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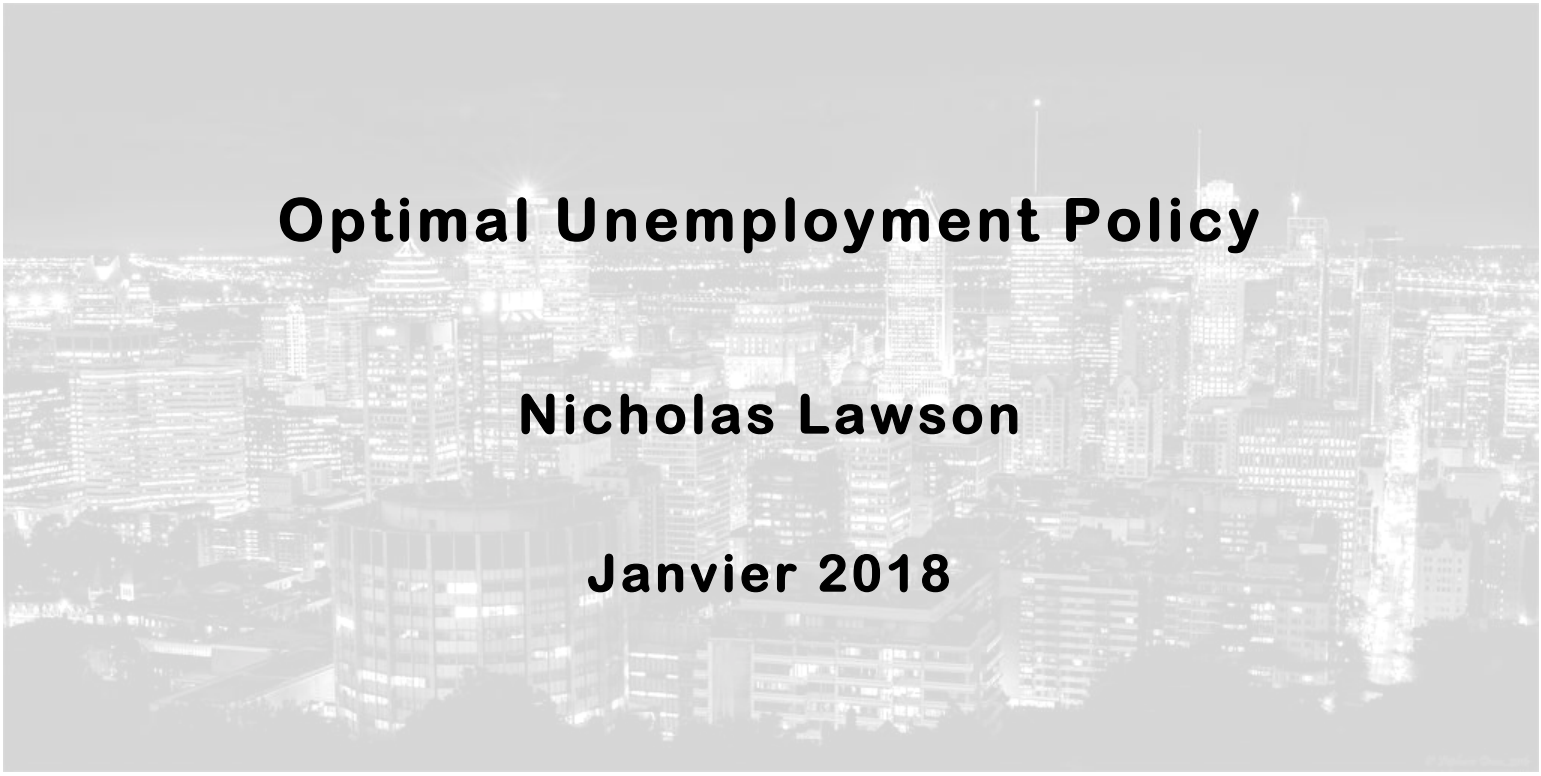

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Département des sciences économiques
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Optimal Unemployment Policy

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Abstract

A vast literature studies the optimal design and generosity of unemployment insurance (UI). However, UI is just one of the variety of programs used in developed countries around the world to deal with unemployment, though unemployment programs other than UI have been subjected to much less welfare analysis. My paper adds to a small but growing literature that evaluates the welfare implications of a wider range of unemployment programs, while incorporating two empirically relevant phenomena that have generally been ignored in this literature: private consumption smoothing and fiscal externalities from income taxes. I estimate a job search model using indirect inference with data from the March CPS, and simulate the model to evaluate a wide variety of policy reforms. I show that monitoring and job search assistance (JSA) play important roles, with welfare impacts at least as large as that of the UI replacement rate. The optimal combined policy incorporates more short-term insurance as well as increased monitoring of search and expanded provision of JSA. I also find that general and partial equilibrium results are generally similar, as programs that raise bargained wages also reduce job-creation, with impacts on welfare that nearly offset.

Keywords: unemployment insurance, labour market programs, optimal policy, general equilibrium

JEL Codes: I38, J08, J64, J65, J68

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1 Introduction

A vast literature studies the optimal design and generosity of unemployment insurance (UI), starting with Baily (1978) and continuing through Hansen and İmrohoroğlu (1992) and Chetty (2008), among many other important contributions. This literature studies a central tradeoff between consumption smoothing and moral hazard: more generous UI prevents a large drop in consumption upon job loss, but also reduces the incentive for job search among the unemployed.[1] However, UI is just one of the variety of programs used in developed countries around the world to tackle the problem of unemployment. Active labour market programs such as monitoring and sanctions, job search assistance (JSA), subsidized employment, and training programs are prominent in many countries, with the goals of improving the labour market prospects of the unemployed and reducing moral hazard costs. In spite of this, unemployment programs other than UI have been the subject of a much smaller welfare analysis literature.

Therefore, my paper seeks to answer the following question: what is the optimal combined unemployment policy? More specifically, is optimal UI sensitive to the inclusion of other unemployment programs? Using an estimated search model, my paper is the first to evaluate such a broader optimal unemployment policy in the presence of the private consumption smoothing and fiscal externalities from income taxes which are highly relevant in the real world.

The literature that attempts to model UI in combination with other labour market programs is relatively small but has been growing in recent years. Fredriksson and Holmlund (2006) and Boone, Fredriksson, Holmlund, and van Ours (2007) consider optimal combined unemployment insurance and monitoring, but rely on a very simple specification for monitoring. Meanwhile, Pavoni and Violante (2007), Pavoni, Setty, and Violante (2013) and Wunsch (2013) examine the optimal "Welfare-to-Work" policy sequence in a principal-agent framework in which the planner attempts to implement the optimal allocation subject to incentive-compatibility constraints.[2] My analysis is complementary in that I instead use a

[1] See, for example, Gruber (1997) and Engen and Gruber (2001) on consumption smoothing, and Meyer (1990), Lalive, van Ours, and Zweimüller (2006) and Chetty (2008) on the moral hazard costs of UI.

[2] These papers find that traditional UI should be followed by monitored or assisted search and then social assistance. Other related studies include a simple study of monitoring with linear precision in van der Linden (2003), and more recent principal-agent papers such as Setty (2015), which considers monitoring of binary search, Pavoni, Setty, and Violante (2016), who study "soft" programs including JSA, and Jung and Kuester (2015), who consider the optimal combination of UI, vacancy subsidies, and layoff taxes, in recessions.

welfare maximization approach – what Koehne and Kuhn (2015) refer to as the "Ramsey optimal policy" approach[3] – to search for the optimal policy combination among a set of policies that are typical in developed countries.

However, while it is standard in the optimal UI literature to incorporate private consumption smoothing,[4] all papers that I am aware of in the literature on optimal combined unemployment policy assume that individuals are incapable of private consumption smoothing. Indeed, principal-agent models, since they aim to implement an optimal allocation, assume either that there is no private consumption smoothing, or that the planner can intervene to perfectly control such behaviour. However, empirical studies such as Gruber (1997) and Engen and Gruber (2001) find that consumption smoothing during unemployment is significant and responsive to UI.

Additionally, with only a few exceptions,[5] previous optimal unemployment policy papers have also ignored fiscal externalities from income taxes. Lawson (2017a) demonstrates that fiscal externalities, or impacts of programs on income tax revenues through their impacts on labour market outcomes, can dramatically alter optimal UI policy recommendations: if UI leads to lengthened durations of unemployment, this also means less time working and paying taxes, with an additional fiscal cost that is ignored when the model is misspecified through the omission of income taxes.[6] The lesson of Lawson (2017a) is that the gains from getting unemployed workers into good jobs as quickly as possible are bigger than previously realized; programs that worsen the pre-existing tax distortion in the labour market have large marginal welfare costs, and those that alleviate distortions on job search generate large marginal welfare gains. However, Lawson (2017a) abstracts from unemployment programs other than UI. The current paper represents the first evaluation of a broader optimal unemployment policy – beyond just UI benefits – that incorporates both of these empirically relevant features.

[3]See also, for example, Hansen and İmrohoroğlu (1992) and Wang and Williamson (2002) for optimal UI, and Michelacci and Ruffo (2015) for life-cycle UI.

[4]See Abdulkadiroğlu, Kuruşçu, and Şahin (2002), Chetty (2006), and Krussell, Mukoyama, and Şahin (2010), among many others.

[5]van der Linden (2003) includes a payroll tax paid by firms, while Wunsch (2013) and Setty (2015) calibrate their models to tax rates of 36% and 29% respectively.

[6]On the other hand, if more generous UI enables workers to be more patient and find a better match paying higher wages, there could be a positive effect on tax revenues. In each case, it is the existence of a large tax that is of central importance: an individual's actions in reducing search intensity or taking a lower-paid job impose a negative externality on everyone else through the tax system, as the tax rate must be raised to make up the lost revenue, or public good provision decreased.

I begin my analysis with a simple two-period model adapted from Baily (1978), to build intuition; Baily's model inspired the "sufficient statistics" approach to optimal UI later used by Shimer and Werning (2007) and Chetty (2008). I demonstrate that fiscal externalities provide a case not only for less generous UI, but also for job search assistance, as well as monitoring with sanctions for those found not to be searching hard enough. However, it is difficult to say much about the optimal combined policy with only an analytical model: the simplicity of the sufficient statistics approach, which makes it so valuable in the analysis of one-dimensional policy problems such as optimal UI, also makes it unsuitable for the estimation of a multi-dimensional optimal policy vector.

A more realistic numerical model is required, and therefore the rest of the paper focusses on a standard job search model with a representative risk-averse worker and consumption smoothing through home production. I consider both a partial equilibrium single-agent setting, and a general equilibrium version of the model featuring a Mortensen-Pissarides matching framework. Unlike the existing literature on optimal combined policy, where numerical analysis is based on a simple calibration of the model, I structurally estimate the parameters of the model using indirect inference on data from the March CPS. I then simulate a variety of policies – UI, JSA, monitoring and sanctions, and job-creation bonuses – both independently and combined, where the parameters on the effectiveness and costs of each policy are calibrated from existing evidence.

I find that reductions in UI generosity on their own lead to increases in welfare: the optimal replacement rate is in the range of 30-36%, while if the duration of UI can also be modified, benefits should be kept near the current level of about 50% while duration is cut from 6 to 3 or 4 months. However, this no longer holds once UI is combined with monitoring and JSA. In particular, monitoring corrects a significant portion of the moral hazard costs of UI, allowing for more insurance, at least in the early months of an unemployment spell.[7] The optimal combined policy features UI that starts out more generous than in current policy, and which remains more generous in the partial equilibrium model for at least 12 months, while in general equilibrium the optimal replacement rate declines significantly over an unemployment spell. In both cases, the average benefit received by unemployed individuals is more generous than at baseline, and significantly more generous than the optimal policy in the absence of

[7] A similar result was found by Fredriksson and Holmlund (2006) and Boone, Fredriksson, Holmlund, and van Ours (2007), but their numerical results were significantly different due to their omissions of consumption smoothing and fiscal externalities.

monitoring and JSA.

Additionally, monitoring and JSA play roles of previously unrecognized importance. The optimal combined policy includes an average monthly monitoring probability of at least 10%, as well as the provision of JSA if the cost of doing so is within an empirically plausible range. On their own, the welfare gain from each policy is at least as large as the welfare gain from optimizing the UI replacement rate, making it surprising that the latter has been the focus of a vast policy literature while monitoring and JSA have received relatively little attention. The empirical literature on active labour market programs has tended to find that programs such as JSA have small impacts on job-finding rates,[8] but my analysis highlights an important point: even programs that have seemingly small impacts on labour market outcomes could have big welfare impacts if those outcomes were already significantly distorted by taxes. Future work on unemployment policy should take much more seriously the role of programs such as monitoring and JSA.

Finally, studying a general equilibrium setting allows me to consider the effect of UI and other unemployment programs on bargaining and vacancy creation. I find that, if the Hosios condition on bargaining power is satisfied, the optimal policy results are quite similar to those from the partial equilibrium setting: with Nash bargaining, policies that raise bargained wages and lower vacancy creation generate slightly reduced welfare gains, but the effect is small in all but the case of the combined policy. The reason for this is simple and intuitive: general equilibrium adjustments take place along two dimensions that are linked by a zero-profit condition: wages and vacancy creation rates. If a program raises the workers' bargained wages, it will necessarily reduce vacancy creation and, all else equal, raise unemployment; since firms face a zero-profit condition and are unaffected, and these effects on workers counteract each other, there is little net welfare impact. This result is quite general, and is also found in a recent theoretical paper by Landais, Michaillat, and Saez (2018b): in any standard job search model, welfare implications of policy will be similar in partial and general equilibrium models unless the matching equilibrium deviates significantly from efficiency.[9]

I contribute to the literature discussed above, on optimal combined unemployment policy,

[8] See, for example, the surveys provided by Card, Kluve, and Weber (2010) and Kluve (2010).

[9] Landais, Michaillat, and Saez (2018a), however, argue that the efficiency of matching equilibrium does not generally hold across the business cycle, with workers' bargaining power countercyclical relative to its efficient level.

in several ways. First of all, as the first paper in this literature to account for the empirically relevant phenomena of private consumption smoothing and fiscal externalities from income taxes, I am able to provide more credible numerical estimates on optimal unemployment policy: I show that policies other than UI are of considerable quantitative significance, and that incorporating both consumption smoothing and fiscal externalities generates qualitatively and quantitatively novel results. Second, this is the first paper in the optimal combined policy literature to perform a structural estimation of a job search model,[10] and my use of the indirect inference method with data from the March CPS is, to my knowledge, a novel application for the estimation of a search model.

Finally, my comparison of partial and general equilibrium policy analyses highlights the important point that we should not assume that a general equilibrium adjustment that weakens the impact of a policy on one targetted dimension necessarily weakens its welfare impact; rather, the impact is channeled into a different dimension such as a price change, with welfare implications that are different but not necessarily smaller. This is an important issue to keep in mind for future research.

The rest of the paper proceeds as follows. Section 2 presents a simple model of unemployment and derives analytical results for the welfare implications of policy. Section 3 then introduces the main search model of the paper, and section 4 describes the estimation of the model. Section 5 presents the numerical policy results, and section 6 concludes the paper. Four appendices presents additional details and results.

2 A Simple Model of Unemployment

In this section, I begin my analysis with a simple two-period model of unemployment and job search. The model is a simplified version of the already-parsimonious model from the seminal optimal UI paper by Baily (1978), which inaugurated the sufficient statistics approach to optimal UI that was later used in papers such as Shimer and Werning (2007) and Chetty (2008). My analysis will highlight the basic intuitions underlying optimal unemployment policy, as well as the challenges in performing welfare analysis of multiple programs in combination.

