in the job-rationing model. But the mechanism is different. Higher employment implies more production, lower prices in the goods market, and higher real wages by nominal wage rigidity. Firms are willing to hire more workers only if tightness is lower, which reduces recruiting costs and compensates for the higher real wage. Moreover, the labor demand increases with M: After a negative money-supply shock, prices fall. Nominal wage rigidity combined with a lower price level leads to a higher real wage and a higher marginal cost of labor, which leads to lower hiring and higher unemployment. The labor demand slopes downward in the (l,θ) plane, as depicted in Figure 3(c). The labor demand shifts inward when the money supply decreases, but the labor demand does not shift after a change in UI. Jobs are also rationed in slumps. If money supply is low enough ($M < \mu^{\frac{1}{1-\zeta}}$), then $l^d(\theta = 0, M) < 1$ and jobs are rationed: firms would not hire all the workers even if workers searched infinitely hard.

It is clear by now that the aggregate-demand model has exactly the same properties as the job-rationing model, except that money-supply shocks and not technology shocks generate fluctuations in tightness and employment. To conclude, we list all the properties of the aggregate-demand model. The interpretation is the same as in the job-rationing model.

PROPOSITION 11. *Increasing UI raises tightness: $d\theta/d\Delta v < 0$. The elasticity wedge is*

$$1 - \frac{\varepsilon^M}{\varepsilon^m} = \left(1 + \frac{\eta}{1-\eta} \cdot \frac{\zeta}{1-\zeta} \cdot \frac{1}{1+\varepsilon^f} \cdot \tau(\theta)\right)^{-1} > 0. \tag{30}$$

PROPOSITION 12. *For a given utility gain from work, an equilibrium with lower money supply has lower tightness and lower employment: $\partial\theta/\partial M\big|_{\Delta v} > 0$ and $\partial l/\partial M\big|_{\Delta v} > 0$.*

PROPOSITION 13. *Suppose that Assumption 1 holds. An equilibrium with lower money supply has higher elasticity wedge: $\partial \left[1 - \varepsilon^M/\varepsilon^m\right]/\partial M\big|_{\Delta v} < 0$.*

Proof. The proofs follow the same logic as those of Propositions 8, 9, and 10. □

6 Empirical Implementation of the Formula

In this section we implement the optimal UI formula using empirical evidence. We propose two implementations. The first one is in the public-finance tradition. It requires few functional-form assumptions but only allows us to say whether the current UI replacement rate should be increased or decreased. The second one is in the macroeconomic tradition. It requires more assumptions but allows us to quantify the optimal replacement rate at different stages of the business cycle.

These implementations rely on two key statistics: the elasticity wedge, which indicates the effect of UI on tightness, and the recruiter-producer ratio, which indicates the effect of tightness on welfare. We borrow estimates of the elasticity wedge from the literature. We construct a new time series for the recruiter-producer ratio.

6.1 The Dynamic Model

To offer a better mapping between the theory and the data, we first embed the static model into a dynamic environment. We work in continuous time.

At time t, the number of employed workers is $l(t)$ and the number of unemployed workers is $u(t) = 1 - l(t)$. Labor market tightness is $\theta_t = o_t/(e_t \cdot u_t)$. Jobs are destroyed at rate $s > 0$. Unemployed workers find a job at rate $e(t) \cdot f(\theta(t))$. Thus, the law of motion of employment is

$$\dot{l}(t) = e(t) \cdot f(\theta(t)) \cdot (1 - l(t)) - s \cdot l(t). \tag{31}$$

In steady state $\dot{l}(t) = 0$. Hence, employment, effort, and tightness are related by

$$l = \frac{e \cdot f(\theta)}{s + e \cdot f(\theta)}. \tag{32}$$

Let $L(x) = x/(s+x)$. The elasticity of L with respect to x is $1 - L$. It is because $l = L(e \cdot f(\theta))$ in the dynamic model instead of $l = e \cdot f(\theta)$ in the static model that the factor $1 - l$ appears in many formulas of the dynamic model.

Firms employ $n(t)$ producers and $l(t) - n(t)$ recruiters. Each recruiter handles $1/r$ vacancies so the law of motion of the number of employees is

$$\dot{l}(t) = -s \cdot l(t) + \frac{l(t) - n(t)}{r} \cdot q(\theta(t)). \tag{33}$$

In steady state $\dot{l}(t) = 0$ and the number of employees is proportional to the number of producers: $l = (1 + \tau(\theta)) \cdot n$, where $\tau(\theta) = (s \cdot r)/[q(\theta) - (s \cdot r)]$.[22]

[22]The wedge $\tau(\theta)$ is a different function of the parameters in the static and dynamic environments, but $\tau(\theta)$ should

We focus on the steady state of the model with no time discounting. Firms, workers, and government maximize the flow value of profits, utility, and social welfare subject to the steady-state constraints. Given w and θ, the firm chooses n to maximize $y(n) - w \cdot (1 + \tau(\theta)) \cdot n$. The optimal employment level satisfies (2). Given θ, c^e, and c^u, the representative unemployed worker chooses e to maximize (with l given by (32))

$$l \cdot v(c^e) + (1-l) \cdot v(c^u) - (1-l) \cdot k(e) \tag{34}$$

subject to (32). Routine calculations show that the optimal search effort e satisfies

$$k'(e) = \frac{l}{e} \cdot (\Delta v + k(e)). \tag{35}$$

Finally, the government chooses c^e and c^u to maximize (34) subject to (1), (2), (32), (35), and (4).

Without discounting, the static results are barely modified in the dynamic model. Following the same steps as in the static model, we can show that the formula of Lemma 1 becomes

$$\frac{\theta}{l} \cdot \frac{\partial l^s}{\partial \theta}\bigg|_{\Delta v} = (1-l) \cdot (1+\varepsilon^f) \cdot (1-\eta)$$

The only difference with the original formula is the extra factor $1-l$. In the dynamic environment, equation (20), which links micro- and macroelasticity becomes

$$\varepsilon^M = \varepsilon^m + l \cdot (1-\eta) \cdot \left(1+\varepsilon^f\right) \cdot \frac{\Delta v}{\theta} \cdot \frac{d\theta}{d\Delta v}. \tag{36}$$

As expected, the only difference with the original formula is that a factor l replaces the factor $l/(1-l)$. Equation (20) is an important building block to compute the elasticity wedge. Accordingly, in the dynamic model, the wedge becomes

$$1 - \frac{\varepsilon^M}{\varepsilon^m} = -l \cdot (1-\eta) \cdot \frac{1+\varepsilon^f}{\varepsilon^m} \cdot \frac{\Delta v}{\theta} \cdot \frac{d\theta}{d\Delta v}. \tag{37}$$

Here again, the only difference with the original wedge is that a factor l replaces the factor $l/(1-l)$.

be considered as a sufficient statistic defined as $1 + \tau(\theta) \equiv l/n$. That is, $\tau(\theta)$ is the recruiter-producer ratio.

Accordingly, in the dynamic model, the formula of Proposition 2 becomes

$$R = \frac{l}{\varepsilon^m}\frac{\Delta v}{w}\left[\frac{1}{v'(c^e)} - \frac{1}{v'(c^u)}\right] + \frac{1}{1+\varepsilon^f}\left[1 - \frac{\varepsilon^M}{\varepsilon^m}\right]\left[\frac{\Delta v + k(e)}{w \cdot \phi} + R\left(1+\varepsilon^f\right) - \frac{\eta}{1-\eta}\frac{\tau(\theta)}{1-l}\right]. \quad (38)$$

where ϕ satisfies equation (15). Two differences appear in the correction term: Δv is replaced by $\Delta v + k(e)$ and $\tau(\theta)$ is replaced by $\tau(\theta)/(1-l)$.