The model features an ex-ante representative individual who spends the first period

[10] Lentz (2009) represents a rare example of structural estimation of a search model in a more simple optimal UI context.

employed at a wage that is normalized to one, and chooses an amount of savings k (which could be negative, and for which the interest rate is zero), thus receiving consumption $c_1 = 1-k$. At the end of the first period, the individual separates from their initial job and begins searching for a new job. They choose a search intensity s subject to a convex utility cost $e(s)$, and their status in the second period is influenced by this choice: with probability s, they find a new job (at the same fixed wage of one), pay a tax equal to τ, and thus receive consumption $c_e = 1-\tau+k$. Meanwhile, with probability $1-s$, they spend the second period unemployed, and receive a UI benefit equal to b, thus receiving consumption $c_u = b+k$.

There is no discounting, and the individual chooses k and s to maximize expected utility:

$$V = U(1-k) + sU(1-\tau+k) + (1-s)U(b+k) - e(s) \tag{1}$$

where $U(c)$ is utility from consumption. Meanwhile, the government chooses the value of b subject to a government budget constraint:

$$s\tau = (1-s)b + G \tag{2}$$

where G is an amount of required spending on other government programs. The existence of this revenue requirement means that the budget-balancing tax rate is larger – perhaps considerably larger – than the small tax that would suffice to pay for UI benefits. G, therefore, is the principle source of the fiscal externality in this model, and as demonstrated by Lawson (2017a), analyses of optimal UI that ignore other categories of government spending such as G are misspecified and will generally provide misleading answers.

The objective of the government is to maximize expected utility subject to the individual's choice of k and s. To study this welfare maximization problem, I will first consider the optimal UI benefit, and then think about adding additional policies aimed at enhancing or enforcing job search.

2.1 Optimal Unemployment Insurance

Let us consider the optimal level of the UI benefit b. When b changes, the individual's choices of k and s are likely to change, but this has no first-order welfare impact, because those choices were made by individuals to maximize V; therefore, $\frac{\partial V}{\partial k}$ and $\frac{\partial V}{\partial s}$ are both equal to zero. The budget-balancing tax rate τ will also change with b, and therefore the derivative of welfare with respect to b is given by:

$$\frac{dV}{db} = \frac{\partial V}{\partial b} + \frac{\partial V}{\partial \tau}\frac{d\tau}{db}. \tag{3}$$

It is easy to solve for the terms in this equation by differentiating (1) and (2); if I define second-period unemployment as $u = 1 - s$, and the elasticity of unemployment with respect to b as $\varepsilon_{ub} \equiv \frac{b}{1-s}\frac{d(1-s)}{db}$, I can solve for:

$$\frac{dV}{db} = (1-s)U'(c_e)\left[\frac{U'(c_u) - U'(c_e)}{U'(c_e)} - \frac{b+\tau}{b}\varepsilon_{ub}\right].$$

I then use a Taylor series expansion of $U'(c_u)$ around $U'(c_e)$: $U'(c_u) \simeq U'(c_e) + (c_u - c_e)U''(c_e)$. Then it is easy to show that $\frac{U'(c_u)-U'(c_e)}{U'(c_e)}$ is approximately equal to $R\frac{\Delta c}{c_e}$, where R is the coefficient of relative risk-aversion and $\Delta c = c_e - c_u$ is the consumption gap between employed and unemployed individuals. Therefore, the expression for the welfare derivative is:

$$\frac{dV}{db} = (1-s)U'(c_e)\left[R\frac{\Delta c}{c_e} - \frac{b+\tau}{b}\varepsilon_{ub}\right]. \tag{4}$$

The two terms inside the square brackets capture the benefit and cost of UI: the risk-aversion coefficient times the consumption drop upon unemployment represents the gain from consumption smoothing, while the term including the elasticity of unemployment identifies the moral hazard cost.

τ appears only once in this expression, as part of the latter term:[11] all else equal, a higher tax rate raises the moral hazard cost of providing UI. The logic is quite simple: when more generous UI reduces job search and increases unemployment, it also reduces employment, thus reducing the tax base and the revenues available to the government to pay for the other spending captured by G. The tax rate thus has to increase further than would otherwise be the case in order to make up the lost revenue. Therefore, we may conclude that the optimal level of b will be lower when we recognize that τ is large.

This result is not new; it is merely a simplified example of the result from Lawson (2017a). However, the framework allows me to ask the question: can we do better than just optimizing b? That is, are there alternative policies that we might incorporate, and how would they be affected by fiscal externalities? I consider this question in the following subsections.

2.2 Optimal Policy with Job Search Assistance

First, I will consider job search assistance (JSA). Suppose that the probability of finding a job is now λs, where λ is initially equal to one but can be raised by the government subject to

[11] If we think about actually raising τ, it is clear that the other terms in the expression could well change, leading to ambiguous results. However, if we think about simply recognizing that τ is large, where previous work assumed it to be quite small, it is appropriate to think in "partial derivative" terms.

cost $c(\lambda)$. While raising λ does not solve the moral hazard problem, it does help to raise the job-finding rate from an inefficiently low level. Differentiating expected utility with respect to λ:

$$\frac{dV}{d\lambda} = \frac{\partial V}{\partial \lambda} + \frac{\partial V}{\partial \tau}\frac{d\tau}{d\lambda}.$$

Evaluating the terms in this expression is straightforward, and leads to the following result:

$$\frac{dV}{d\lambda} = s\left[U(c_e) - U(c_u)\right] + U'(c_e)\left[(b+\tau)\frac{d(\lambda s)}{d\lambda} - c'(\lambda)\right].$$

The first collection of terms in this expression captures a simple utility gain from shifting more people into employment: those individuals get to enjoy $U(c_e)$ instead of $U(c_u)$. Meanwhile, the second half of the equation represents the fiscal impact of JSA: increasing λ generates more tax revenue and requires less spending on UI, as long as the total job-finding rate λs increases, but also requires increased spending $c'(\lambda)$. The only appearance of τ in this expression is positive: higher taxes amplify the fiscal benefit of increasing employment, and so we can conclude that the fiscal externality from income taxes increases the welfare gain from JSA.

If I now return to the optimal UI problem and update the solution for $\frac{dV}{db}$ in (3) to incorporate λ, the result is very simple:

$$\frac{dV}{db} = (1-\lambda s)U'(c_e)\left[R\frac{\Delta c}{c_e} - \frac{b+\tau}{b}\varepsilon_{ub}\right]$$

The welfare gain is made directly smaller by JSA, since unemployment is reduced. However, unlike the partial equilibrium analysis of fiscal externalities, in which we assume that nothing else changes when we increase τ – see footnote 11 – here we must also consider changes in individual choices: how are the other terms in the equation affected when λ is incorporated? This is theoretically ambiguous; on the one hand, a reduction in unemployment due to JSA could make providing insurance more necessary, since individuals will tend to save less when facing a lower risk of unemployment, but search could also become more responsive to UI since the marginal cost of search is flatter, raising the moral hazard cost driven by ε_{ub}. In this simple model, I cannot be sure which will dominate.

2.3 Optimal Policy with JSA & Monitoring

I now add monitoring to the mix of policies available to the government. Suppose that the government can choose a threshold for search, which I denote by x, and a probability of

monitoring ϕ, subject to a cost of q per individual monitored, where monitoring is assumed to be perfectly accurate. Individuals are monitored at random, and if a monitored individual is found to be searching less than the threshold amount, i.e. $s < x$, they lose the right to UI benefits if they fail to find a job.

Given a value of x, clearly there are only two possible values of ϕ that the government would optimally choose: zero, or a value just large enough that workers prefer to search at $s = x$. I assume that there is some welfare-improving regime with non-zero monitoring that improves welfare, so I consider the latter case and look for the optimal x subject to a cost $q\phi(x)$, where $\phi(x)$ denotes the value of ϕ required to make workers search with intensity x, and clearly $\phi'(x) > 0$.

The welfare derivative for x takes the same basic form as those for b and λ:

$$\frac{dV}{dx} = \frac{\partial V}{\partial x} + \frac{\partial V}{\partial \tau}\frac{d\tau}{dx}.$$

Evaluating each of the terms, I find:

$$\frac{dV}{dx} = U(c_e) - U(c_u) - e'(x) - U'(c_e)(q\phi'(x) - b - \tau).$$

The first three terms capture the direct welfare gain from higher x: individuals are more likely to obtain employment, but at the cost of higher search effort. If x is greater than the privately-optimal s^*, the sum of these three terms will generally be negative, since $e(s)$ is convex and s^* is the value that sets $e'(s) = U(c_e) - U(c_u)$. If I evaluate the welfare derivative at $x = s^*$, considering the marginal gain from increasing s above the privately-optimal value, I can simply the equation to focus on the final term which expresses the fiscal impact of monitoring:

$$\frac{dV}{dx}|_{x=s^*} = U'(c_e)(b + \tau - q\phi'(x)).$$

Raising the monitoring threshold earns the government additional tax revenues τ and saves them UI benefits b, but this comes at a cost of $q\phi'(x)$. Unsurprisingly, τ appears in this expression, and the general expression for $\frac{dV}{dx}$, with a positive sign: a larger value of τ increases the return to making people search harder and find jobs faster.

If I now consider all three policies together, the effects of monitoring on optimal UI and JSA are ambiguous. Consider first the optimal UI problem:

$$\frac{dV}{db} = (1 - \lambda x)U'(c_e)\left[R\frac{\Delta c}{c_e} - \frac{q\phi_b}{1 - \lambda x}\right].$$

A high value of x will tend to reduce the absolute value of the welfare derivative, as it would lower unemployment, but the more interesting result is found inside the square brackets: the moral hazard cost of UI, previously driven by ε_{ub}, is now replaced by a term depending on the derivative of the cost of monitoring with respect to b, ϕ_b. Given that the cost of monitoring has generally been found to be quite low – studies cited in section 5 tend to find values on the order of 1% of per-person output or less – we might conclude that optimal monitoring is almost unrestricted by monitoring cost, and that therefore the cost is not likely to increase much when monitoring probability increases, thus raising the optimal level of UI. However, in the context of this sufficient-statistic analysis, this can only be a guess.

Switching to the optimal JSA problem, the welfare derivative is now:

$$\frac{dV}{d\lambda} = x\left[U(c_e) - U(c_u)\right] + U'(c_e)\left[x(b+\tau) - c'(\lambda) - q\phi_\lambda\right].$$

The major change in this expression is found, again, in the fiscal impact in the second set of square brackets; replacing s with x, I find that a term of the form $(b+\tau)\lambda\frac{ds}{d\lambda}$ has been replaced by $q\phi_\lambda$. That is, instead of JSA encouraging individuals to search harder, JSA now reduces monitoring costs, as I assume that $\phi_\lambda < 0$: more JSA makes it easier for individuals to reach the threshold, requiring less monitoring. If monitoring costs are small, as discussed above, this suggests that monitoring could reduce the value of JSA; on the other hand, the other terms in $\frac{dV}{d\lambda}$ are increasing in x, as more strict monitoring makes the added search ability granted by JSA more valuable. As a result, the interaction between JSA and monitoring is ambiguous.

In general, therefore, I conclude that incorporating high taxes into unemployment policy analysis is likely to reduce optimal UI and increase the value of JSA and monitoring when considering each policy on its own; however, the interactions between policies are far less obvious, and the optimal design of a combined policy remains an open question. Further insight can only come from a more detailed and realistic model, and this is what the following sections seek to provide.

3 Dynamic Job Search Model

I now present the main model of the paper. I start with the partial equilibrium version, a standard job search model focussing on a single representative individual; then I extend the model to general equilibrium, adding firms and their vacancy-creation decisions in a

Mortensen-Pissarides-style matching framework. I conclude the section with a brief description of the role of government in the baseline model.

3.1 Partial Equilibrium Model Setup

The initial version of the model is a fairly standard single-agent infinite-horizon search model: an ex-ante representative individual alternates stochastically between states of employment and unemployment. As is standard in the literature, I ignore ex-ante heterogeneity to simplify the analysis, but the analysis of optimal policy for different worker types could be an important subject for future research.[12]

When employed, the individual receives a wage of w in each period, which is taxed at rate τ, and also receives a lump-sum transfer L from the government. They enjoy utility of $U(c)$, where c is consumption and is simply equal to after-tax income $w(1-\tau)+L$; there is no saving in the model. At the end of each period, an employed worker faces a probability δ that their job is destroyed, leaving them unemployed in the following period.

An unemployed individual who is in period t of their unemployment spell receives a lump-sum transfer L and a UI benefit b_t, as well as some direct utility or disutility of being unemployed α, and makes two substantive economic choices. First, they decide how hard to search for a new job, choosing search intensity s_t subject to a convex effort cost $E_t(s_t)$; the effort cost of search is allowed to vary with elapsed duration of unemployment, as in Wunsch (2013).[13] λ will denote the effectiveness of search effort, and therefore the individual's probability of finding a new job is equal to λs_t. For simplicity, all new jobs are assumed to be identical with a wage of w, in keeping with an empirical literature that has found little consistent evidence of effects of programs such as UI on wages.[14]

[12]The main model of Boone, Fredriksson, Holmlund, and van Ours (2007) features a representative individual, while Pavoni and Violante (2007) and Pavoni, Setty, and Violante (2013) only differentiate individuals ex-post based on a stock of time-varying human capital; in my model, ex-post differentiation is performed by an effort cost of search that varies with duration of unemployment. However, individuals with different pre-labour-market characteristics – education, for example – may respond to unemployment policy differently and thus face different programs at the global optimum. Such an analysis would be a useful extension of the literature.

[13]It is common to model some factor that leads to decreasing return from search over time; for instance, depreciation of human capital over an unemployment spell in Pavoni and Violante (2007), Pavoni, Setty, and Violante (2013), and Spinnewijn (2013). However, this expands the state space, as one needs to keep track of skill levels of employed workers, and my study of multiple policies requires computational brevity.

[14]In a model with a distribution of wages, more generous UI might be expected to raise reservation wages, potentially leading to higher wages in new jobs. The empirical evidence on this question is mixed; see the finding of no effect of UI on wages in Austria in Card, Chetty, and Weber (2007), and the more recent conflicting findings of Schmieder, von Wachter, and Bender (2016) and Nekoei and Weber (2017). Lawson

The second choice made by unemployed individuals is an amount of home production h_t, subject to a convex cost $D_t(h_t)$. Home production is a standard component of many search models,[15] and allows for consumption smoothing without the vast expansion of the state space that modelling savings and assets would require.[16] In allowing choice over home production, I am following the suggestion of Hagedorn and Manovskii (2008) that home production responds to changes in UI, compensating for UI reductions with increased home production.[17] Additionally, my assumption is consistent with the finding of Gruber (1997) that private consumption smoothing during unemployment is significant, and the finding in Chetty (2008) that unemployed individuals in the US tend to have limited savings upon job loss. In the estimation of the model, I will use results from existing empirical studies of consumption smoothing and its responsiveness to UI as auxiliary parameters in an indirect inference procedure, to pin down the parameters of the cost function $D_t(h_t)$.

In the baseline model, I assume that UI benefits take the standard form of a constant benefit b received for T periods, which in practice will be 6 months as is typical in the United States; I also assume that deterioration of search and home production abilities ends after those T periods, so that I only need to keep track of $T+1$ unemployed states.[18] With a discount factor of β, I can then write out the value functions as follows:

$$V_e = U(w(1-\tau)+L) + \beta\left[\delta V_{u1} + (1-\delta)V_e\right] \tag{5}$$

$$V_{ut} = U(b+L+h_t) - E_t(s_t) + \alpha - D_t(h_t) + \beta\left[\lambda s_t V_e + (1-\lambda s_t)V_{u(t+1)}\right], t \leq T \tag{6}$$

$$V_{u(T+1)} = U(L+h_{T+1}) - E_{T+1}(s_{T+1}) + \alpha - D_{T+1}(h_{T+1}) + \beta\left[\lambda s_{T+1} V_e + (1-\lambda s_{T+1})V_{u(T+1)}\right] \tag{7}$$

(2017a) shows that, if more generous UI raises average wages – and if this represents a gain in overall output and not simply a transfer from firms – this would increase the optimal generosity of UI.

[15] See, for example, surveys by Mortensen and Pissarides (1999) and Rogerson, Shimer, and Wright (2005).

[16] Variable home production provides a way to capture the consumption smoothing which is empirically important in a parsimonious way, and given that I will search over a 21-parameter policy vector when I consider the optimal combined policy, such savings of computational time are particularly valuable. The sufficient statistics analysis of Chetty (2006) demonstrates that it is the consumption gap that is relevant for the welfare impact of UI, not the precise mechanism underlying it, as long as that mechanism is chosen by the individual in a privately-optimal way.

[17] In this context, home production could stand for any number of consumption smoothing mechanisms, including borrowing from family and friends, spousal labour earnings, or working in an informal labour market, which provide consumption but at some personal utility cost to the individual. Home production can also provide a reduced-form way of capturing the spending down of savings that must later be replenished, though Chetty (2008) finds that such savings are limited among the unemployed.

[18] Kroft, Lange, and Notowidigdo (2013) provides suggestive experimental evidence in favour of this: they find that the interview-finding rate drops from about 7% to about 4% over the first six months of an unemployment spell, then remains roughly constant.

where V_e is the value of employment, and V_{ut} is the value of being in the t-th period of unemployment (the value remains constant after $T+1$ periods of unemployment). Maximizing the unemployment value functions with respect to search intensity and home production, I find:

$$U'(b+L+h_t) = D'_t(h_t), t \leq T;\ U'(L+h_{T+1}) = D'_{T+1}(h_{T+1}) \tag{8}$$

$$E'_t(s_t) = \beta\lambda(V_e - V_{u(t+1)}), t \leq T;\ E'_{T+1}(s_{T+1}) = \beta\lambda(V_e - V_{u(T+1)}). \tag{9}$$

Given functional forms and parameter values, it is easy to numerically solve this set of equations for the optimal allocations and values.

3.2 Matching Framework for General Equilibrium

The partial equilibrium model above is a standard job search model with a few minor alterations, and is thus representative of the type of model used in a large portion of the optimal UI literature. However, when considering UI and other policies aimed at unemployment, it could be important to consider the impact of those policies on wages and vacancy-creation, for which purpose we need a general equilibrium model that incorporates wage bargaining and firm decisions over vacancies. My general equilibrium model starts where the partial equilibrium model concluded, with value functions and solutions for search intensity and home production as given in equations (5) through (9); in general equilibrium the wage w and the search effectiveness λ are allowed to adjust to changes in labour market conditions.

I assume a standard Cobb-Douglas matching function: $M(u\bar{s}, v) = \gamma(u\bar{s})^{\chi}v^{1-\chi}$, where u is unemployment and $\bar{s}$ is average unemployed worker search intensity, so that $u\bar{s}$ is total worker search, while v is the number of vacancies and γ is a constant. Consider the problem of a firm deciding whether or not to open a vacancy. If they do, they must pay a vacancy cost of k per period that the vacancy remains open; once the job is filled, a wage w is set through bargaining and the firm receives a profit of $p-w$ per period, where p is output from a filled job. Therefore, the value functions J for a filled job and V for a vacancy can be written as:

$$J = (p-w) + \beta\left[\delta V + (1-\delta)J\right]$$

$$V = -k + \beta\left[\frac{M(u\bar{s},v)}{v}J + \left(1 - \frac{M(u\bar{s},v)}{v}\right)V\right].$$

Next, the standard assumption of free entry is imposed, implying that vacancies will be opened up to the point at which $V = 0$; this zero-profit condition implies that the following

must be true in equilibrium:

$$k = \beta\gamma \left(\frac{u\bar{s}}{v}\right)^{\chi} \frac{p-w}{1-\beta(1-\delta)}.$$

If I define tightness as $\eta \equiv \frac{v}{u\bar{s}}$, I can rearrange the zero-profit condition to find the following expression for equilibrium tightness:

$$\eta = \left(\frac{\beta\gamma(p-w)}{(1-\beta(1-\delta))k}\right)^{\frac{1}{\chi}}.$$

Finally, consider the λ term introduced in the partial equilibrium model, which represents the effectiveness of worker search; in the context of the matching model, it is the probability that one unit of worker search produces a match, which is equivalent to $\frac{M(u\bar{s},v)}{u\bar{s}} = \gamma\eta^{1-\chi}$. Therefore, in equilibrium:

$$\lambda = \gamma \left(\frac{\beta\gamma(p-w)}{(1-\beta(1-\delta))k}\right)^{\frac{1-\chi}{\chi}}. \tag{10}$$

Thus, the effectiveness of worker search increases with β and γ, as more vacancies are opened when firms are more patient, and vacancies are easier to fill when γ is large; and λ decreases with w and k, as both represent costs to firms that reduce vacancy creation.

The other quantity from the partial equilibrium model that is allowed to adjust in general equilibrium is the wage. I assume Nash bargaining, as is standard in the literature, and therefore $w = \arg\max(V_e(w) - E_f(V_{u(t+1)}))^{\rho} J(w)^{1-\rho}$, where $E_f(V_{u(t+1)})$ is the expected value of unemployment next period from the perspective of the firm. That is, while I assume that bargaining takes place at the individual level, so that the value of unemployment is unaffected by the negotiated wage, the firm bargains as if the worker's fallback position is the average value of unemployment experienced by workers faced by the firm, weighted by search intensity of workers at different durations.[19] Effectively, I assume that firms do not know workers' remaining UI eligibility, and set wages accordingly; but this is a weak assumption if we presume that wages could be renegotiated after workers regain the right to

[19]Given the distribution of unemployed workers across durations in steady-state, and their search intensities, the firm can calculate the expected value of the $V_{u(t+1)}$ of a randomly drawn unemployed worker. I allow for transitional dynamics when considering policies, but I assume that firms set their wage once and for all after any policy change using the discounted expected value of $V_{u(t+1)}$.

UI.[20] I solve to find that the equilibrium wage is implicitly defined by:

$$\rho(p-w)U'(c_e)(1-\tau) = (1-\rho)\left[U(c_e) + \beta\delta V_{u1} - (1-\beta(1-\delta))E_f(V_{u(t+1)})\right] \tag{11}$$

where $c_e \equiv w(1-\tau) + L$ denotes consumption when employed.

The general equilibrium version of the model can be solved iteratively: for any policy change, I solve the partial equilibrium model assuming $w = \lambda = 1$, and then solve (11) for the bargained wage, and (10) for the new value of λ. I then solve the partial equilibrium model again with the new w and λ, and repeat the process until all variables converge.

3.3 Public Sector

Both versions of the model are closed with a simple description of the baseline public sector. The tax rate τ is chosen to balance the intertemporal government budget constraint (where β, the discount factor, is also assumed to equal $\frac{1}{1+i}$, where i is the interest rate):

$$\tau w \sum_{m=0}^{\infty} \beta^m (1-u_m) = \sum_{m=0}^{\infty} \beta^m u_m^i b + \frac{G+L}{1-\beta}$$

where u_m is the unemployment rate, u_m^i is the insured unemployment rate, and G is an exogenous quantity of other government spending which, along with L, generates the fiscal externality. I use m to denote month, since t has already been used to denote time spent unemployed.

As in Lawson (2017a), both the lump-sum transfer L and the exogenous other government spending G are imposed exogenously from outside the model; they do not perform any useful economic purpose in the model as specified so far. Rather, L and G represent the reality that governments need to fund a variety of public goods, and that the average tax rate for low-to-middle income individuals who are most likely to receive UI is lower than the marginal rate, both because of the progressive structure of the income tax system, and because some of the tax revenues go to the provision of social benefits which make up additional portions of the safety net. One could extend the current model to present an economic rationale for both L and G, by incorporating ex-ante heterogeneity and private valuation of public goods,

[20] Without this assumption, I would have to keep track of durations of previous unemployment for all currently employed individuals, in order to calculate their wage. However, the difference between the outcome in such a case and the current one would be modest if wages could be renegotiated after workers regain the right to UI, as they would then all bargain from the same position, and thus the total expected wage would be nearly identical for unemployed individuals at all durations.

but this would unnecessarily complicate the model. Therefore, I take the baseline tax system as given, modelling it as one in which a single marginal tax rate is applied to all income, with some exogenous amount of that tax revenue rebated in a lump-sum fashion, and the remainder after UI used to finance G. This represents a good first-order approximation to reality, and I will calibrate L and G to reproduce estimated baseline marginal and average tax rates faced by the typical UI recipient.

Introducing L and G into the model allows me to capture the large fiscal externalities that Lawson (2017a) shows to have large effects on optimal UI: if UI leads to longer unemployment spells, this means less time working and paying taxes to pay for L and G, with an additional fiscal cost that is ignored when income taxes are omitted from the model.[21]

This completes the description of the baseline model; alterations of the model to incorporate new policies will be described as those policies are introduced later in the paper. The only difference between the partial and general equilibrium versions of the model is the fact that w and λ are exogenous in the former, but endogenous in the latter and determined by Nash bargaining and the firm's vacancy creation decision.

4 Estimation and Calibration of Model

For both versions of the model, the goal will be to simulate the policies of interest, to analyze their impacts on labour market outcomes and welfare. To do so, functional forms and parameters of the model need to be selected. In this section, I describe that parameterization. I begin by presenting the method that I use to estimate the parameters of the partial equilibrium model, as well as the estimation results, and then the general equilibrium extension is calibrated as described in the final subsection.

4.1 Estimation of Partial Equilibrium Model

In this subsection, I present the procedure used for the structural estimation of the partial equilibrium model, followed by the estimation results. I perform the estimation using the method of indirect inference; see Gourieroux, Monfort, and Renault (1993) for a description of the method. Simply put, the method consists of estimating "auxiliary models" in both the

[21] Alternatively, the phenomenon of fiscal externalities can be explained as a pre-existing tax distortion in the labour market: search effort is inefficiently low in the presence of taxes, and since the welfare cost of a tax distortion is generally convex in the size of the distortion, programs that add to pre-existing distortions on job search have large welfare costs, and those that alleviate such distortions produce large welfare gains.

data and in simulated data generated from the model; the goal is to choose parameters in the model that provide the best match between the auxiliary estimation results from the data and from the simulated model. The auxiliary models do not need to be correctly specified; they simply need to be outcomes that depend on the parameters of the model, through a theoretical construct known as the binding function which links the parameters of the search model and the auxiliary models.

I use indirect inference to take advantage of the size and scope of the data available in the Current Population Survey's Annual Social and Economic Supplement. A wide variety of datasets have been used to study the impact of unemployment insurance on job-finding outcomes: early studies often used public evaluation datasets such as Service to Claimants or the Employment Opportunity Pilot Projects.[22] More recently, studies have used the Continuous Wage and Benefit History data, the Panel Study of Income Dynamics, the Displaced Worker Survey, and the Survey of Income and Program Participation.[23] However, these datasets are limited in size, typically featuring between 1000 and 5000 observations.[24]

Instead, I use the Current Population Survey's Annual Social and Economic Supplement, commonly known as the March CPS, from the IPUMS public-use project (Flood, King, Ruggles, and Warren, 2015). The Current Population Survey features far larger samples, but has been used by relatively few studies of UI because of missing data on several important dimensions. Some papers have examined transitions of labour force status between monthly surveys for retained households, but there is no data available on current receipt of UI. On the other hand, the March supplement includes data on both unemployment benefit receipt and the number of weeks unemployed in the previous calendar year, but this cannot be used as unemployment spell durations as some spells would have been in progress either at the beginning or end of the calendar year in question.

However, the March CPS data is well adapted to an indirect inference procedure, as I can easily estimate an informative auxiliary model: the distribution of time spent unemployed within a calendar year, and the responsiveness of this distribution to UI, can be calculated from the March CPS, and can be simulated from my model by running the model for 12

[22]Burgess and Kingston (1976) and Holen (1977) used StC, while Blau and Robins (1986) used the EOPP.

[23]See, for example, Moffitt (1985) and Meyer (1990) for the CWBH, Katz and Meyer (1990) for the PSID, Addison and Blackburn (2000) for the DWS, and Chetty (2008) for the SIPP.

[24]Exceptions include Holen (1977), whose StC sample includes nearly 20000 observations, and Meyer (1989), who uses 43012 observations in total from the Continuous Wage and Benefit History, divided into observations around both policy changes and placebo periods.

months and keeping track of the resulting distribution. Restricting my sample to male recipients of UI who did not receive supplemental or union benefits,[25] I have 26846 observations over the period of 1987-2007 (I drop observations after 2007 to avoid the Great Recession). A further description of the data and the estimation procedure can be found in appendix A.

Therefore, indirect inference allows me to make use of the CPS in a way that, to my knowledge, it has never been used before: I use this large and frequently-studied dataset, with lots of variation in UI across time and state, to estimate the structural parameters of a search model. The flexibility of indirect inference in using the scope and scale of the March CPS makes it the most powerful option available for estimating a search model such as the one in this paper.

The estimation takes the following form. To correspond to the model, I aggregate weeks of unemployment up to months, as described in appendix A. I then need to account for measurement error, which is significant for variables such as self-reported weeks of unemployment; there is a strong tendency to cluster at certain round numbers. To do so, I use the finding reported in Polivka and Miller (1998): from November 1992 to December 1993 in the CPS, only 26.1% of individuals unemployed in consecutive months report an increase in their duration of unemployment of 3, 4, or 5 weeks between months. Since the measurement error is clearly not uncorrelated with the true duration, I instead assume that the log of the true duration equals the log of reported duration plus a normally distributed random noise z with mean zero and standard deviation σ_z. Then, using the baseline distribution of unemployment from the March CPS for individuals unemployed at the time of survey in 1988-93,[26] I find the value of σ_z for which individuals staying unemployed for an additional month would have only a 26.1% probability of reporting a 3-5 week increase in duration, which is $\sigma_z = 0.162$.

Armed with a reported unemployment duration for each individual in my main sample, and $\sigma_z = 0.162$, I then calculate the probability for each individual that their true duration of unemployment is 1 month, 2 months, and so forth, generating probabilities

[25]The variable measuring the amount of unemployment income received during the previous calendar year, called INCUNEMP in the IPUMS CPS data files, does not distinguish between government-provided UI, employer benefits, and union or strike benefits; however, a separate variable called SRCUNEMP identifies individuals who received only government UI and those that also received additional unemployment income. Including recipients of supplemental benefits makes little difference to the results.

[26]The redesign of the CPS in January 1994 means that the estimates of Polivka and Miller (1998) apply only to data collected prior to 1994; since I am using current unemployment – variable DURUNEMP from the IPUMS March CPS data – this means unemployment spells from surveys up to and including 1993.