While it seems that the formula is modified in the dynamic model, the two formulas are in fact identical once expressed with the correct statistics. It appears in the derivation of the formula that the Δv in the correction term stands for the utility gap between employed and unemployed workers. This gap is Δv in the static model where both workers and the unemployed search while it is $\Delta v + k(e)$ in the dynamic model where only the unemployed search. It also appears that the $\tau(\theta)$ in the correction term should be divided by the elasticity of the function L, defined by $l^s(\theta, \Delta v) = L(e^s(\theta, \Delta v) \cdot f(\theta))$. This elasticity is 1 in the static model and $1 - l$ in the dynamic model.

6.2 Estimates of the Microelasticity, Macroelasticity, and Elasticity Wedge

The Microelasticity. A large body of work has estimated the microelasticity ε^m, and provides compelling evidence that UI increases unemployment durations.[23] The ideal experiment to estimate ε^m is to offer higher or longer UI benefits to a randomly selected and small subset of jobseekers within a labor market and compare unemployment durations between treated and non-treated jobseekers. In practice, ε^m is estimated by comparing individuals with different benefits in the same labor market at a given time, while controlling for individual characteristics. As mentioned above, most empirical studies estimate the elasticity with respect to the benefits level or equivalently the replacement rate R, which we denote ε^m_R.

In US administrative data from the 1980s, the classic study of Meyer [1990] finds an elasticity $\varepsilon^m_R = 0.6$ using state fixed-effects (Table VI, columns (6) to (9), p. 773). In a larger US administrative dataset for the same early 1980s years, and using a regression kink design to compellingly identify the elasticities, Landais [2012] finds an elasticity $\varepsilon^m_R = 0.3$ (Table 4, column (1)). Therefore, $\varepsilon^m_R = 0.5$ is a reasonable estimate.

[23] See Krueger and Meyer [2002] for a comprehensive survey.

The Macroelasticity. Estimating the macroelasticity ε^M, is inherently more difficult than estimating ε^m because it necessitates exogenous variation in UI benefits across comparable labor markets, instead of exogenous variations across comparable individuals within a single labor market. The ideal experiment to estimate ε^M is to offer higher UI benefits to all individuals in a randomly selected subset of labor markets and compare unemployment rates between treated and non-treated labor markets. Very few estimates of ε^M are available.[24] We discuss two notable macro estimates here. Both use variation in benefits duration instead of benefits levels.

Card and Levine [2000] analyze UI benefit extensions in New Jersey. They estimate that the long-run effect of a 13-week extended benefit program would be a 7 percentage point increase in the regular exhaustion rate and a roughly 1 week increase in the average number of weeks of regular UI collected by claimants (p. 136, where simulations are using estimates of Table 6 column (2)). This translates into an elasticity of unemployment with respect to benefits duration, denoted ε_D^M, of 0.12. This elasticity appears smaller than the corresponding micro-elasticities of unemployment with respect to benefits duration, denoted ε_D^m, that are around 0.4.[25] Hence, Card and Levine [2000] appears consistent with a positive elasticity wedge, $1 - \varepsilon^M/\varepsilon^m > 0$.

In recent work, Hagedorn et al. [2013] use the large UI extensions implemented in the US in the 2009–2013 period and compare border counties across states with different UI durations. They find a large macroelasticity of $\varepsilon_D^M = 0.55$.[26] With a microelasticity ε_D^m around 0.4, Hagedorn et al. [2013] is consistent with a negative elasticity wedge, $1 - \varepsilon^M/\varepsilon^m < 0$.

The Elasticity Wedge. The ideal experiment to estimate the elasticity wedge, $1 - \varepsilon^M/\varepsilon^m$, is a design with double randomization : (i) some randomly selected areas are treated and some are not, and (ii) within treated areas, all but a randomly selected and small subset of jobseekers are treated.

[24] Most studies surveyed in Krueger and Meyer [2002] do not distinguish between micro- and macroelasticity: they often use both micro and macro variations and thus obtain an average of the micro- and macroelasticity.

[25] For example, the classic study by Katz and Meyer [1990] finds a microelasticity with respect to UI duration of 0.43 (Table 4, p. 66). Landais [2012], using a more compelling regression kink design on the same data finds an elasticity around 0.35 (Table 4, column (1)). The recent studies by Rothstein [2011] and Farber and Valletta [2013] find smaller microelasticities during the Great Recession than these previous studies, with $\varepsilon_D^m = 0.1$. That could be partly explained by noise in the Current Population Survey data relative to the superior administrative data used by Katz and Meyer [1990] and Landais [2012].

[26] They note that (p. 14) "We find that the effect of permanently increase the benefits from 26 to 99 weeks is quite sizable: the effect on unemployment is 110%, meaning that such a permanent increase would increase the long-run average unemployment rate from 5 to 10.5%." Therefore elasticity of unemployment with respect to benefit duration is $\ln(10.5/5)/\ln(99/26) = 0.55$.

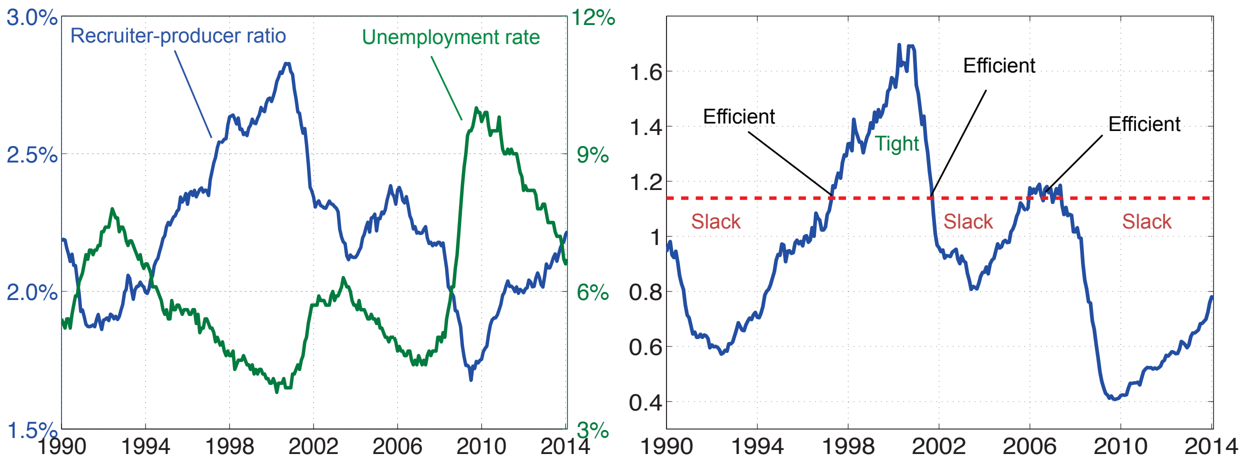
The treatment is to offer higher or longer UI benefits. The elasticity wedge can be estimated by comparing the unemployment durations of non-treated jobseekers in non-treated areas to that of non-treated jobseekers in treated areas. We discuss two recent studies that estimate this wedge.

Lalive, Landais and Zweimüller [2013] use a natural experiment that offers the desired design: the Regional Extended Benefit Program (REBP) implemented in Austria in 1988–1993. The treatment was an increase in benefit duration from 52 to 209 weeks for eligible unemployed workers in a subset of regions. Their estimates suggest a positive elasticity wedge $1-\varepsilon^M/\varepsilon^m = 0.3 > 0$.

Marinescu [2014] offers another route to assess the sign and magnitude of the elasticity wedge by directly estimating the effect of UI on tightness. She uses the same UI extensions as Hagedorn et al. [2013] and very detailed information on vacancies and job applications from CareerBuilder.com, the largest American online job board, to compute the effects of UI extensions on aggregate search effort ($e \cdot u$) measured by job applications and on vacancy posting (o) at the state level. She finds a negative effect of UI extensions on job applications but no effect of UI extensions on vacancy posting. Since $\theta = o/(e \cdot u)$, these results imply that UI extensions have a positive effect on tightness which is consistent with a positive elasticity wedge $1-\varepsilon^M/\varepsilon^m > 0$

These two studies capture both rat-race and job-creation effects. Several papers have tried to estimate the magnitude of the rat-race effect. They find that an increase in the search effort of some jobseekers, induced for example by job training programs, has a negative effect on the job-finding probability of other jobseekers [Burgess and Profit, 2001; Crepon et al., 2013; Ferracci, Jolivet and van den Berg, 2010; Gautier et al., 2012]. This findings are consistent with rat-race effects.

The best way to measure the job-creation effect is to look directly at whether a more generous UI increases wages. At the macro level, Hagedorn et al. [2013] find significant effects of UI extensions on wages, which is evidence of job-creation effect. At the micro level, a number of studies have investigated whether more generous UI benefits affect the re-employment wage. Most studies find no effect on wages or even slightly negative effects [Card, Chetty and Weber, 2007]. However, more generous benefits induce longer unemployment durations that may have a negative effect on wages if, for instance, the duration of unemployment spells affects the productivity of unemployed workers or is interpreted by employers as a negative signal of productivity. It is difficult to disentangle this negative effect from the positive effect of UI on wages through bargaining, which is the relevant effect for our analysis. In German data, Schmieder, von Wachter and Bender [2013] attempt such a



(a) Recruiter-producer ratio and unemployment

(b) Departure from the efficiency condition

Figure 5: A measure of the state of the labor market over time

Notes: The time period is January 1990–February 2014. In panel (a) the unemployment rate u_t (green line, right scale) is the seasonally adjusted monthly unemployment rate constructed by the BLS from the CPS. The recruiter-producer ratio τ_t (blue line, left scale) is constructed as $\tau_t = \sigma \cdot rec_t/(l_t - rec_t)$, where rec_t is the seasonally adjusted monthly number of workers in the recruiting industry (NAICS 56131) computed by the BLS from CES data, l_t is the seasonally adjusted monthly number of workers in all private industries computed by the BLS from CES data, and $\sigma = 8.56$ is a scaling factor ensuring that the recruiter-producer ratio in 1997 is 2.6% as in Villena Roldan [2010]. In panel (b) the solid blue line is $[\eta/(1-\eta)] \cdot \tau_t/u_t$ with $\eta = 0.7$ as in Petrongolo and Pissarides [2001]. The dashed red line is $(\Delta v + k(e))/(\phi \cdot w) + R \cdot (1 + \varepsilon^f)$. We set the replacement rate to $R = 58\%$, consistent with the US system. We set the discouraged-worker elasticity to $\varepsilon^f = 0.021$, consistent with a microelasticity of $\varepsilon^m = 0.3$. Last, we set $(\Delta v + k(e))/(\phi \cdot w) = 0.54$, consistent with the normalization that $k(e) = 0$ on average, the assumptions of log utility and linear production function, and the calibration $R = 58\%$.

decomposition by controlling for the duration of the unemployment spell and find a negative effect of UI on wages through longer unemployment durations but zero effect through wage bargaining. Lalive, Landais and Zweimüller [2013] use the same methodology and find a positive but small effect of UI through wage bargaining in Austria. Therefore, there is no consensus on the magnitude of the job-creation effect in the literature.

As substantial uncertainty remains about the sign of the elasticity wedge, we will be unable to stand firmly in favor or against countercyclical UI. Below, we explore two approaches that will be useful to quantify optimal UI once robust estimates of the elasticity wedge become available.

6.3 Is the Labor Market Slack or Tight?

We use the efficiency term from Definition 3 to test empirically whether the labor market is tight or slack. In the dynamic environment, the efficiency term is

$$\frac{\Delta v + k(e)}{w \cdot \phi} + R \cdot \left(1 + \varepsilon^f\right) - \frac{\eta}{1-\eta} \cdot \frac{\tau(\theta_t)}{u_t},$$

where ϕ satisfies equation (15). This term determines the state of the labor market. For a given level of UI, all the statistics except $\tau(\theta_t)/u_t$ are fairly stable. To illustrate our methodology, we assume that $(\Delta v + k(e))/(\phi \cdot w) + R \cdot (1 + \varepsilon^f)$ remains constant over time at its average level and we only measure $\tau(\theta_t)/u_t$ at high frequency. The results are presented in Figure 5.

We measure the efficiency term in US data. Here, we only sketch the overall measurement strategy, highlight the measurement of the most interesting statistics, and list the values for the other statistics. The Appendix contains all the details.

We set $\eta = 0.7$, in line with empirical evidence [Petrongolo and Pissarides, 2001]. We measure unemployment, u_t, with the seasonally adjusted monthly unemployment rate constructed by the Bureau of Labor Statistics (BLS) from the Current Population Survey (CPS). The average unemployment rate over the December 2000–February 2014 period is 6.6%.

We measure the recruiter-producer ratio, $\tau(\theta_t)$, from the number of employees in the recruiting industry. More precisely, we construct $\tau(\theta_t) = \sigma \cdot rec_t/(l_t - rec_t)$. The series rec_t is the seasonally adjusted monthly number of workers in the recruiting industry computed by the BLS from Current Employment Statistics (CES) data. The recruiting industry is the industry with North American Industry Classification System (NAICS) code 56131. Its official name is "employment placement agencies and executive search services". It comprises firms primarily engaged in listing employment vacancies and referring or placing applicants for employment, and firms providing executive search, recruitment, and placement services. The series is available over the period January 1990–February 2014. This industry is composed of 279,800 workers on average. The series l_t is the seasonally adjusted monthly number of workers in all private industries computed by the BLS from CES data.

The workers employed in the recruiting industry are only a small share of all the workers devoted to recruiting. Many workers in firms outside of the recruiting industry spend a lot of time and effort to recruit workers for their own firm. To account for these workers and capture the total amount of labor devoted to recruiting in the economy, we scale up our measure based on the recruiting industry by a factor $\sigma = 8.56$. This scaling factor ensures that the average recruiter-producer ratio in 1997 is 2.6%. We obtain this amount from a comprehensive source of information on recruiting: the National Employer Survey (NES) conducted in 1997 by the Census Bureau. The survey gathered employer data on employment practices, especially recruiting. In the 1997 survey, 4500 establishments answered detailed questions about the methods used to recruit applicants. Villena Roldan [2010] analyzes this survey and finds that firms spend 2.5% of their total labor cost in recruiting activities. In other words, 2.5% of the workforce is devoted to recruiting, which implies a recruiter-producer ratio of $0.025/(1-0.025) = 2.6\%$.[27] Our measure of $\tau(\theta)$ is valid as long as the share of recruitment done through recruiting firms is stable over the business cycle.

Figure 5(a) displays $\tau(\theta_t)$ on the left y-axis. The figure also depicts the unemployment rate on the right y-axis. The recruiter-producer ratio is clearly procyclical. This result implies that the number of recruiters move more than one-for-one with the number of producers in the labor market. This result is consistent with the prediction of the matching model that $\tau(\theta)$ is an increasing function of θ. To our knowledge, this is the first time that such a result is established.

UI benefits replace between 50% and 70% of the pre-tax earnings of a worker [Pavoni and Violante, 2007]. Following Chetty [2008] we set the benefit rate to 50%. Since earnings are subject to a 7.65% payroll tax, we set the average replacement rate to $R = 0.5 + 0.0765 = 58\%$. Combining this replacement rate with the resource constraint yields an employed-unemployed consumption ratio of $c^e/c^u = 1.79$. We assume a log utility of consumption, $v(c) = \ln(c)$, which implies a coefficient of relative risk aversion $\rho = 1$, consistent with labor supply behavior [Chetty, 2006b].[28] We normalize the average search effort to $e = 1$ and the disutility of effort such that $k(e = 1) = 0$.[29] The term $(\Delta v + k(e))/(\phi \cdot w)$ now only depends on R, c^e/c^u, and the average unemployment rate. With $R = 58\%$, $c^e/c^u = 1.79$, and $u = 6.6\%$, we get $(\Delta v + k(e))/(\phi \cdot w) = 0.54$.