$u_{ji}, j \in \{1, 2, ..., 7\}$, for each individual i. Category 7 represents the probability of having been unemployed for 7 months or more, and thus $\sum_{j=1}^{7} u_{ji} = 1$, implying that only 6 of these categories can take independent values. From the CPS data, I estimate the means $\bar{u_j}$ across individuals for months 1 through 6 over the entire 1987-2007 period, and then I run the following regression for each j from 1 through 6:

$$u_{ji} = \omega_j + \nu_j \log(UI_i) + \xi_j X_i + \pi_y + \psi_s + \epsilon_{ji}, j \in \{1, ..., 6\}$$

where ω_j is a constant, π_y is a year fixed effect, ψ_s is a state fixed effect, and ϵ_{ji} is the error term. X_i is a set of individual control variables,[27] with a vector of coefficients ξ_j, and the main coefficient of interest is ν_j, the coefficient on log weekly UI benefits, where the latter is instrumented by the log of the state average weekly benefit by year, as reported by the Employment and Training Administration, to deal with potential measurement error in reported UI benefits. All dollar amounts are deflated to 1999 dollars using the CPI, the regressions are weighted using the March Supplement weights, and standard errors are clustered at the state level.

This gives me 12 moments: the average $\bar{u_j}$ and the effect of UI ν_j for each of $j = \{1, 2, ..., 6\}$. To these I add three other important quantities: the unemployment rate, the average baseline consumption gap between employed and unemployed individuals, and the slope of that gap with respect to UI. The latter two quantities are taken from Gruber (1997), whereas the unemployment rate is estimated from the overall March CPS sample. For any functional forms and parameterization of the model, I can simulate the model for 12 months, starting from steady-state and keeping track of the distribution of individuals in terms of how many months of unemployment they experience during the year; to simulate ν_j, I simulate the model again at a UI benefit that is 1% larger and divide the change in each $\bar{u_j}$ by the percentage change in average benefits. I then search for the model parameters that provide the best match to this set of 15 auxiliary model parameters.

The parameters of the model are defined as follows. I assume a functional form of $E_t(s_t) = \theta_t \left(\frac{1-(1-s_t)^{1-\kappa_t}}{1-\kappa_t} - s_t \right)$ for the search cost function, which features a cost and marginal cost of zero at $s_t = 0$, with the marginal cost going to infinity as $s_t \to 1$, so that s_t is always between zero and one. The moments estimated from the March CPS indicate that search

[27] The control variables include categorical variables for race, hispanic origin, marital status, education, class of worker last year, and 10 occupation and 14 industry categories, as well as years of age and a 7-piece spline of log real earnings per week.

in the first period of unemployment is low and unresponsive to UI benefits, so I allow the parameters θ and κ to change between the first and second periods: $\{\theta_1, \kappa_1\}$ apply for $t = 1$, while $\{\theta_2, \kappa_2\}$ apply for all subsequent periods of unemployment.

Meanwhile, the disutility function for home production is assumed to be constant over time, $D(h) = d_1 h^{d_2}$, while utility from consumption takes the CRRA form, $U(c) = \frac{c^{1-R}}{1-R}$. This provides a set of 7 parameters, to which must be added the utility from unemployment α, the job separation rate δ, the wage w and search effectiveness λ, the discount factor β, and the baseline parameters of the tax system. The latter include the marginal tax rate τ, the lump-sum transfer L, and the baseline level of the UI benefit, which I define as $b = rw(1-\tau_b)$, where r is the replacement rate and τ_b the tax rate applied to UI income; G can be backed out from this set of fiscal parameters and government budget balance.

The full set of parameters is summarized in Table 1: those in panel B will be set in the structural estimation, whereas those in panel A are selected to match standard estimates from the literature. Specifically, the coefficient of relative risk-aversion is $R = 2$ as in Lawson (2017a), and w and λ are both normalized to one. The discount rate is $\beta = 0.9975$, implying a 3% annual discount and interest rate, and the baseline UI replacement rate r is 0.46, which was the average effective replacement rate in the US during 1988-2009, as reported by the Department of Labor.

As in Lawson (2017a), the baseline tax system is calibrated from publications by the Congressional Budget Office and the Institute on Taxation & Economic Policy, as well as a sample of workers from the 2008 March CPS; Appendix A provides the details. I find that, in 2007, the average UI recipient faced a marginal tax rate of 0.282 on earned income and 0.17 on UI income, as well as an average tax rate of 0.121. Therefore, $\tau = 0.282$, $\tau_b = 0.17$, and to calibrate L, I define the average tax rate as $ATR = \frac{\tau(1-u)-L}{1-u} = \tau - \frac{L}{1-u}$; this means $L = 0.161(1-u) = 0.1513$, since Table 2 below indicates that the target for the unemployment rate is 6.02%.

Table 2 presents the auxiliary model parameters used in the structural estimation. In each case, the first number is the value of the auxiliary parameter, while the number in the final column is the standard error, which will be used to bootstrap standard errors for the model parameters. Gruber (1997) estimates a relationship of $\%\Delta c = 0.222 - 0.265r$, which equals 0.1001 at $r = 0.46$; however, in the sample of Gruber (1997), the average consumption drop is found to be 0.068, with a standard error of 0.0106, so I take the same ratio and use a

Table 1: Parameters for Calibration & Estimation

Name	Description	Value
	Panel A: Calibrated Parameters	
R	coefficient of relative risk-aversion	2
w	wage per month of work	1
λ	effectiveness of job search	1
β	discount factor per month	0.9975
r	baseline UI replacement rate	0.46
τ	baseline marginal tax rate	0.282
L	exogenous lump-sum transfer	0.1513
τ_b	marginal tax rate applied to UI income	0.17
	Panel B: Parameters for Estimation	
θ_1	level of search cost function for $t = 1$	$*$
θ_2	level of search cost function for $t = \{2, ..., 7\}$	$*$
κ_1	curvature of search cost function for $t = 1$	$*$
κ_2	curvature of search cost function for $t = \{2, ..., 7\}$	$*$
d_1	level of home production disutility function	$*$
d_2	curvature of home production disutility function	$*$
α	direct utility value of unemployment	$*$
δ	job separation rate per month	$*$

Notes: Panel A presents parameters for which values are selected from external estimates. Panel B presents parameters whose values will be set by structural estimation, as indicated by the use of a $*$ in place of a numerical value.

standard error of $0.1001 \times \frac{0.0106}{0.068} = 0.0156$. The standard errors for the regression coefficients ν_j are relatively large, because there is a significant amount of collinearity with the wide variety of other variables included in the regressions. However, the pattern that higher UI leads to fewer short durations of unemployment and more very long durations (more than 6 months), with little effect on middle durations, is strong and unsurprising: the negative coefficient for month 2 is strongly significant with a p-value of 0.024, whereas the positive coefficient of 0.108 for month 7 (not shown in the table as it is collinear with months 1-6) is marginally significant with a p-value of 0.108.

The 15 moments in Table 2 are used to estimate the 8 parameters in panel B of Table 1. The nature of the binding function between the model parameters in Table 1 and the auxiliary parameters in Table 2 is straightforward: the θ parameters for the level of the search cost function strongly affect the distribution of unemployment durations, while the κ parameters for the curvature of the search cost function are closely related to the regression

Table 2: Auxiliary Model Parameters for Structural Estimation

Name	Description	Value	Std. Error
$\bar{u_1}$	fraction of unemployment of 1 month or less	0.1287	0.0039
$\bar{u_2}$	fraction of unemployment between 1 and 2 months	0.1643	0.0034
$\bar{u_3}$	fraction of unemployment between 2 and 3 months	0.1728	0.0020
$\bar{u_4}$	fraction of unemployment between 3 and 4 months	0.1254	0.0019
$\bar{u_5}$	fraction of unemployment between 4 and 5 months	0.1081	0.0015
$\bar{u_6}$	fraction of unemployment between 5 and 6 months	0.0970	0.0019
ν_1	regression coefficient on $\log(UI_i)$ for $j = 1$	-0.0343	0.0481
ν_2	regression coefficient on $\log(UI_i)$ for $j = 2$	-0.0878	0.0389
ν_3	regression coefficient on $\log(UI_i)$ for $j = 3$	-0.0114	0.0400
ν_4	regression coefficient on $\log(UI_i)$ for $j = 4$	-0.0011	0.0263
ν_5	regression coefficient on $\log(UI_i)$ for $j = 5$	0.0058	0.0256
ν_6	regression coefficient on $\log(UI_i)$ for $j = 6$	0.0203	0.0230
u	unemployment rate	0.0602	0.0019
$\%\Delta c$	% consumption gap between employed and unemployed	0.1001	0.0156
$\frac{\partial \%\Delta c}{\partial r}$	slope of consumption gap with respect to r	-0.265	0.0910

This table presents the set of 15 moments used for the structural estimation. The final column presents standard errors. For the baseline consumption gap $\%\Delta c$, Gruber (1997) estimates a relationship of $\%\Delta c = 0.222 - 0.265r$, which equals 0.1001 at $r = 0.46$. Gruber (1997) finds a mean consumption gap of 0.068 with a standard error of 0.0106; I take the same ratio and use a standard error of $0.1001 \times \frac{0.0106}{0.068} = 0.0156$.

coefficients ν_j. Meanwhile, the two parameters of the home production function are primarily identified by the level and slope of the consumption gap. Finally, α and δ are both highly relevant for determining the unemployment rate, but they also influence the relative levels of the unemployment distribution.

I search for the 8 structural parameters that provide the best match to my set of 15 auxiliary parameters, in the sense of minimizing the sum of squared errors. That is, I use a uniform weighting matrix, as numerous papers argue that the use of an "optimal" weighting matrix – the inverse of the covariance matrix of the auxiliary parameters – often generates significant finite-sample bias.[28] This is particularly true in my case, where my moments come from different types of estimation, with very different variances: additional results (available upon request) show that estimation when each moment is weighted by the inverse of its variance generates a particularly poor match for the regression coefficients.[29]

[28]See, for example, page 21 of Bruins, Duffy, Keane, and Smith Jr. (2018): "...estimates of optimal weight matrices often do not perform well in finite samples".

[29]The mean absolute deviation for the regression coefficients ν_j is 0.0084 with a uniform weight matrix and 0.0204 when weighting by inverse variance. The mean absolute deviation is also higher for the $\bar{u_j}$ and the slope of the consumption gap when weighting by inverse variance.

Table 3 presents the estimation results. Most of the parameters are hard to interpret, as they depend on each other to some extent; the only parameter with an obvious interpretation is δ, the job separation rate, which is approximately 1% per month, implying an expected duration of an employment spell of slightly over 8 years. Since all jobs are identical, note that this does not correspond to an expected duration of 8 years at any one real-world job, but rather to a period of 8 years between spells on UI.

Table 3: Estimates of Model Parameters

Name	Description	Estimate
θ_1	level of search cost function for $t = 1$	0.0005977
θ_2	level of search cost function for $t = \{2, ..., 7\}$	0.1335
κ_1	curvature of search cost function for $t = 1$	181.3308
κ_2	curvature of search cost function for $t = \{2, ..., 7\}$	12.5113
d_1	level of home production disutility function	1.8474
d_2	curvature of home production disutility function	1.4471
α	direct utility value of unemployment	0.6230
δ	job separation rate per month	0.01034
ε_b^u	elasticity of unemployment rate with respect to b	0.2327

Notes: This table presents the results from the estimation of 8 parameters – and the resulting elasticity of unemployment with respect to UI benefits, ε_b^u – using indirect inference.

The model does a good job of fitting the auxiliary parameters; the sum of squared errors is 0.0012, equivalent to a deviation of 0.0089 per moment. The fit of the model is also summarized in Figures 1 and 2 below, where we can see that the estimated parameters do a good job of matching the overall pattern of the distribution of unemployment durations and the regression coefficients ν_j. The other three moments are also matched very closely: the model-generated unemployment rate is 0.0607 instead of 0.0602, while the consumption gap terms $\%\Delta c$ and $\frac{\partial \%\Delta c}{\partial r}$ are almost perfectly matched to the data. An additional test of the model's fit is provided by simulating the model to calculate the elasticity of unemployment with respect to UI benefits, and as can be seen in the final row of Table 3, I find an arc elasticity of 0.2327 for a 10% increase in benefits; the elasticity estimated from a regression of the log of reported weeks of unemployment on log UI benefits (instrumented by log average state benefits) in the March CPS data is 0.2317. These values are consistent with standard estimates of the elasticity of unemployment to UI in the literature,[30] and so my estimation

[30]Typical estimates of the elasticity of durations of unemployment spells with respect to UI are about 0.5 for individuals receiving UI; Lawson (2017a) shows that this is equivalent to an elasticity of total unemployment

provides a good fit to standard estimates of the three principal "sufficient statistics" for optimal UI identified by Chetty (2006) and presented in (4): the elasticity of unemployment with respect to UI, the coefficient of relative risk-aversion, and the consumption drop upon unemployment.

Figure 1: Fit of Estimation over Unemployment Amounts $\bar{u}_j$

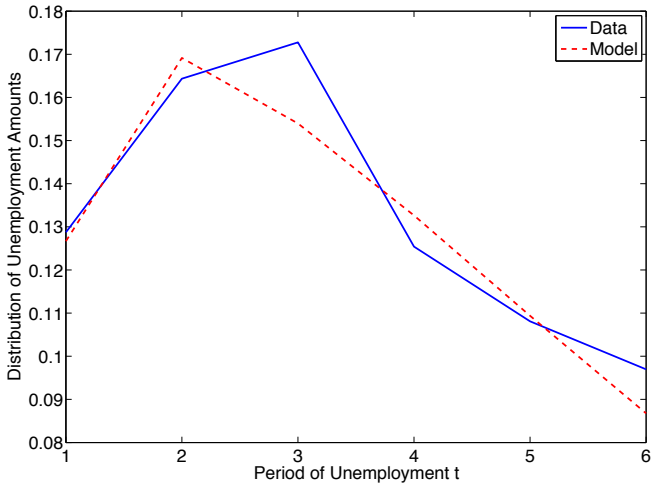
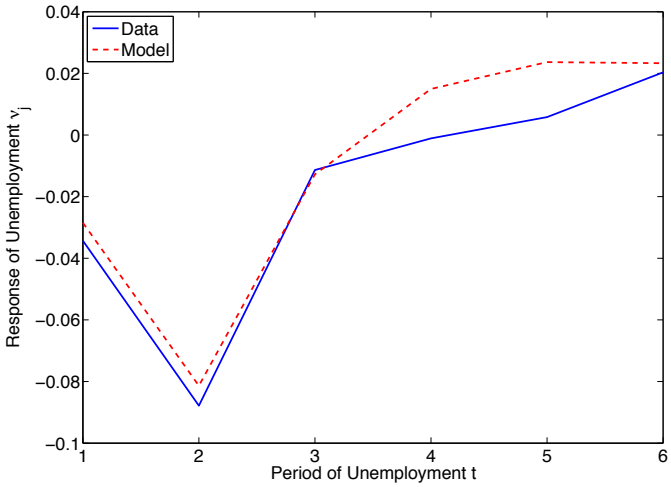


Figure 2: Fit of Estimation over Unemployment Responses ν_j



with respect to UI of about 0.24, given that only about half of unemployed individuals receive UI benefits at any point in time.

4.1.1 Identification and Bootstrap Confidence Intervals

Table 4 presents the estimation results once again, this time with 95% confidence intervals calculated using a bootstrapping procedure in which, on each of 999 bootstrap iterations, values of the 15 target quantities are drawn from normal distributions characterized by the estimated variances of those quantities; the same estimation procedure as above is then used to estimate the coefficients that provide the best fit to these values on each iteration. This produces a distribution of estimates, one for each bootstrap round, and taking the 25th- and 975th-highest values for each parameter provides a 95% confidence interval.