The last statistic to measure is the discouraged-worker elasticity, ε^f. We do not have direct evidence on ε^f, but ε^f is closely related to the microelasticity, ε^m, for which we have good estimates.

[27] In monetary terms in 1997, firms spent on average \$4200 per recruited worker.

[28] This coefficient of relative risk aversion is maybe on the low side of available estimates, but using log utility simplifies the measurement of the efficiency term. Naturally, the higher risk aversion, the more generous optimal UI.

[29] This normalization implies that on average, the costs of search while unemployed are of same magnitude as the costs of work while employed (which are not modeled).

Indeed, on average,

$$\varepsilon^f = \frac{u}{1-u} \cdot \varepsilon^m. \tag{39}$$

Using (12) and the estimate $\varepsilon_R^m = 0.5$ from the literature, we get $\varepsilon^m = 0.3$. With $\varepsilon^m = 0.3$ and $u = 6.6\%$, we get $\varepsilon^f = 0.021$. Since $\varepsilon^m = 0.3$, our calibration implies a strong response of search effort to UI.[30] Since $\varepsilon^f = 0.021$, our calibration is also consistent with the evidence that the response of search effort to the job-finding rate is very weak [Shimer, 2004].

Figure 5(b) displays $(\Delta v + k(e))/(\phi \cdot w) + R \cdot (1 + \varepsilon^f)$ in dashed line, and $[(1-\eta)/\eta] \cdot \tau(\theta)/u$ in solid line. As depicted on the figure, when $[(1-\eta)/\eta] \cdot \tau(\theta)/u$ is above $(\Delta v + k(e))/(\phi \cdot w) + R \cdot (1 + \varepsilon^f)$, the market is tight, and when it is below, the market is slack. The market was tight in the 1997–2001 period, was efficient in the 2006–2008 period, and was slack otherwise. Unsurprisingly, the labor market was the most slack in 2009 during the Great Recession.

6.4 A Reduced-Form Implementation to Evaluate the Current UI System

Our formula is useful to explore whether the current UI replacement rate should be increased or decreased. The evaluation of current UI system requires reduced-form statistics but does not require assumptions about the underlying model of the economy. The possibility to evaluate the current UI system without making structural assumptions demonstrates the value expressing a formula in terms of sufficient statistics. Of course, a limitation is that we can only assess whether the replacement rate should be increased or decreased but not obtain the level of the optimal replacement rate.

The optimal UI formula in a dynamic environment is (38). Since the right-hand-side term of (38) can be evaluated using current estimates, the formula can be used to assess the desirability of a small reform around the current system. If the current replacement rate is less than the right-hand-side term of (38), increasing UI increases welfare, and conversely if the current replacement rate is more than the right-hand-side term, decreasing UI increases welfare.

The statistics in the Baily-Chetty term, microelasticity ε^m and coefficient of risk aversion, are well measured and are commonly used to estimate the Baily-Chetty level of UI [for example, Gruber, 1997]. With log utility, $u = 6.6\%$, and $\varepsilon^m = 0.3$, the current replacement rate $R = 58\%$ approximately

[30] We show in the Appendix that ε^m is l times the elasticity of search effort with respect to Δv.

satisfies the Baily-Chetty formula.[31] Since the current replacement rate is approximately at the Baily-Chetty level, the sign of the correction term determines whether the current replacement rate is above or below the right-hand-side term of (38), and thus whether the current replacement rate should be increased or decreased.

To illustrate the method, assume that the elasticity wedge is estimated to be positive. Our measure of the efficiency term in Figure 5 immediately indicates how to adjust the current replacement rate, following the argument in Table 1. When the efficiency term is positive and the labor market is slack, the current replacement rate should be increased. When the efficiency term is negative and the labor market is tight, the current replacement rate should be decreased.

6.5 A Structural Implementation to Quantify Optimal UI over the Cycle

Our formula is useful to quantify the optimal UI replacement rate over the business cycle. We simulate a dynamic and calibrated version of the matching models of Section 5 and use the formula to determine the optimal replacement rate at the different stages of the business cycle. Compared to the reduced-form implementation of the formula, this structural implementation has the advantage of providing the level of the optimal replacement rate over the business cycle but the disadvantage of relying on functional-form assumptions.

The elasticity wedge and the efficiency term, which are the two critical statistics determining the cyclicality of optimal UI, are outcomes of the simulations. This does not mean that the empirical estimates of the elasticity wedge and efficiency term provided above are irrelevant; these estimates are fundamental to conduct relevant simulations. The sign of the elasticity wedge estimated in empirical work allows researchers to choose the right model of the labor market: a negative wedge advocates for using the standard model whereas a positive wedge advocates for using the job-rationing or aggregate-demand model. Here we simulate all the models because empirical evidence on the elasticity wedge is inconclusive. The estimated magnitude of the elasticity wedge allows researchers to calibrate their model appropriately: here, we calibrate the production-function parameter, α, in the job-rationing model and the wage-rigidity parameter, ζ, in the aggregate-demand model to match

[31] With log utility the Baily-Chetty formula, given by (22), can be written $R/(1-R) = (1-u)\cdot\Delta v(R)/\varepsilon^m$ where $\Delta v(R) = \ln(c^e/c^u) = \ln\left([1+\alpha\cdot(1-R)\cdot u/(1-u)]\,/\,[1-\alpha\cdot(1-R)]\right)$. The Appendix derives the expression of c^e/c^u as a function of R, u, and the production-function parameter, α. Setting $\varepsilon^m = 0.3$ and $u = 6.6\%$ and solving the Baily-Chetty formula for R, we obtain $R = 55\%$ (with $\alpha = 2/3$) or $R = 61\%$ (with $\alpha = 1$).

the positive estimates of the elasticity wedge in the literature. Last, the fluctuations of the efficiency term allow researchers to choose the right shock to generate business cycles. The evidence in Figure 5 advocates for using shocks that generate inefficient fluctuations in unemployment. Hence, we select shocks generating inefficient business cycles.

We represent the business cycle as a succession of steady states with different values for the bargaining power, technology, or money supply. Formally, the simulations provide a comparative steady-state analysis. This analysis provides a good approximation to a dynamic simulation because labor market matching models reach their steady state quickly.[32] For each model, we compute a collection of steady states spanning all the stages of the business cycle, from slumps with high unemployment to booms with low unemployment. For each model, we perform two types of simulations. We first simulate a collection of steady states in which the replacement rate remains constant at its average value of 58%. We then simulate steady states for the same values of the underlying parameter but with the optimal replacement rate, given by (38).

Computing a steady state is straightforward. For a given replacement rate, we find the utility gain from search, Δv, and given Δv, we determine n, l, θ, and e by solving a system of 4 equations and 4 unknowns. Furthermore, we have analytical expressions for all the elasticities. Hence, we can compute all the relevant elasticities once we have solved for the steady state, and we can use them to evaluate the optimal UI formula at the given replacement rate. To determine the optimal replacement rate, we compute steady states associated with a collection of replacement rates; the optimal replacement rate is the only one for which the optimal UI formula holds.

We calibrate all the models to US data, as summarized in Table 3. Here, we only sketch the calibration; some details are provided in Section 6.3, and all the other details are discussed in the Appendix. We begin with the parameters common to all the models. We use a log utility, $v(c) = \ln(c)$. We use a Cobb-Douglas matching function $m(e \cdot u, o) = \omega_m \cdot (e \cdot u)^{\eta} \cdot o^{1-\eta}$ with $\eta = 0.7$. Over the December 2000–February 2014 period, the average job-destruction rate is $s = 3.5\%$, average unemployment rate is $u = 6.6\%$, average tightness is $\theta = 0.37$, and average effort is normalized to

[32] Shimer [2005] and Pissarides [2009] argue that in a standard matching model, the steady-state equilibrium with technology a approximates well the equilibrium in a stochastic environment when the realization of technology is a. They have two reasons. First, after a shock the labor market rapidly converges to a situation where inflows to and outflows from employment are balanced because rates of inflow to and outflow from unemployment are large [Hall, 2005*b*]. Second, the underlying source of the business cycle (say, technology) is usually very persistent. Michaillat [2012] validates this approximation with numerical simulations (see Appendix A5 in Michaillat [2012]).

$e = 1$. Matching these values requires $\omega_m = 0.67$. We calibrate the recruiting cost r to match the average recruiter-producer ratio of $\tau(\theta) = 2.2\%$ over the December 2000–February 2014 period. We set $r = 0.82$. We use a disutility of effort $k(e) = \omega_k \cdot e^{\kappa+1}/(\kappa+1) - \omega_k/(\kappa+1)$. We set $\kappa = 3.11$ to match the microelasticity of $\varepsilon^m = 0.3$. When the production function is linear, $\Delta v = 0.58$ so $\omega_k = 0.54$. When the production function is concave with $\alpha = 0.76$, $\Delta v = 0.41$ so $\omega_k = 0.38$. We discuss the calibration of the remaining, model-specific parameters when we simulate that model.

The Standard Model. Figure 6 displays the results of the simulations of the standard model. Each steady state is indexed by the workers' bargaining power, β. The average value of the bargaining power, which yields an unemployment rate of 6.6% for a replacement rate of 58%, is $\beta = 0.65$. For the entire simulation, β spans the interval $[0.25, 0.95]$. The steady states with high β have high wages and therefore high unemployment: they represent slumps. Conversely, the steady states with low β have low wages and low unemployment: they represent booms. As showed in Figure 6(a), unemployment falls from 12.6% to 4.0% when β falls from 0.95 to 0.25 and UI remains constant.

It is not the unemployment rate but the efficiency term that matters for optimal UI. This term is presented in Figure 6(b). In a slump (high β), it is positive and the labor market is slack. The labor market is efficient for $\beta = 0.55$ and an unemployment rate of 5.9%. In booms (low β), it is negative and the labor market is tight.

The efficiency term is combined with the elasticity wedge to determine the departure of optimal UI from the Baily-Chetty level. In the dynamic environment without discounting, the wedge is

$$1 - \frac{\varepsilon^M}{\varepsilon^m} = -\frac{(1-\eta)\cdot(1-u)}{(1-\eta)\cdot(1-u)+\eta} \cdot \frac{1+\varepsilon^f}{\varepsilon^m} \cdot \frac{\Delta v}{\Delta v + k(e)}.$$

This expression is an extension of (24) to the dynamic environment without discounting.[33] Figure 6(c) displays the elasticity wedge: it is negative and broadly constant around its average value of -0.97. The wedge is larger in absolute value than the estimate of $1 - \varepsilon^M/\varepsilon^m = 1 - 0.55/0.4 = -0.38$ implied by Hagedorn et al. [2013]. Since the wedge is negative, the optimal replacement rate should be above the Baily-Chetty level in booms and below it in slumps.

[33]To obtain it, we establish that the wage obtained by sharing surplus is $w = 1 - (1-\beta)\cdot u \cdot (\Delta v + k(e))/\beta$. Plugging the wage into the condition (2), we obtain the following equilibrium condition: $\tau(\theta)/(1+\tau(\theta)) = (1-\beta)\cdot u \cdot (\Delta v + k(e))/\beta$. We differentiate this condition with respect to Δv to obtain the effect of UI on tightness: $(\Delta v/\theta)\cdot(d\theta/d\Delta v) = [1/(\eta + (1-\eta)\cdot l)] \cdot [\Delta v/(\Delta v + k(e))]$. Combining the effect of UI on tightness with (36) yields the elasticity wedge.

Table 3: Parameter values in the simulations of the matching models

Parameter		Value	Source
		A. Average values	
u	unemployment rate	6.6%	CPS, 2000–2014
θ	labor market tightness	0.37	JOLTS and CPS, 2000–2014
$\tau(\theta)$	recruiter-producer ratio	2.2%	Villena Roldan [2010] and CES, 2000–2014
ε^m	microelasticity	0.3	literature
e	search effort	1	normalization
R	replacement rate	58%	Chetty [2008]
		B. Common parameters	
η	unemployment-elasticity of matching	0.7	Petrongolo and Pissarides [2001]
ρ	relative risk aversion	1	Chetty [2006b]
s	monthly job-destruction rate	3.5%	JOLTS, 2000–2014
ω_m	matching efficacy	0.67	matches average values
r	recruiting cost	0.82	matches average values
κ	convexity of disutility of search	3.11	matches average values
		C. Parameters of the standard model	
ω_k	level of disutility of search	0.54	matches average values
		D. Parameters of the rigid-wage model	
ω_k	level of disutility of search	0.54	matches average values
ω	level of real wage	0.98	matches average values for $a = 1$
γ	technology-elasticity of real wage	0.7	Haefke, Sonntag and van Rens [2008]
		E. Parameters of the job-rationing model	
α	marginal returns to labor	0.76	matches $1 - \varepsilon^M/\varepsilon^m = 0.3$
ω_k	level of disutility of search	0.38	matches average values
ω	level of real wage	0.76	matches average values for $a = 1$
γ	technology-elasticity of real wage	0.7	Haefke, Sonntag and van Rens [2008]
		F. Parameters of the aggregate-demand model	
ω_k	level of disutility of search	0.54	matches average values
μ	level of nominal wage	1.00	matches average values for $M = 1$
ζ	price-elasticity of nominal wage	0.76	matches $1 - \varepsilon^M/\varepsilon^m = 0.3$

The analysis so far suggests that optimal UI should be rather high in booms and rather low in slumps. Figure 6(c) quantifies this statement. It shows that the optimal replacement rate is sharply procyclical: it increases from 45% in a slump ($\beta = 0.95$) to 75% in a boom ($\beta = 0.25$). In these simulations our theoretical characterization of optimal UI relative to the Baily-Chetty level in tight and slack markets translates into a correlation between the optimal replacement rate and the parameter underlying business cycles, which is the usual notion of cyclicality in macroeconomics. This will generally be true when the Baily-Chetty rate is constant over the business cycle and business cycles are inefficient—such that the labor market is slack in slumps and tight in booms.

Finally, the unemployment rate responds to the adjustment of the replacement rate from its original level to its optimal level. In slumps, the optimal replacement rate is below its original level so the unemployment rate falls below its original level as well. For instance, at $\beta = 0.95$ the unemployment rate falls by 2.2 percentage point from 12.6% to 10.4%. In booms, the optimal replacement rate is above its original level so the unemployment rate rises above its original level. For instance, at $\beta = 0.25$ the unemployment rate rises by 2.3 percentage point from 4.0% to 6.3%. On the other hand, the elasticity wedge does not seem sensitive to the replacement rate.

In general, the source of fluctuations is critical to determine the cyclicality of optimal UI. If the business cycle is driven by changes in workers' bargaining power, as in our paper and in Jung and Kuester [2014], business cycles involve systematic departure from efficiency. Indeed, our numerical results are consistent with the findings in Jung and Kuester [2014] that UI should be lower in slumps caused by high bargaining power and higher in booms caused by low bargaining power.[34] However, if the business cycle is driven by changes in technology, as in Mitman and Rabinovich [2011], business cycles may not involve systematic departures from efficiency and may not lead to systematic deviations of optimal UI from Baily-Chetty. It is therefore hard to link our results to those of Mitman and Rabinovich [2011].