Table 4: Estimates of Model Parameters with Confidence Intervals

Name	Estimate	95% Confidence Interval
θ_1	0.0005977	$[3.829 \times 10^{-122}, 2.524 \times 10^{7}]$
θ_2	0.1335	$[2.918 \times 10^{-13}, 1.673 \times 10^{7}]$
κ_1	181.3308	$[7.363 \times 10^{-7}, 3.167 \times 10^{9}]$
κ_2	12.5113	$[5.876 \times 10^{-7}, 157.9307]$
d_1	1.8474	[1.6006,2.8935]
d_2	1.4471	[1.0898,2.3065]
α	0.6230	[0.3490,0.7458]
δ	0.01034	[0.008832,0.01161]
ε_b^u	0.2327	[0.0830,0.3654]
r^*	0.3602	[0.2088,0.5200]

Notes: This table presents the results from the estimation of 8 parameters – and the resulting elasticity of unemployment with respect to UI benefits, ε_b^u, and optimal partial-equilibrium replacement rate, r^* – using indirect inference. The second column presents the estimated point values, while the final column presents 95% confidence intervals from bootstrapping.

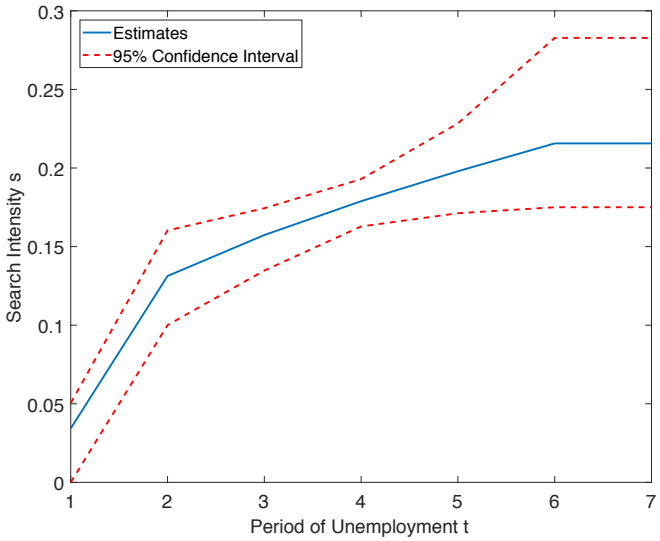
The confidence intervals for d_1, d_2, α, and δ are of reasonable sizes, but the confidence intervals for the θ and κ parameters appear to be very large. However, this appearance is deceptive, because the relative values of θ and κ depend closely on each other: larger values of θ tend to coincide with smaller values of κ.[31] The joint implications of θ and κ – the level and slope of the search cost function – are well identified through the binding function.

[31] This dependence is a general feature of convex search cost functions; even a simple power function such as θs^κ or $\frac{\theta}{\kappa} s^\kappa$ will present a similar complication. However, this point seems not to have been noticed in the past, perhaps because few attempts have been made to structurally estimate a job search model featuring a continuous job search decision. Lentz (2009) is one of the few previous papers to do so, and obtains economically reasonable confidence intervals, but does so using a functional form for effort cost from search that has no closed-form solution. As this adds a numerical solution step to each iteration of the model, it is not practical for my analysis, in which I need to be able to numerically compute an optimal 21-parameter policy vector.

This can be seen from the final two rows of Table 4, which present the 95% confidence interval for the elasticity of unemployment with respect to UI, as well as for the optimal UI replacement rate (in partial equilibrium) that will be calculated in section 5.2.1. These two quantities can be calculated for each of the 999 bootstrap parameter vectors, and the results are quite empirically reasonable: the interval for the elasticity of unemployment ranges from 0.0830 to 0.3654, while that for the optimal UI replacement rate covers 0.2088 to 0.5200.

Figures 3 and 4 further confirm that the model is well-identified, by showing the confidence bands for the intensity of search effort and its derivative with respect to b. Figure 3, in particular, demonstrates that the confidence bands for the intensity of search effort are relatively narrow; in Figure 4, the derivatives cover a wider but still empirically plausible range. The fact that both of these outcomes can be identified with reasonable precision demonstrates that the joint implications of θ and κ are well identified even if the number values do not appear so. Appendix B presents additional evidence on the identification and standard errors of the model.

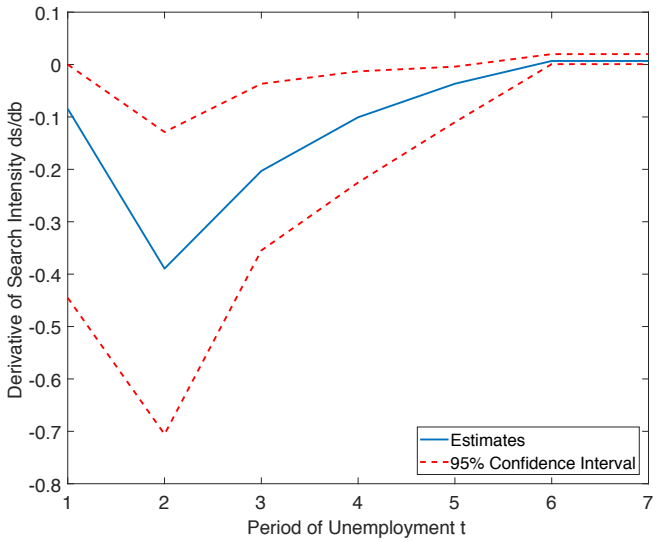
Figure 3: 95% Bootstrap Confidence Intervals for Search Intensity



4.2 Calibration of GE Matching Model

After estimation of the partial equilibrium model, I calibrate the general equilibrium parameters. First, I set the elasticity of matching with respect to worker search to $\chi = 0.3$, as found by Borowczyk-Martins, Jolivet, and Postel-Vinay (2013). As is standard in search and

Figure 4: 95% Bootstrap Confidence Intervals for Derivative of Search Intensity with respect to b



matching models, I satisfy the Hosios condition by setting worker bargaining power to the same value, $\rho = 0.3$. During normal economic times, the ratio of unemployed individuals to vacancies is typically around 2, according to the Job Openings and Labor Turnover Survey, and so I want the baseline $v = 0.5u$ when $\lambda = 1$; given a baseline average search intensity of 0.160, this normalizes γ to 0.4504.

Given these values, I solve the wage bargaining equation for the value of p that leads to an equilibrium wage of 1, which is $p = 1.0590$; then I solve the zero-profit condition for $k = 1.4695$. This value may seem somewhat high relative to the vacancy costs used in other papers – for example, a value around 0.6 in Hagedorn and Manovskii (2008), or more recently about 1 in Lalé (2014) – but the value of k is driven by normalizations in calibration which affect how the "size" of a vacancy is interpreted. In my case, this is primarily the normalization of $\lambda = 1$, which implicitly defines a vacancy as quite "large." If I adjust for normalizations, it is easy to show that my value of k is consistent with the literature.[32]

[32]Variations in other assumptions and parameter choices also play a role. Consider Lalé (2014): in his calibration, a period equals half a quarter, and his matching function is $M = 0.5952u^{0.7}v^{0.3}$. Relative to my analysis, he makes two important normalizations: he sets the baseline $\eta = 1$ instead of 0.5, and by ignoring search intensity he implicitly sets $\bar{s} = 1$; Lalé also uses $\chi = 0.7$ instead of 0.3. My matching function is $M = 0.4504(u\bar{s})^{0.3}v^{0.7}$; if I set $\bar{s}$ to its baseline average value, this is $M = 0.2599u^{0.3}v^{0.7}$. Suppose $u = 0.0602$; then with a job destruction rate of $\delta = 0.01034$, my steady-state matching rate must be $M = (1-u)\delta = 0.009715$, whereas in Lalé (2014) the job destruction rate is 0.0417, implying a steady-state matching rate of $M = 0.03916$. The values of v that generate these matching rates at $u = 0.0602$ are $v = 0.03047$ for my model and $v = 0.08095$ for Lalé (2014). Thus, the assumptions of my model make

With these values, the calibration is complete: the general equilibrium side of the model can be simulated by inputting the tax rate and value functions into the wage bargaining equation (11) to solve for w, and then solving the free-entry condition (10) for λ.

5 Welfare Analysis & Numerical Results

The objective of the government is assumed to be maximization of mean discounted utility over time, which in practice is achieved by maximizing the average of the value functions for individuals today. To do so, the government can use a variety of policies aimed at supporting or providing incentives to unemployed individuals: unemployment insurance, monitoring with sanctions, job search assistance, and job-creation or job-finding bonuses.[33] In each case, I take estimates from the existing literature on the effectiveness and cost of the policy, and I simulate the model in both its partial and general equilibrium forms, to find the impact of introducing and changing these policies. Simulation of the partial equilibrium model proceeds using policy function iteration over search intensity, and when the general equilibrium model is used I iterate between the partial equilibrium solution and solving for the general equilibrium wage and search effectiveness λ.

In the first subsection, I explain how each of these policies is modelled, while I present partial and general equilibrium optimal policy results in the second subsection.

5.1 Policy Modelling

This paper considers four categories of unemployment policy, as described in what follows. I will consider the welfare impact of each on its own, and then the optimal combined policy.

5.1.1 Unemployment Insurance

I vary unemployment insurance benefits in three different ways: I vary the replacement rate r, I alter the duration of benefits (which I will now call N rather than T, to distinguish it

one of my "vacancies" equal to about 2.66 of Lalé's "vacancies"; the definition of a unit of vacancy is itself normalized, and in Lalé's world my vacancy cost roughly corresponds to a value of about 0.55.

[33] As discussed earlier, the numerical analysis throughout the paper assumes ex-ante identical workers; a valuable task for future research would be to evaluate optimal policies for different types of individuals. Additionally, the analysis in this paper is restricted to the set of policies usually considered in the existing literature, but such an analysis could be further extended to consider other policies, such as public employment or training programs; see Spinnewijn (2013) for an analysis of the latter type of program.

from the point at which $D_t(h_t)$ and $E_t(s_t)$ become constant), and I allow for a more flexible time path of benefits, or a b_t for each period.

In the value functions, raising the replacement rate r simply raises the value of UI benefits b in V_{ut}. When the duration of benefits or a flexible time path of benefits is considered, it is simplest to think of benefits taking the form b_t, where in the varying-duration case $b_t = b$ for $t \leq N$ and $b_t = 0$ for $t > N$. The value functions for V_{ut} and $V_{u(T+1)}$ are replaced by:

$$V_{ut} = U(b_t + L + h_t) - E_t(s_t) + \alpha - D_t(h_t) + \beta \left[\lambda s_t V_e + (1 - \lambda s_t) V_{u(t+1)}\right], t \leq T$$

$$V_{ut} = U(b_t + L + h_t) - E_{T+1}(s_t) + \alpha - D_{T+1}(h_t) + \beta \left[\lambda s_t V_e + (1 - \lambda s_t) V_{u(t+1)}\right],$$
$$T < t \leq N \ \ if \ \ N > T$$

$$V_{u(Z+1)} = U(L + h_{Z+1}) - E_{T+1}(s_{Z+1}) + \alpha - D_{T+1}(h_{Z+1}) + \beta \left[\lambda s_{Z+1} V_e + (1 - \lambda s_{Z+1}) V_{u(Z+1)}\right]$$

where $Z = \max\{T, N\}$.

The government budget constraint does not change form when r is varied, but in the other two cases the first term on the right-hand side becomes $\sum_{m=0}^{\infty} \beta^m u_m E_m(b_t)$, where $E_m(b_t)$ is the average benefit received by all individuals unemployed at time m.

5.1.2 Monitoring & Sanctions

Monitoring and sanctions are fairly common in the US, but very mild, typically involving the loss of benefits for one week;[34] for this reason, I abstracted from monitoring in the baseline estimation of the model. In this section, I instead consider a more radical monitoring policy: the government chooses a monitoring probability ϕ_t and a search threshold x_t at each duration of unemployment, and an individual monitored and found to be searching less than x_t loses all entitlement to UI until their next spell of employment. However, I assume that the government cannot perfectly observe search effort; they instead observe $\hat{s_t} = s_t + \epsilon_s$, where ϵ_s is measurement error drawn from a normal distribution with mean zero and standard deviation σ.[35]

The value function for employment remains the same as the baseline model, but now V_{ut} for $t \leq T$ takes a different form, and I define a new value function V_{nt} for individuals

[34] Grubb (2001) documents the situation in 1998: the probability of sanction for insufficient search was 0.64% per week per UI recipient, with the normal penalty consisting of loss of benefits for that week only.

[35] "Fuzzy" monitoring has previously been used by Fredriksson and Holmlund (2006) and Boone, Fredriksson, Holmlund, and van Ours (2007), but they used a highly simplified specification where the probability of being sanctioned is $1 - as$, where $a \geq 0$ is some constant. While this captures a simple intuition about monitoring raising the incentive to search, it likely does not represent the policy available to government.

who are unemployed at duration t but without eligibility for UI. If the probability of being sanctioned if monitored is $Pr(\hat{s} < x|s) = Pr(\epsilon_x < x - s) \equiv P(s, x)$, these value functions now take the following form:

$$V_{ut} = U(b + L + h_t) - E_t(s_t) + \alpha - D_t(h_t)$$

$$+\beta \left[\lambda s_t V_e + (1 - \lambda s_t) \left(\phi P(s_t, x_t) V_{n(t+1)} + (1 - \phi P(s_t, x_t) V_{u(t+1)}\right)\right], t \leq T$$

$$V_{nt} = U(L + h_t) - E_t(s_t) + \alpha - D_t(h_t) + \beta \left[\lambda s_t V_e + (1 - \lambda s_t) V_{n(t+1)}\right], t \leq T$$

where clearly $V_{n(T+1)} = V_{u(T+1)}$.

The government budget constraint now takes the form:

$$\tau w \sum_{m=0}^{\infty} \beta^m (1 - u_m) = \sum_{m=0}^{\infty} \beta^m u_m^i (b + qE_m(\phi_t)) + \frac{G + L}{1 - \beta}$$

where, as in section 2.3, q is the cost per individual monitored.

5.1.3 Job Search Assistance

Many European countries have job search assistance programs which are operated by the government in order to assist unemployed workers with the task of matching with an employer; footnote 42 provides a few basic examples. As in section 2.2, job search assistance allows the government to increase λ at a cost, but here I assume a discrete choice: the government has the option to provide a finite amount of JSA to all unemployed individuals at a cost of c_{JSA} per period per person. To avoid confusion in the general equilibrium case, let me denote the parameter affected by the government as λ_s and the value determined by wage bargaining as λ_w, where $\lambda = \lambda_s \lambda_w$.[36] The value functions are exactly the same as in the baseline case, and the government budget constraint is also unchanged except for an additional term on the right-hand side equal to $\sum_{m=0}^{\infty} \beta^m u_m c_{JSA}$.

5.1.4 Job-Creation Subsidies

The final policy that I consider is a job-creation subsidy: a payment either to the worker or to the firm upon the creation of a new match. In the partial equilibrium case, firms are not explicitly considered, and thus the payment can only be made to the worker. Consider a

[36]Note that λ_w is calculated in exactly the same way as before: the bargained wage determines the zero-profit condition on tightness, which is now defined as $\eta \equiv \frac{v}{u\lambda_s \bar{s}}$, and $\lambda_w = \frac{M(u\lambda_s \bar{s}, v)}{u\lambda_s \bar{s}} = \gamma \eta^{1-\chi}$.

payment of y to a worker in their first period on a new job; this requires that I define value functions for two different states of employment:

$$V_{e1} = U(w(1-\tau) + L + y) + \beta\left[\delta V_{u1} + (1-\delta)V_{e2}\right]$$

$$V_{e2} = U(w(1-\tau) + L) + \beta\left[\delta V_{u1} + (1-\delta)V_{e2}\right].$$

Value functions for unemployed individuals remain the same except that V_{e1} replaces V_e on the right-hand side. The government budget constraint now includes a new term on the right-hand side equal to $\sum_{m=0}^{\infty} \beta^m n_m^j y$, where n_m^j is the number of new jobs formed in period m.