The Rigid-Wage Model. There remain two parameters to calibrate: the level of the real wage, ω, and the elasticity of the real wage with respect to technology, γ. We normalize average technology to $a = 1$ and $\tau(\theta) = 2.2\%$ on average so the steady-state relationship $1 = \omega \cdot a^{\gamma-1} \cdot (1 + \tau(\theta))$ yields

[34] Jung and Kuester [2014] also find that when UI is combined with other policies such as vacancy subsidies and layoff taxes, UI should remain broadly constant over the business cycle. These results are also consistent with our theory. Essentially, vacancy subsidies and layoff taxes maintain the labor market at efficiency and optimal UI is always at the Baily-Chetty level, which is broadly acyclical, as showed in Figure 7.

$\omega = 0.98$. We calibrate γ from microeconometric estimates of the elasticity for wages in newly created jobs—the elasticity that matters for job creation [Pissarides, 2009]. In panel data following production and supervisory workers from 1984 to 2006, Haefke, Sonntag and van Rens [2008] find that the elasticity of new hires' earnings with respect to productivity is 0.7.[35] Hence, we set $\gamma = 0.7$.

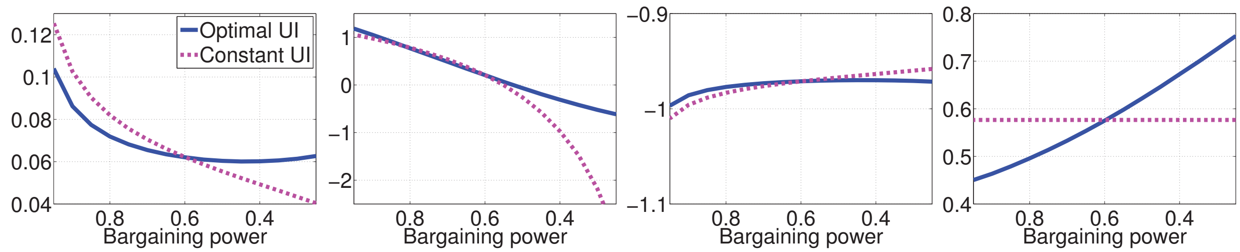
Figure 7 displays the results of the simulations. Each steady state is indexed by technology, $a \in [0.95, 1.10]$. Because of wage rigidity, the steady states with low a have a high wage-technology ratio and therefore high unemployment: they represent slumps. Conversely, the steady states with high a have a low wage-technology ratio and low unemployment: they represent booms. As showed in Figure 7(a), unemployment falls from 10.8% to 4.7% when a increases from 0.95 to 1.10 and UI remains constant. This numerical results implies that even a modest amount of wage rigidity, in line with the empirical findings of Haefke, Sonntag and van Rens [2008], generates realistic fluctuations in unemployment. Indeed, the elasticity of unemployment with respect to technology implied by the simulations is 6.3, larger than the elasticity of 4.2 observed in US data.[36]

The efficiency term is presented in Figure 7(b). In a slump (low a), it is positive and the labor market is slack. At $a = 1$, it is slightly positive and the labor market is mildly slack. The labor market is efficient for $a = 1.02$ and an unemployment rate of 5.9%. In booms (low a), it is negative and the labor market is tight. Figure 7(c) displays the elasticity wedge, which is always zero. Since the wedge is zero, UI has no effect on tightness and the optimal replacement rate is always at the Baily-Chetty level. Figure 7(d) shows that the optimal replacement rate constant at 61%. This result suggests that the replacement rate given by the Baily-Chetty formula is very stable over the business cycle. It also suggests that the US replacement rate of 58% is close to the Baily-Chetty level.

The Job-Rationing Model. The key parameter here is the production-function parameter, $\alpha < 1$. This parameter determines the magnitude of the elasticity wedge and of the rat-race effect. We calibrate α to match the estimate of the elasticity wedge provided by Lalive, Landais and Zweimüller

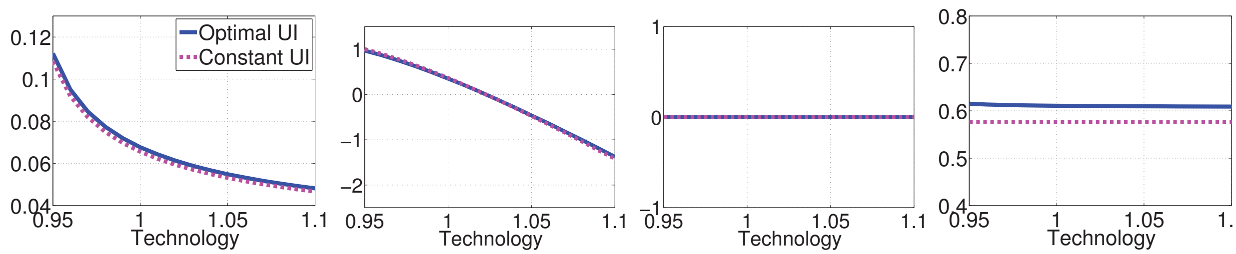
[35] See Table 6, Panel A, column 4 in Haefke, Sonntag and van Rens [2008].

[36] The elasticity is obtained by looking at a small change in technology around the average. When $a = 1$, $u = 6.56\%$ and when $a = 0.99$, $u = 6.97\%$ so the elasticity is $(1/6.56) \cdot (6.97 - 6.56)/(1 - 0.99) = 6.3$. Michaillat [2012] shows that the elasticity of unemployment with respect to technology over the 1964–2009 period in the US is 4.2.



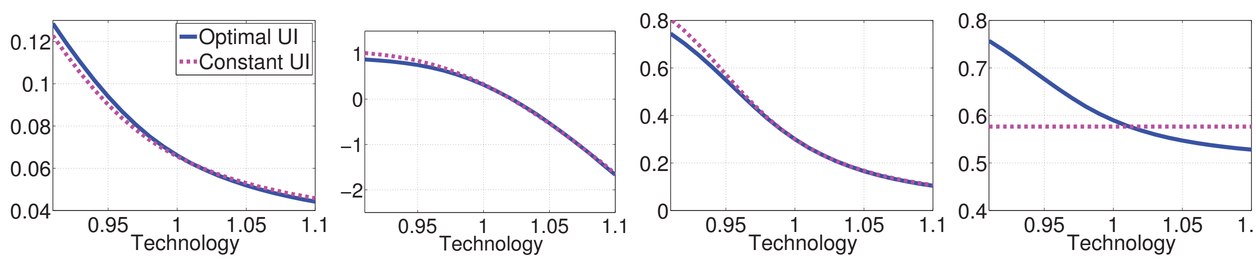
(a) Unemployment rate (b) Efficiency term (c) Elasticity wedge (d) Replacement rate

Figure 6: Steady states under constant UI and optimal UI in the standard model



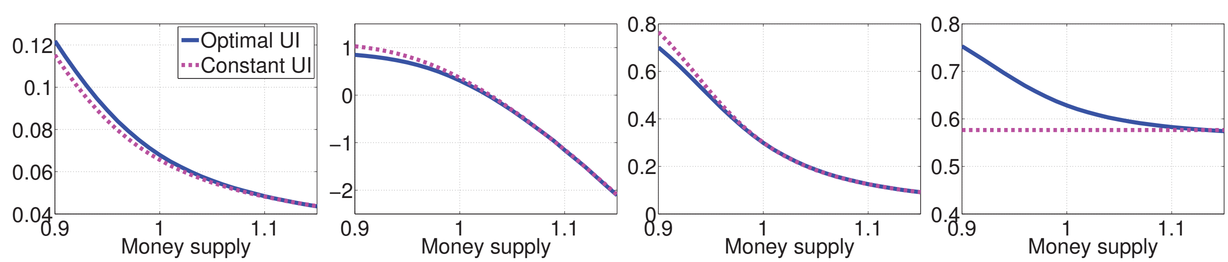
(a) Unemployment rate (b) Efficiency term (c) Elasticity wedge (d) Replacement rate

Figure 7: Steady states under constant UI and optimal UI in the rigid-wage model



(a) Unemployment rate (b) Efficiency term (c) Elasticity wedge (d) Replacement rate

Figure 8: Steady states under constant UI and optimal UI in the job-rationing model