In the general equilibrium case, the subsidy can either be given to the worker or the firm; I will denote these as y_w and y_f to avoid confusion. In the former case, the analysis proceeds as above except that the Nash bargain for the wage will be altered (defining $c_{e1} = w(1-\tau) + L + y_w$ and $c_{e2} = w(1-\tau) + L$ to save space):

$$\rho(p-w)(1-\tau)\left[(1-\beta(1-\delta))c_{e1}^{-R} + \beta(1-\delta)c_{e2}^{-R}\right]$$

$$= (1-\rho)\left[(1-\beta(1-\delta))\frac{c_{e1}^{1-R}}{1-R} + \beta(1-\delta)\frac{c_{e2}^{1-R}}{1-R} + \beta\delta V_{u1} - (1-\beta(1-\delta))E_f(V_{u(n+1)})\right].$$

Finally, if the subsidy is given to the firm, the worker value functions are identical to baseline, and the government budget constraint is the same as in the worker subsidy case above. However, the Nash bargain is again altered, though this time the $(p-w)$ on the left-hand side is simply replaced by $(p-w+(1-\beta(1-\delta))y_f)$. And finally, the firm's zero-profit condition is altered, now taking the form:

$$\lambda = \gamma\left(\frac{\beta\gamma(p-w+(1-\beta(1-\delta))y_f)}{(1-\beta(1-\delta))k}\right)^{\frac{1-\chi}{\chi}}.$$

5.2 Numerical Results for Optimal Policy

I now present the numerical results for the optimal design of each program on its own, followed by the optimal combined policy. I do this, in each case, for both the partial and general equilibrium model. Relative to the partial equilibrium model, the general equilibrium model simply adds an additional iterative step to the procedure: I perform policy function iteration as in the partial equilibrium setting assuming $w = \lambda = 1$, and then I evaluate the Nash bargaining condition (11) for the new equilibrium wage, as changes in the value

of unemployment (which serves as a fallback option) and the tax rate affect the bargaining solution. Then I solve the firm's zero-profit condition (10) for the resulting value of λ; if a change in policy improves the worker's bargaining position and allows them to obtain a higher wage, equilibrium tightness will decline as firms open fewer vacancies. Armed with these updated values for w and λ, I again solve the individual's partial equilibrium problem, then iterate back to the general equilibrium solutions for w and λ. This process continues until w and λ converge. An alternative approach to general equilibrium features Kalai bargaining, but in appendix C I show that the results from such a specification are very similar to those from Nash bargaining. All numerical results are summarized in Table 5.

Table 5: Numerical Results for Optimal Unemployment Policy

	Optimal Value	Welfare Gain	w	λ
Panel A: Partial Equilibrium				
UI Replacement Rate r	0.360	0.05%	1	1
UI Duration N	4 months	0.11%	1	1
$\{r, N\}$	$\{0.521, 4\}$	0.11%	1	1
UI Time Path	$\{0.623, 0.601, 0.437, 0.303, 0.185, 0.072\}$	0.14%	1	1
Monitoring:	$\phi_t = \{0.071, 0.113, 0.115, 0.119, 0.136\}$	0.33%	1	1
	$x_t = \{0.031, 0.219, 0.220, 0.223, 0.227\}$			
JSA with $c_{JSA} = 0.01$		0.20%	1	1
JSA with $c_{JSA} = 0.04$		0.004%	1	1
Job-Creation Subsidy y	0.0023	0.00001%	1	1
Combined Program:	see Figure 8	0.72%	1	1
Panel B: General Equilibrium				
UI Replacement Rate r	0.302	0.08%	0.999	1.054
UI Duration N	3 months	0.23%	0.995	1.198
$\{r, N\}$	$\{0.557, 3\}$	0.24%	0.996	1.186
UI Time Path	$\{0.624, 0.596, 0.387, 0.147\}$	0.25%	0.996	1.173
Monitoring:	$\phi_t = \{0.050, 0.072, 0.071, 0.086, 0.141\}$	0.28%	1.001	0.964
	$x_t = \{0.033, 0.216, 0.224, 0.234, 0.243\}$			
JSA with $c_{JSA} = 0.01$		0.18%	1.002	0.926
JSA with $c_{JSA} = 0.04$		-0.02%	1.002	0.919
Job-Creation Subsidy y_w	0.0049	0.00003%	1.000	1.000
Job-Creation Subsidy y_f	2.318	0.01%	1.029	1.022
Combined Program:	see Figure 9	0.50%	1.000	0.991

Notes: The last two columns presents the equilibrium values of the wage w and the search effectiveness λ; in the case of job search assistance, this represents λ_w rather than λ_s. Results for optimal monitoring assume a cost of $q = 0.01$ and a standard deviation of monitoring of $\sigma = 0.01$. Results for the optimal combined program use the same values for q and σ and assume $c_{JSA} = 0.02$.

5.2.1 Optimal Unemployment Insurance

I begin with the partial equilibrium results. When considering the UI replacement rate r, I find that the optimal value is $r = 0.360$, or about 10% points lower than the baseline value of $r = 0.46$. With a marginal tax rate of 28.2%, the fiscal cost of UI's moral hazard effect is strong enough to outweigh a significant portion of the consumption smoothing benefits of unemployment insurance. This is similar to the finding in Lawson (2017a) of a significantly reduced optimal level of UI in the presence of fiscal externalities.[37]

Using the 999 bootstrap parameter vectors, I can calculate an optimal replacement rate for each, and thus construct a 95% confidence interval for r^*. The resulting interval ranges from 0.2088 to 0.5200; this rules out replacement rates above 52%, which have been found to be optimal in numerous studies that ignore fiscal externalities, including Davidson and Woodbury (1997), Hopenhayn and Nicolini (1997), and Coles and Masters (2006).[38]

I also calculate the welfare gain from implementing the optimal policy as a percentage of mean consumption. To do so, I calculate the increase in welfare V_g and find the value c_g that sets $U(c_m + c_g) = U(c_m) + (1 - \beta)V_g$, where c_m is mean baseline consumption; I then report $\frac{c_g}{c_m}$ in the third column of Table 5, and we can see that changing r to 0.360 would generate a welfare gain equivalent to 0.05% of mean consumption for all time, a relatively small number in comparison to the size of the UI program, which amounts to 1.96% of mean consumption in the baseline model.

When I instead consider the optimal benefit duration N, I find that a UI benefit of baseline generosity $r = 0.46$ per period should only be provided for the first four months of unemployment, rather than the current six. If I simultaneously optimize both r and N, I now find $N = 4$ and $r = 0.521$: UI should be slightly more generous, but of shorter duration. The welfare gain from these policy changes are both 0.11% of mean consumption; thus, reducing the duration of UI is preferable to reducing the monetary amount per month.

The reason why reducing the duration of UI is a better option than reducing r is that the consumption smoothing provided by UI depends on today's UI benefit, whereas the moral hazard cost depends on tomorrow's benefit, since a worker decides how hard to search

[37] The optimal replacement rate is lower in Lawson (2017a), however, due to model differences: the baseline finding of zero in that paper was based on a standard steady-state analysis, which gives considerably lower optimal UI levels than one that accounts for transitional dynamics, but Lawson (2017a) also found an optimal replacement rate of $r = 0.25$ with transitional dynamics.

[38] Chetty (2008) finds that the replacement rate should be increased from 50%, which seems unlikely to be optimal in light of my findings. See Lawson (2017a) for further discussion of the literature.

depending on the value of unemployment generated by tomorrow's UI. Therefore, a benefit that declines over time is likely to be preferable. This rationale also explains the optimal flexible time path of UI, which features a replacement rate that declines from $r = 0.623$ in the first month to 0.072 in the sixth month, with zeros thereafter, and a resulting welfare gain of 0.14%. This decline is faster and more dramatic than is typical in the literature;[39] this is partly because of the fiscal externalities that have been ignored in the previous literature, but also because the principal-agent framework typically used does not allow for private consumption smoothing, so the results from that literature are more accurately understood as unemployed consumption levels rather than optimal UI benefits.

When I incorporate the general equilibrium adjustment of the wage and vacancy creation rate, the optimal policy results change, but not dramatically. The optimal replacement rate is now $r = 0.302$, nearly 6 percentage points lower than before, with an increased welfare gain of 0.08% of mean consumption. When considering the optimal benefit duration, reductions in generosity also appear more beneficial, as the optimal duration is now 3 months instead of 4, with a larger welfare gain of 0.23%. Finally, the optimal time path of UI is also less generous, especially from the 4th month onwards when the replacement rate drops to 0.147 and then to zero. In each case, the optimal policy is accompanied by reductions in wages and increases in λ, as less generous UI reduces unemployed workers' bargaining power and thus reduces wages; firms respond by opening more vacancies. These reductions in bargained wages appear to raise welfare, though the effect is never particularly large, and as is discussed in appendix D, caution is required because a welfare gain from lower wages is not a universal result of general equilibrium analysis.[40]

5.2.2 Optimal Monitoring

Several studies have found that the cost of monitoring is quite small, typically at most 1% of average output per individual monitored; this, for example, is the conclusion in Boone, Fredriksson, Holmlund, and van Ours (2007) for Sweden and van den Berg and van der Klaauw (2013) for the Netherlands. Therefore, I assume $q = 0.01$. For the baseline results in partial equilibrium in Table 5, I assume that the standard deviation of monitoring is $\sigma = 0.01$.

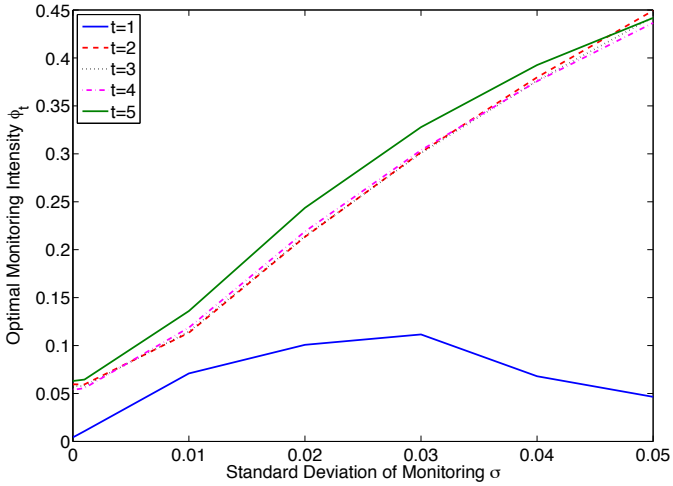
[39] In Hopenhayn and Nicolini (1997), for example, even without a wage tax that increases with unemployment duration, the optimal benefit is still 0.28 after 6 months and 0.13 after a year.

[40] Also, as suggested by Landais, Michaillat, and Saez (2018b), the results are sensitive to the workers' bargaining power: in results that are available upon request, I find that if the Hosios condition is not satisfied, the optimal replacement rate decreases with ρ, from $r = 0.423$ if $\rho = 0.15$ to $r = 0.151$ if $\rho = 0.45$.

The resulting optimal intensity of monitoring rises over the course of an unemployment spell, with a frequency of monitoring ranging from 7% to 14% per month. Meanwhile, the search threshold is quite low in the first period, as search in that period is very difficult, but then rises to about 0.22 to 0.23 in subsequent months. The baseline search intensity without monitoring increases gradually from 0.131 in month 2 to 0.216 in month 5, so monitoring does substantially raise search intensity, and the unemployment rate drops from 6.07% to 5.12%. The welfare gain is 0.33% of mean consumption, significantly higher than for optimal UI; the cost of monitoring is sufficiently low that monitoring provides an efficient way of encouraging search without depriving the unemployed of UI benefits (except in rare cases when a large negative monitoring error is drawn, leading to an observed search effort below the threshold and a termination of benefits).

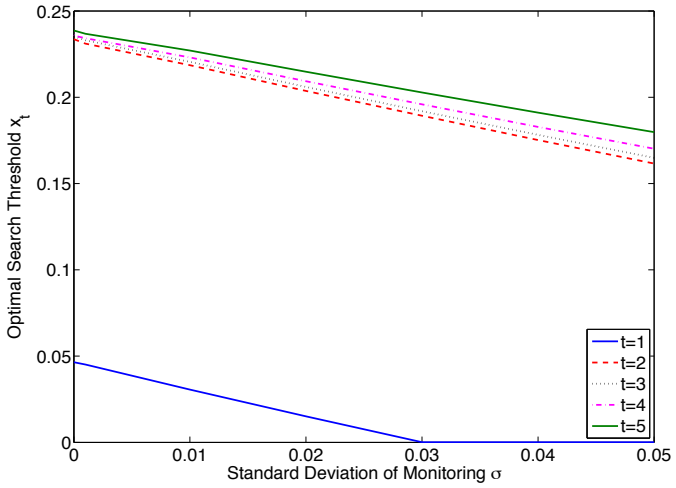
In Figures 5 and 6, I present the optimal values of ϕ and x as a function of the standard deviation of monitoring σ. The remarkable feature of Figure 5 is that, except for period 1 at sufficiently large σ, the optimal monitoring intensity actually increases as σ increases. The reason for this is that a very precise monitoring technology acts as a spike in a job-searcher's utility at x; even with a low probability of monitoring, individuals will tend to position themselves right at the spike. However, a less precise monitoring technology acts as a bump in the utility distribution, and the less precise it is the more spread out this bump is. Therefore, the less precise is monitoring, the larger must be the monitoring frequency to make the bump large enough to significantly affect workers' chosen search intensities.

Figure 5: Optimal Monitoring Intensity as a Function of Accuracy



Meanwhile, Figure 6 shows that the search threshold decreases with σ; this is a simple consequence of the fact that, with a less precise monitoring technology, there is a greater probability of a false negative leading to termination of benefits even if the worker searched slightly above the threshold. Therefore, for any given threshold, as σ increases, workers aiming to avoid the loss of benefits will search harder to stay well away from the threshold; to generate a given desired search intensity, a lower threshold is required as σ increases.

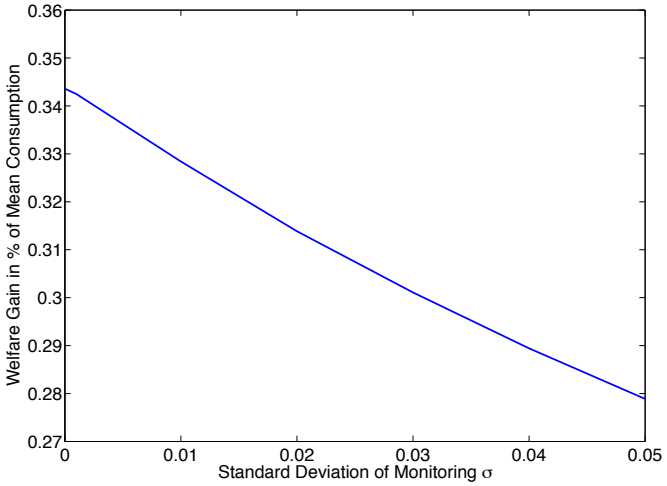
Figure 6: Optimal Monitoring Threshold as a Function of Accuracy



Finally, Figure 7 presents the welfare gain from the optimal monitoring system as a function of σ; even though a less precise monitoring technology is used more often, the welfare gain decreases monotonically in σ, as a more precise monitoring technology is always more useful in welfare terms.

In general equilibrium, optimal monitoring intensities go down in all but the final period, whereas the search thresholds increase at most durations. Wages are slightly raised, because the increase in search from monitoring raises tax revenues by more than enough to compensate for the cost of monitoring, and both lead to increased incentives for job search and thus a willingness to search harder even at lower monitoring intensities. The welfare gain is slightly smaller now, but in all respects, the results are very similar to those from the partial equilibrium model.