(a) Unemployment rate (b) Efficiency term (c) Elasticity wedge (d) Replacement rate

Figure 9: Steady states under constant UI and optimal UI in the aggregate-demand model

[2013]: $1-\varepsilon^M/\varepsilon^m = 0.3$. Extending (27) to the dynamic environment without discounting yields

$$1-\frac{\varepsilon^M}{\varepsilon^m} = \left(1+\frac{\eta}{1-\eta}\cdot\frac{\alpha}{1-\alpha}\cdot\frac{1}{1+\varepsilon^f}\cdot\frac{\tau(\theta)}{u}\right)^{-1}.$$

We set $1-\varepsilon^M/\varepsilon^m = 0.3$, $\eta = 0.7$, $\varepsilon^f = 0.021$, $\tau(\theta) = 2.2\%$, and $u = 6.6\%$ and obtain $\alpha = 0.76$. As in the rigid-wage model, we set $\gamma = 0.7$. We exploit the steady-state relationship $\alpha \cdot n^{\alpha-1} = \omega \cdot a^{\gamma-1} \cdot (1+\tau(\theta))$. We set $a = 1$, $\alpha = 0.76$, $\tau(\theta) = 2.2\%$, and $n = (1-u)/(1+\tau(\theta)) = 0.915$ and get $\omega = 0.76$.

Figure 8 displays the simulations of the job-rationing model. As in the rigid-wage model, steady states are indexed by technology, $a \in [0.91, 1.10]$. The steady states with low a represent slumps and those with high a represent booms. As showed in Figure 8(a), unemployment falls from 12.3% to 4.6% when a increases from 0.91 to 1.10 and UI remains constant.

The efficiency term is presented in Figure 8(b). In a slump, it is positive and the labor market is slack. The labor market is efficient for $a = 1.02$ and an unemployment rate of 6.0%. In booms, it is negative and the labor market is tight. Figure 8(c) displays the elasticity wedge. The wedge is positive, which implies that optimal UI should be below the Baily-Chetty level in booms and above it in slumps. The wedge is also countercyclical, consistent with the results of Proposition 10. In an average situation ($a = 1$), the wedge is 0.3. The average wedge matches exactly the estimate from Lalive, Landais and Zweimüller [2013] due to our calibration of the production-function parameter, α. From a slump ($a = 0.91$) to a boom ($a = 1.10$), the wedge falls from 0.81 to 0.11.

Figure 8(d) shows that the optimal replacement rate is sharply countercyclical: it falls from 76% in a slump ($a = 0.91$) to 53% in a boom ($a = 1.10$). Thus, the theoretical characterization of optimal UI relative to the Baily-Chetty level in tight and slack markets translates into a correlation between the optimal replacement rate and the parameter underlying business cycles.

Finally, the unemployment rate responds to the adjustment of the replacement rate from its original level to its optimal level. In slumps, the optimal replacement rate is higher than its original level so the unemployment rate increases above its original level, but not by much. At $a = 0.91$ the unemployment rate increases by 0.5 percentage point from 12.3% to 12.8%. UI has little influence on unemployment in a slump because the macroelasticity is very low, as suggested by the high elasticity wedge in slumps: for $a = 0.91$, $\varepsilon^M = 0.06$ whereas $\varepsilon^m = 0.28$. In booms, the optimal replacement rate is below its original level so the unemployment rate falls below its original level. At $a = 1.10$ the unemployment rate falls by 0.2 percentage point from 4.6% to 4.4%.

The Aggregate-Demand Model. The key parameter here is the wage-rigidity parameter, $\zeta < 1$, because it determines the magnitude of the elasticity wedge. We calibrate ζ to match the estimate provided by Lalive, Landais and Zweimüller [2013], $1 - \varepsilon^M / \varepsilon^m = 0.3$. Extending (30) to the dynamic environment without discounting yields

$$1 - \frac{\varepsilon^M}{\varepsilon^m} = \left(1 + \frac{\eta}{1-\eta} \cdot \frac{\zeta}{1-\zeta} \cdot \frac{1}{1+\varepsilon^f} \cdot \frac{\tau(\theta)}{u}\right)^{-1}.$$

As in the job-rationing model, we get $\zeta = 0.76$. Using the steady-state relationship $1 = \mu \cdot (n/M)^{1-\zeta} \cdot (1 + \tau(\theta))$, the normalization $M = 1$, $\tau(\theta) = 2.2\%$, $\zeta = 0.76$, and $n = 0.915$, we get $\mu = 1.00$.

Figure 9 displays the simulations of the aggregate-demand model. Each steady state is indexed by a money supply, $M \in [0.9, 1.15]$. The steady states with low M have a low price level and thus a high real wage, because of nominal wage rigidity. These steady states therefore have high unemployment: they represent slumps. Conversely, the steady states with high M have a high price level, a low real wage, and low unemployment: they represent booms. As showed in Figure 7(a), unemployment falls from 11.5% to 4.4% when M increases from 0.95 to 1.15 and UI remains constant.

The results are almost identical to those in the job-rationing model, so we only discuss them briefly. As showed in Figure 9(b), the labor market is slack in slumps (low M) and tight in booms (high M). As showed in Figure 9(c), the elasticity wedge is positive and strongly countercyclical. And as showed in Figure 9(d), the optimal replacement rate is sharply countercyclical: it falls from 75% in a slump ($M = 0.9$) to 57% in a boom ($M = 1.15$).

These results reinforce two points that we made in Section 5. First, diminishing marginal returns to labor are not necessary to obtain a countercyclical optimal UI. Here, marginal returns to labor are constant but optimal UI is sharply countercyclical. The necessary ingredients to obtain this result are a downward-sloping labor demand and wages that do not respond much to UI. Second, technology shocks are not necessary to obtain large unemployment fluctuations. Here, large fluctuations arise from monetary shocks.

7 Conclusion

This paper studies the response of optimal UI to the state of the labor market. The paper shows that optimal UI is the sum of a conventional Baily-Chetty term, which captures the trade-off between insurance and job-search incentives, and a correction term, which is positive if UI brings equilibrium labor market tightness closer to efficiency. Since tightness is inefficiently low in a slack labor market and inefficiently high in a tight labor market, the response of optimal UI to the state of the labor market depends on the effect of UI on tightness. The paper develops an empirical criterion for determining whether UI raises or lowers tightness: we show that UI raises tightness if and only if the macroelasticity of unemployment with respect to UI is smaller than its microelasticity.

The question that is especially relevant for policy is whether UI should be increased or decreased when the unemployment rate rises. Our analysis indicates how to answer this question. The first step is to verify that the labor market indeed becomes slack as unemployment rises. Section 6.3 proposes a methodology to do this. The second step is to compare the macroelasticity to the microelasticity. The studies by Card and Levine [2000], Lalive, Landais and Zweimüller [2013], and Marinescu [2014] find that the macroelasticity is smaller than the microelasticity. But Hagedorn et al. [2013] find the opposite. Thus, further empirical research comparing the microelasticity to the macroelasticity is required before we can take a stand on the cyclicality of optimal UI.

In principle, our methodology could be applied to the optimal design of other public policies over the business cycle. We conjecture that a policy that maximizes welfare in an economy with inefficient tightness obeys the same general rule as the one derived in this paper for UI. The optimal policy is the sum of the optimal policy when the economy is efficient plus a correction term when the economy is slack or tight. If a marginal increase of the policy increases tightness, the correction is positive in a slack economy and negative in a tight economy. We conjecture that the methodology could be applied to the provision of public good. In the model of Michaillat and Saez [2013], public good provision stimulates aggregate demand and increases tightness. As a result, the government should provide more public good than in the Samuelson [1954] rule when the economy is slack and less when the economy is tight. We conjecture that the methodology could also be applied to income taxation. In the model of Michaillat and Saez [2013], if high-income earners have a lower propensity to consume than low-income earners, transfers from high-income earners to low-income earners stimulate aggregate demand and increase tightness. As a result, the top income tax rate should be higher than in the Mirrlees [1971] optimal top income tax formula in a slack economy and lower in a tight economy. This agenda in normative analysis could help bridge the gap between the analysis of tax, social insurance, and public good policies in public economics and the analysis of business-cycle stabilization policies in macroeconomics.[37]

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[37] This agenda is closely related in spirit to the conceptual framework proposed by Farhi and Werning [2013] to study optimal macroeconomic policies in the presence of price rigidities. They obtain the same decomposition of optimal policies into standard policies plus a correction term. However, their correction term arises not because of matching frictions but because of price rigidities.