Figure 7: Monitoring Welfare Gain as a Function of Accuracy



5.2.3 Welfare Impact of Job Search Assistance

I assume that job search assistance consists of increasing λ (or λ_s in the general equilibrium case) by enough to reduce partial-equilibrium unemployment by 5 percent from the baseline, i.e. from 6.07% to 5.77%. This is consistent with many of the empirical findings in the literature; for example, van den Berg and van der Klaauw (2006) find a 6% increase in the job-finding rate, while Osikominu (2013) finds that short-term job-search-oriented training reduces subsequent time in unemployment by 8.6%. I consider a range of values for the cost of job search, c_{JSA}; estimates of this value have ranged from about 25 Euros per month, or close to 1% of mean output, in the Netherlands, to nearly 400 Euros per month in Germany.[41] However, the majority of the estimates are 100 Euros per month or less, or a range of values for c_{JSA} from about 0.01 to 0.04.[42]

I therefore evaluate the partial equilibrium welfare impact at both of $c_{JSA} = \{0.01, 0.04\}$, with results presented in panel A of Table 5. The welfare gain is substantial if the cost is at the low end; in fact, the welfare gain of 0.20% is considerably larger than that obtained from the optimization of the unemployment insurance system, even though the latter has been the subject of a far larger welfare analysis literature than the former. However, a cost of

[41] See van den Berg and van der Klaauw (2006) for the former and Wunsch (2013) for the latter.

[42] Gautier, Muller, van der Klaauw, Rosholm, and Svarer (2018) finds an estimate of 285 Euros for most of a year in Denmark; in the UK, Dolton and O'Neill (2002) estimate that JSA interviews can be provided for 15 pounds, or a job search class for 110 pounds per person; Crépon, Duflo, Gurgand, Rathelot, and Zamora (2013) find that standard French JSA costs 575 Euros over, apparently, an 8-month period, while the enhanced program tested in that paper costs roughly twice as much.

0.04 is nearly sufficient to reduce the welfare gain to zero. Given that many of the existing JSA programs appear to have costs in this range, the implication is that most programs do generate welfare improvements.

In general equilibrium, the impact of JSA on unemployment is much smaller: JSA raises the bargaining power of unemployed individuals and thus the bargained wage – by about 0.2% in this case – and as a result firms don't open as many vacancies. For $c_{JSA} = 0.01$, unemployment only drops by 1.61% rather than 5%, and the drop in unemployment is even smaller at higher values of c_{JSA}. This effect is consistent with previous studies, where it has been interpreted negatively: if a program designed to reduce unemployment doesn't actually reduce it very much, then it may seem obvious that the program is a failure; see, for example, Cahuc and Le Barbanchon (2010) and Gautier, Muller, van der Klaauw, Rosholm, and Svarer (2018).[43] However, I find that the welfare gain is almost identical to that from partial equilibrium, because higher wages and lower vacancy creation nearly offset from the perspective of workers: with $c_{JSA} = 0.01$, the welfare gain decreases from 0.20% to 0.18%, while a small decrease is also visible at $c_{JSA} = 0.04$. This result is due to an increase in wages in general equilibrium, whereas Crépon, Duflo, Gurgand, Rathelot, and Zamora (2013) claim that, in their study of French JSA, there is no significant treatment effect on wages; however, the point estimates in Online Appendix Table IX in Crépon, Duflo, Gurgand, Rathelot, and Zamora (2013) indicate increases in average wages of 4.7% after 8 months and 2.3% after 12 months, and a decrease of 6.1% after 20 months. While none of these coefficients are statistically significant, my results indicate that they are highly economically significant: the average of the three is a 0.3% increase in wages, slightly larger than the wage increase in my simulation which implies welfare gains from JSA. Further discussion of the general equilibrium results can be found in appendix D.

It is also possible, both in partial and general equilibrium, to evaluate the optimal UI benefit system when JSA is offered. Results are available upon request, but in each case, the effect on optimal benefits is quite small; there is a small complementarity between the two programs, however, in that welfare gains from combined optimal UI and JSA are always at

[43]Both papers ignore fiscal externalities by abstracting from taxes to pay for other government expenditures, and Cahuc and Le Barbanchon (2010) do not perform any explicit welfare analysis. In Gautier, Muller, van der Klaauw, Rosholm, and Svarer (2018), because of the abstraction from fiscal externalities and an assumption that JSA imposes a time cost on workers, JSA actually lowers the bargained wage slightly, and welfare decreases with JSA intensity above a low level. Both papers focus on programs that were only offered to some unemployed individuals.

least as large as the sum of the welfare gains from each optimized program on its own.

5.2.4 Optimal Job-Creation Subsidy

In a partial-equilibrium setting, a job-creation bonus takes the form of a payment to the worker upon re-employment; when I evaluate the optimal value of this bonus, I find $y = 0.0023$. To put this in dollar terms, if average monthly income for someone starting a new job is on the order of \$3000, then the optimal payment to that worker upon finding a job is a tiny \$6.90; the welfare gain is also miniscule, far less than 0.01%.

Why is the job-creation bonus so ineffective? The reason is simple: bonuses are given to employed workers, and the taxes to pay for the bonuses are taken from employed workers, so the policy amounts to giving with one hand and taking with the other. Because currently-existing jobs do not receive the bonus when the policy is first implemented, there is a small redistribution from the currently employed to the currently unemployed, but the effect is very small because, even for the currently unemployed, the increase in taxes on their future job is almost equal in expected present value to the bonus received up front. To generate a significant welfare effect, a job-creation bonus would need to take a more complicated form, perhaps declining with duration of unemployment.

In general equilibrium, the bonus could be paid either to the worker or the firm. If I assume that it is given to the worker as in the partial equilibrium case, the optimal bonus is now $y_w = 0.0049$, or a job-finding bonus of about \$14.70, and again the welfare impact is negligible, for the same reasons as in the partial case. If, instead, the bonus is paid to the firm upon the creation of a new job, the optimal policy is a bonus of $y_f = 2.318$, or nearly \$7000. Although the bonus is larger, the welfare gain is once again quite small, because the firm's vacancy creation activity is relatively insensitive to the bonus.

5.2.5 Optimal Combined Policy

Finally, I now consider how these programs can best be combined. I consider flexible time paths for UI benefits, as well as for monitoring frequency ϕ_t and threshold x_t; however, to keep the optimization program manageable, I assume that UI benefits and monitoring thresholds follow simple functional forms. Specifically, I assume that the replacement rate r_t follows a cubic functional form over time, while x_t also takes a cubic from period 2 onwards, with x_1 chosen independently. The unconstrained optimal policy seems to feature very long-

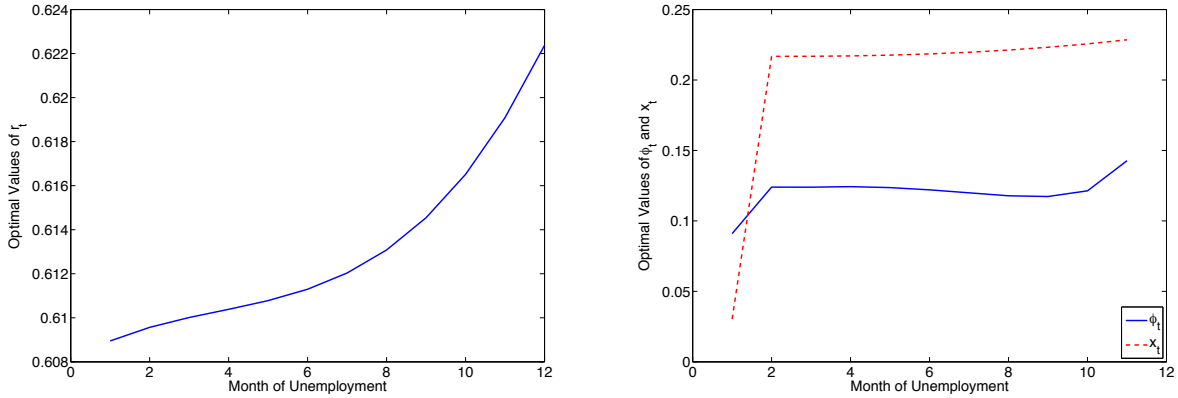
lasting benefits, but to make the computational problem feasible I restrict my attention to policies lasting 12 months.

Therefore, a combined policy can be defined by a set of 21 policy parameters: 4 for the UI cubic, 5 for the monitoring thresholds, 11 for the monitoring frequencies (monitoring is not used in month 12, given that benefits expire at the end of the period in any case), and the binary decision of whether or not to offer job search assistance. I do not include the job-creation bonus, as the analysis above found it to be ineffective.

The optimal combined program in partial equilibrium is presented graphically in Figure 8, along with the fact that JSA is indeed provided; I assume an intermediate value of $c_{JSA} = 0.02$, along with $\sigma = 0.01$ and $q = 0.01$. The monitoring policy looks reasonably similar to that found in section 5.2.2, though obviously persisting for a longer duration, but the optimal UI policy is far more generous: the optimal replacement rate starts slightly lower than would be optimal on its own, but then increases very slightly with duration rather than declining rapidly. As noted at the bottom of panel A in Table 5, the resulting welfare gain is a substantial 0.72% – larger than the value obtained from adding up the welfare gain from each optimized policy on its own – and the unemployment rate drops from 6.07% to 4.65%.

Figure 8: Optimal Combined Policy in Partial Equilibrium

(a) Optimal Replacement Rates (b) Optimal Monitoring Regime



This result can be understood as follows: getting people into jobs as quickly as possible is an important policy goal, and if UI is the only policy available to government, it should be used to achieve this goal by reducing the generosity substantially. Monitoring and sanctions, however, deal with a significant part of the moral hazard problem of UI, providing the possibility of removing benefits from individuals who are not searching intensively; as a

result, the moral hazard cost of UI is reduced relative to the consumption smoothing benefit, and much more generous insurance can be provided. This result has already been found by Fredriksson and Holmlund (2006) and Boone, Fredriksson, Holmlund, and van Ours (2007) using a very simple specification of monitoring and a simple calibration, but the increase in UI generosity is much weaker there, from a replacement rate of 0.5-0.55 without monitoring to about 0.63.

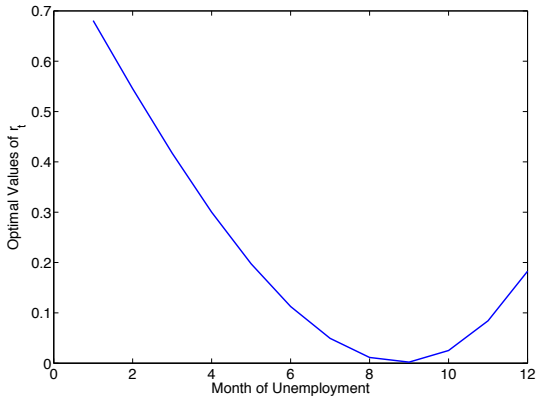
The general equilibrium results can be found in Figure 9 – once again, the optimal policy includes JSA – and for the first time so far the results indicate a significant qualitative difference from the partial equilibrium results: the optimal replacement rate starts out at nearly 0.7, but then declines rapidly, nearly reaching zero in the 9th month, before rising to around 20% in the final month (to provide an incentive for continued search at longer durations). Generous UI combined with monitoring and JSA raises worker bargaining power, thus raising wages, and so UI cuts at longer durations are required to help bring wages down. Monitoring thresholds are roughly the same as before, but the monitoring intensity rapidly increases to about 0.7 by the 6th and 7th months of unemployment, as much stronger monitoring is needed to keep the unemployed searching hard for jobs when UI benefits decline so rapidly. However, relatively few unemployed individuals remain unemployed into the second half of the year, and so in practical terms the optimal policy is not as dramatically different from the partial equilibrium outcome as it might appear: optimal UI remains more generous than the current system for the first few months, and the average benefit received by all unemployed individuals is about 10% higher than at baseline. Further analysis of the general equilibrium results can be found in appendix D.

6 Conclusion

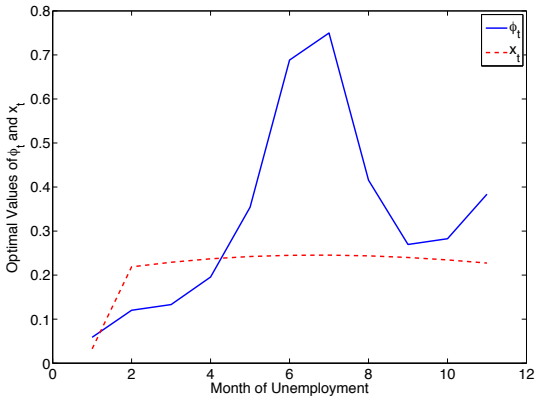
In this paper, I have evaluated the welfare implications of labour market policies such as unemployment insurance, job search assistance, and monitoring and sanctions of UI recipients. I begin with a simple model inspired by the sufficient statistics approach, and show that high income taxes suggest policy reforms to implement less generous UI, more JSA and more frequent and strict monitoring; however, once these policies are combined it is difficult to say anything about optimal policy. I therefore spend the rest of the paper focussing on a more realistic search and matching model, which I estimate using a novel application of

Figure 9: Optimal Combined Policy in General Equilibrium

(a) Optimal Replacement Rates



(b) Optimal Monitoring Regime



indirect inference to the March CPS. I find that while reducing UI and increasing the intensity of JSA and monitoring would generate significant welfare improvements on their own, the optimal combined policy features UI that is more generous, at least in the short-run. In fact, even in the general equilibrium analysis, the amount of UI received per period of unemployment is higher than at baseline, and considerably higher than in the absence of JSA and monitoring.

These results provide new evidence on the optimal mix of policies to deal with unemployment. This paper is the first to consider such an optimal combined policy in a setting characterized by empirically-reasonable fiscal externalities from income taxes and private consumption smoothing, and my results highlight the quantitative importance of policies other than UI: optimal use of monitoring and job search assistance have the potential for welfare gains that are quite large relative to an optimization of UI alone. Such programs should be taken much more seriously in future welfare analyses of unemployment policy. Additionally, my policy simulations suggest the existence of complementarities between UI and other unemployment policies.

Meanwhile, I find that the results are generally similar in partial and general equilibrium; with Nash bargaining, programs that raise wages generally reduce welfare very slightly. Increases in wages are accompanied by offsetting reductions in job-creation, effects which may nearly cancel each other out from a worker's perspective, while the zero-profit condition means that firms are always unaffected in equilibrium. It is therefore possible for the general equilibrium welfare impact of a program to be very similar to the partial equilibrium value

even when it affects certain variables in very different ways, and this is a general result for an equilibrium search model if the matching equilibrium is close to being efficient. These results point in the direction of an important fact: general equilibrium adjustments to policy do not mean that the policy in question necessarily has a smaller effect; rather, it means that the impact of a policy may be redirected onto other dimensions – for example, price changes rather than quantity changes. Thus, policies may have important welfare impacts in general equilibrium that would be missed if only the margin affected in partial equilibrium were considered. This point is important in a wide variety of policy areas, and deserves greater attention in future work.

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A Data and Estimation Procedure

The data used for the structural estimation in section 4.1 are from the March CPS of 1988-2008, as published online by the IPUMS project; these data refer to unemployment and benefit receipt in the previous calendar year, meaning that my data covers 1987 to 2007 inclusive. I use INCUNEMP as my variable for the amount of UI received; prior to 1988, the March CPS did not contain a variable specifically for the amount of UI received, as that income was combined with income from government programs other than welfare and Social Security in INCGOV. I drop data from 2008 to 2013 to avoid the Great Recession; including that data makes the estimated responsiveness of unemployment to UI benefits much weaker.