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Appendix: Details of the Calibration

We provide details of the calibration in Section 6. All the derivations apply to the steady state of the dynamic model without discounting.

Measuring the Employed-Unemployed Consumption Ratio, c^e/c^u. The production function is $y(n) = n^\alpha$ so the firm's optimality condition, given by (2), implies that $y(n) = w \cdot l/\alpha$. We can therefore rewrite the government's budget constraint, given by (4), as $c^e - u \cdot (c^e - c^u) = w \cdot (1-u)/\alpha$, where $u = 1 - l$ is the unemployment rate. We divide this budget constraint by $\Delta c = c^e - c^u$. We get $(c^e/c^u)/(c^e/c^u - 1) = u + (1-u)/[(1-R)\cdot\alpha]$. After some algebra we obtain

$$\frac{c^e}{c^u} = \frac{1 + \alpha \cdot (1-R) \cdot u/(1-u)}{1 - \alpha \cdot (1-R)}, \tag{A1}$$

On average, $u = 6.6\%$ and $R = 58\%$. With a linear production function, $\alpha = 1$, $c^e/c^u = 1.79$. Since we assume log utility, $\Delta v = \ln(c^e/c^u) = 0.58$. With a concave production function and $\alpha = 0.76$, $c^e/c^u = 1.50$ and $\Delta v = \ln(c^e/c^u) = 0.41$.

Measuring $(\Delta v + k(e))/(\phi \cdot w)$. With log utility and $e = 1$, $(\Delta v + k(e))/(\phi \cdot w) = (1-R) \cdot \ln(c^e/c^u) \cdot (u + (1-u) \cdot c^e/c^u)/(c^e/c^u - 1)$. With $R = 58\%$ and $c^e/c^u = 1.79$, we get $(\Delta v + k(e))/(\phi \cdot w) = 0.54$.

Measuring the Microelasticity, ε^m. On average, $R = 58\%$. With a linear production function, $c^e/c^u = 1.79$ and $\Delta v/(v'(c^u) \cdot R \cdot w) = (1-R) \cdot \ln(c^e/c^u)/[R \cdot (c^e/c^u - 1)] = 0.54$. Using (12) and the estimate $\varepsilon^m_R = 0.5$ from the literature, we get $\varepsilon^m = 0.27$. At the other hand of the spectrum, with a concave production function and $\alpha = 2/3$, $c^e/c^u = 1.42$, $\Delta v/(v'(c^u) \cdot R \cdot w) = 0.61$, and $\varepsilon^m = 0.31$. The differences between the two values of ε^m are negligible. We choose a middle value of $\varepsilon^m = 0.3$.

Linking Discouraged-Worker Elasticity, ε^f, to ε^m. Let $\varepsilon^e_\Delta \equiv (\Delta v/e)\cdot(\partial e^s/\partial \Delta v)$, $\kappa \equiv (e/k'(e))\cdot k''(e)$, and $L(x) \equiv x/(s+x)$. The elasticity of $L(x)$ is $1-L(x)$. The effort supply $e^s(f,\Delta v)$ satisfies $k'(e^s) = (L(e^s\cdot f)/e^s)\cdot(\Delta v + k(e^s))$. Differentiating this condition with respect to Δv yields

$$\kappa\cdot\varepsilon^e_\Delta = (1-l)\cdot\varepsilon^e_\Delta - \varepsilon^e_\Delta + \frac{\Delta v}{\Delta v + k(e)} + \varepsilon^e_\Delta\cdot\frac{e\cdot k'(e)}{\Delta v + k(e)}.$$

In equilibrium, $(e\cdot k'(e))/(\Delta v + k(e)) = l$. Therefore, $\varepsilon^e_\Delta = (1/\kappa)\cdot\Delta v/(\Delta v + k(e))$. Since the labor supply satisfies $l^s(f,\Delta v) = L(e^s(f,\Delta v)\cdot f)$, the elasticity of $l^s(\theta,\Delta v)$ with respect to Δv is $(1-l)\cdot\varepsilon^e_\Delta$. By definition, ε^m is $l/(1-l)$ times the elasticity of $l^s(\theta,\Delta v)$ with respect to Δv. Thus,

$$\varepsilon^m = \frac{1-u}{\kappa}\cdot\frac{\Delta v}{\Delta v + k(e)}. \tag{A2}$$

Similarly, differentiating the effort supply condition with respect to f yields

$$\kappa\cdot\varepsilon^f = (1-l)\cdot(\varepsilon^f + 1) - \varepsilon^f + \varepsilon^f\cdot\frac{e\cdot k'(e)}{\Delta v + k(e)},$$

which implies that

$$\varepsilon^f = \frac{u}{\kappa}. \tag{A3}$$

Combining (A2) and (A3), we find (39) when $e=1$ and thus $k(e)=0$.

Calibrating Labor Market Parameters. We focus on the December 2000–February 2014 period. This is the longest period for which the Job Openings and Labor Turnover Survey (JOLTS) is available. We use seasonally adjusted monthly series. We set the job-destruction rate at $s = 3.5\%$, which is the average of the total separation rate in all nonfarm industries constructed by the BLS from JOLTS. We use a Cobb-Douglas matching function $m(e\cdot u, o) = \omega_m\cdot(e\cdot u)^\eta\cdot o^{1-\eta}$, with $\eta = 0.7$. To calibrate ω_m, we exploit the steady-state relationship $u\cdot e\cdot f(\theta) = s\cdot(1-u)$, which implies $\omega_m = s\cdot\theta^{\eta-1}\cdot(1-u)/(u\cdot e)$. On average, $u = 6.6\%$ and $e = 1$. We measure average tightness as the ratio of the average vacancy level in all nonfarm industries constructed by the BLS from the JOLTS to the average unemployment level constructed by the BLS from the CPS (average effort is normalized to 1). We obtain $\theta = 0.37$. Using these averages, we get $\omega_m = 0.67$.

Calibrating the Disutility of Search. We use a disutility of search $k(e) = \omega_k\cdot e^{\kappa+1}/(\kappa+1) - \omega_k/(\kappa+1)$. To calibrate κ, we use (A2). On average, $u = 6.6\%$, $e = 1$, and ε^m=0.3 so $\kappa = 3.11$. To calibrate ω_k, we exploit the steady-state relationship $k'(e) = [(1-u)/e]\cdot(\Delta v + k(e))$. This implies $\omega_k = (1-u)\cdot\Delta v$ when $e = 1$. With a linear production function, $\Delta v = 0.58$ so $\omega_k = 0.54$. With a concave production function and $\alpha = 0.76$, $\Delta v = 0.41$ so $\omega_k = 0.38$.

Calibrating the Recruiting Cost, r. To calibrate r we exploit the steady-state relationship $\tau(\theta) = r\cdot s/[o_m\cdot\theta^{-\eta} - r\cdot s]$, which implies $r = o_m\cdot\theta^{-\eta}\cdot\tau(\theta)/[s\cdot(1+\tau(\theta))]$. Taking the average of the recruiter-producer ratio series constructed in Section 6, we find $\tau(\theta) = 2.2\%$. Using $\omega_m = 0.67$, $s = 3.5\%$, $\theta = 0.37$, and $\tau(\theta) = 2.2\%$, we obtain $r = 0.82$.