The sample for the main estimation consists of men aged 18 to 64, with those in the armed forces and those with zero March Supplement weights dropped. This large sample, with 1025983 observations (of which 883417 are in the labour force), is used to estimate the mean unemployment rate using current employment status.

For the estimation of the distribution of unemployment amounts, and the regressions, I make additional sample restrictions. I limit the sample to individuals with some positive amount of unemployment in the previous calendar year, and I drop individuals with no unemployment benefits, and those who also received supplemental and/or strike benefits, to limit myself to a population that received only regular UI; results are not sensitive to including those with supplemental and/or strike benefits. I also restrict the sample to those with some positive labour earnings, and I drop individuals with only one week of reported unemployment, since many states have a one-week waiting period for UI; these sample restrictions reduce the sample size to 28717. Incomes are topcoded in the March CPS, so I identify all observations where one or both of the two labour income components (INCLONGJ and OINCWAGE) are topcoded, and I apply the same simple adjustment applied by Katz and Murphy (1992): topcoded values are replaced by 1.45 times the topcode amount.

I then use a migration status variable called MIGSTA1 to replace state of residence with that of the previous year if an individual moved from a different state; this forces me to drop observations from 1994, as that variable was not collected in that year. I also drop 94 individuals who were living abroad in the previous year, as they would presumably not be eligible for American UI, leaving me with 27142 observations. Finally, I generate the UI benefit per week of unemployment in 1999 dollars, and I drop 296 outliers reporting more than $1000 per week, leaving a final sample size of 26846.

To correspond to the model, I aggregate weeks of unemployment up to months: one month is roughly equal to $4\frac{1}{3}$ weeks, and so accounting for the standard one-week waiting period for UI, I define month 1 as extending from week 2 to the first third of week 6, month 2 as including the final two thirds of week 6, all of weeks 7-9, and the first two thirds of week 10, and so forth. However, because the unemployment variable WKSUNEM1 gives the self-reported number of weeks of unemployment in the previous calendar year, measurement error is likely to be a significant problem; indeed, many observations cluster at certain salient numbers – for example, 11.39% of observations report 12 weeks of unemployment, compared to 0.66% and 3.24% at 11 and 13 weeks respectively. To account for this, I assume that there is a log-normal measurement error: the log of the true number of weeks unemployed in the previous year is equal to the log of the reported number plus an independent normally distributed measurement error z. Thus, the error is correlated with the true value, but I assume that someone reporting a given number of weeks is equally likely to have rounded down or rounded up. To determine the standard deviation σ_z, I take all currently unemployed individuals from the March CPS for 1988-1993, and I shift them forward by 4.33 weeks of unemployment duration; for any given value of σ_z, I can calculate the probability that

each individual would report any particular number of additional weeks of unemployment. Polivka and Miller (1998) found for the CPS from November 1992 to December 1993 that only 26.1% of individuals unemployed in consecutive months reported an increase in duration of unemployment of 3, 4, or 5 weeks, so I find the value of σ_z that satisfies this finding, which is $\sigma_z = 0.162$.

I then use the estimated σ_z to compute the distribution of possible unemployment durations by month for every individual in my main sample of 26846. For someone reporting n weeks of unemployment, I add a normal random variable $\hat{z}$ with mean zero and standard deviation 0.162 to $\log(n)$, and compute the probability that the individual was really unemployed for 1 month (i.e. $\log(n) + \hat{z} < \log(5.33)$), 2 months ($\log(n) + \hat{z} \in [\log(5.33), \log(9.67)$), and so forth. These are the values u_{ji} used in the structural estimation.

Average UI benefits by state and year are taken from the Employment and Training Administration website, from the Claims Data report included in the ET Financial Data Handbook 394 Report. Meanwhile, industry and occupation variables for the previous calendar year, IND50LY and OCC50LY, use three-digit codes from the 1950 Census Bureau classification systems; I aggregate the variables up into 14 and 10 categories respectively, which are described in Table 6. I include the industry code 000, for "Not in Universe," to allow for the possibility of individuals working in non-standard industries (this includes only 62 observations, or 0.23% of the sample).

For the simulations of the model, to produce the simulated auxiliary parameters for indirect inference, I start from the steady-state distribution and then simulate forward for 12 months, keeping track of the distribution of the number of months of unemployment, as well as of the number of months of UI receipt (assuming that one month of employment is sufficient to fully recharge UI entitlement to 6 months). Then I convert the UI received into benefits per month of unemployment rather than per month of receipt, to correspond to the approach in the CPS data.

To estimate the baseline tax system, I take a number of estimates from several sources. I begin with a sample of workers from the 2008 March CPS; this sample consists of 1825 individuals aged 18 to 64, with similar sample restrictions to the main sample used in this paper: I drop individuals in the armed forces, those with no UI or with supplemental and/or strike benefits, and those with no more than one week of unemployment in the previous calendar year. I then construct the tax system facing each individual, both at the federal and state level, accounting for their marital status and number of children, and average across the sample (using March Supplement weights) to find the tax rates applying to the average UI recipient. Specifically, I find that the average individual who was unemployed in 2007 faced a 14.3% marginal federal tax rate, a 0.5% EITC tax-back rate, and a 3.9% marginal state tax rate. Meanwhile, the Institute on Taxation & Economic Policy (Davis, Davis, Gardner, McIntyre, McLynch, and Sapozhnikova, 2009) estimates that in 2007 the average individual in the the second quintile of household earnings paid 1.5% of their income in state income taxes, and a Congressional Budget Office publication entitled "Average Federal Tax Rates in 2007" (Congressional Budget Office, 2010) estimates that the average second-quintile individual paid 1.1% in federal income taxes. The latter publication also finds that second-quintile individuals paid 9.5% of their income in social insurance taxes (calculated as the sum of the employee and employer payroll taxes); this is an estimate of average payroll taxes, but 9.5% is also a good estimate of the marginal social insurance tax faced by the typical UI recipient, based on estimates in Cushing (2005), and so I will use 9.5% as both the average and the marginal rate.[44] This implies a marginal tax rate of $\tau = 0.143 + 0.005 + 0.039 + 0.095 = 0.282$, whereas the average tax rate is $0.095 + 0.011 + 0.015 = 0.121$. Finally, UI benefits are subject to federal income taxation, and state taxes in some but not all states; using the 2008 March CPS data, I find that, on average, the marginal state tax rate applied to UI is 2.7%, meaning that the tax rate applied to UI is $\tau_b = 0.17$.

[44] See Lawson (2017a) for further detail on these calculations.

Table 6: Industry & Occupation Categories

Number	Description	Codes
	Panel A: Industries	
0	Not in Universe	000
1	Agriculture, Forest & Fishing	105-126
2	Mining	206-239
3	Construction	246
4	Manufacturing Durables	306-399
5	Manufacturing Non-Durables	406-499
6	Transportation, Communication & Utilities	506-598
7	Wholesale & Retail	606-699
8	Finance, Insurance & Real Estate	716-746
9	Business & Repair Services	806-817
10	Personal Services	826-849
11	Entertainment & Recreational Services	856-859
12	Professional & Related Services	868-899
13	Public Administration	906-936
	Panel B: Occupations	
1	Professional & Technical	000-099
2	Farmers	100-123
3	Managers, Officials & Proprietors	200-290
4	Clerical & Kindred	300-390
5	Sales Workers	400-490
6	Craftsmen	500-595
7	Operatives	600-690
8	Service Workers	700-790
9	Farm Labourers	810-840
10	Labourers	910-970

Notes: Panel A presents the recode of variable IND50LY used for industry categories in the structural estimation, with the codes aggregated into each category listed in the right column. Panel B presents the recode of variable OCC50LY used for occupation categories.

B Robustness Checks of Model Identification

This appendix provides further evidence on the implications of the standard errors reported in section 4.1.1. First of all, whereas Figures 3 and 4 present confidence bands around the search intensity s_t and its derivative with respect to b, Figures 10 and 11 below present similar confidence bands for the equilibrium level of the search cost function, $E_t(s_t)$, and its derivative $E_t'(s_t)$. These quantities are less immediately interpretable than the search intensity, which is expressed in intuitive economic units, and accordingly the confidence bands appear wider on the search cost variables. Nonetheless, it is clear that the search cost function is identified in terms of its implications for both the level and slope.

Finally, Figures 12 and 13 show graphically the entire range of the bootstrapped parameters

Figure 10: 90% Bootstrap Confidence Intervals for Search Effort Cost

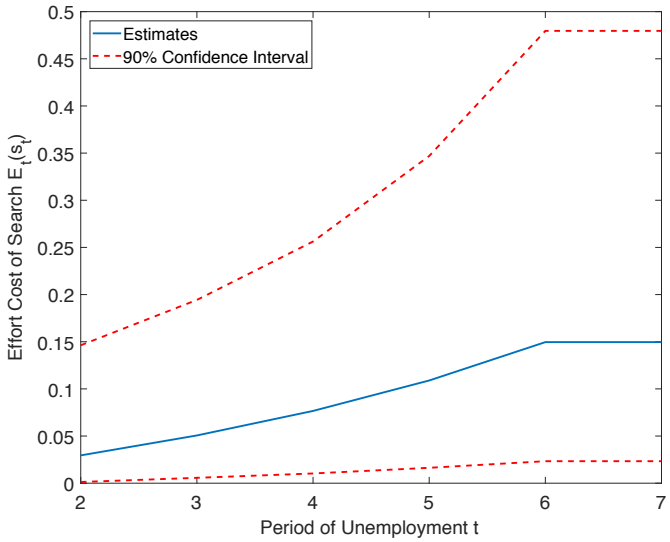
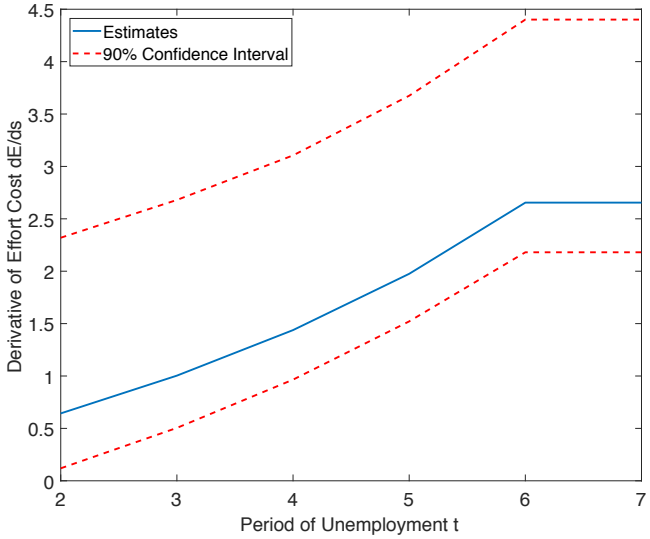


Figure 11: 90% Bootstrap Confidence Intervals for Derivative of Search Effort Cost



for θ_t and κ_t. To make the variation graphically concise, I transform both variables by taking their 20th roots and plotting $\kappa_t^{0.05}$ against $\theta_t^{0.05}$. Two things are apparent from these figures: there is a strong negative relationship between the two parameters (as mentioned in section 4.1.1), and there is nonetheless considerable two-dimensional variation in the values.[45]

[45]This latter point is harder to see in Figure 13 for θ_2 and κ_2, but the cloudy nature of the line indicates differences in κ_2 for a given value of θ_2 that are economically quite large. Thus, in contrast to the concerns of a referee that these parameters might be perfectly collinear, it is apparent that two independent factors are contained within each pair of θ and κ.

Figure 12: Variation in Bootstrapped Values of θ_1 and κ_1

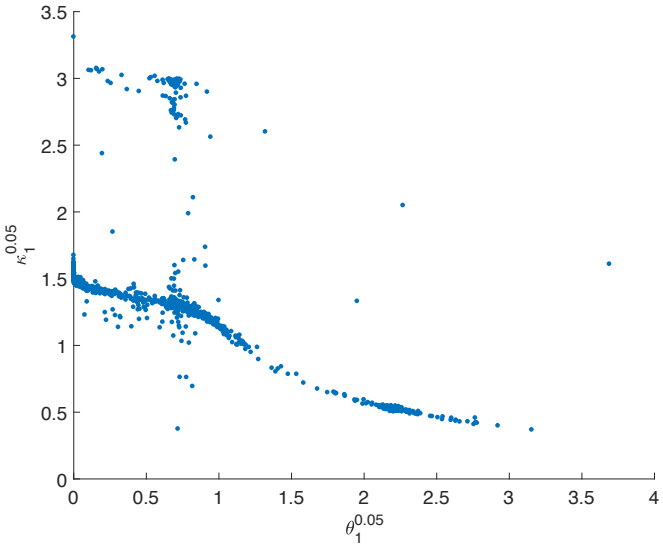
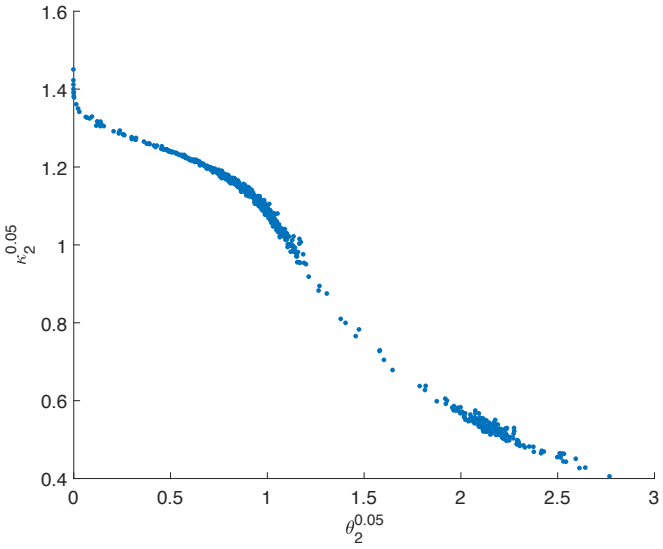


Figure 13: Variation in Bootstrapped Values of θ_2 and κ_2



C Numerical Results with Kalai Bargaining

In this appendix, I present the numerical results for optimal policy in general equilibrium when I assume Kalai bargaining instead of Nash bargaining over wages. Kalai bargaining assumes that the worker and firm receive fixed shares of the surplus, rather than setting the wage to maximize the geometrically-weighted surplus. In the absence of taxes, the resulting allocations are identical, but in the presence of marginal taxation, the tax rate affects worker bargaining power differently in the two cases.

The baseline equation for the equilibrium wage now takes the following form:

$$\rho(p-w) = (1-\rho)\left[\frac{((1-\tau)w+L)^{1-R}}{1-R} + \beta\delta V_{u1} - (1-\beta(1-\delta))E_f(V_{u(t+1)})\right].$$

In fact, the only alteration is that the left-hand side now consists only of $\rho(p-w)$ instead of $\rho(p-w)((1-\tau)w+L)^{-R}(1-\tau)$. Kalai bargaining removes the $V_e'(w)$ term that features in Nash bargaining and which represents the marginal return to bargaining for the worker: a large value of $V_e'(w)$ means workers have a lot to gain from increases in w, and Nash bargaining assumes that that makes them bargain more successfully.

It is important to note at this point that, unlike with Nash bargaining, different normalizations of utility can lead to different bargaining allocations; that is, defining utility from consumption as $U(c) = A\frac{c^{1-R}}{1-R}$, where A is some constant, the value of the bargained wage will tend to decrease in A. The size of the surplus depends on how firm and worker payoffs are denominated, and giving the worker ρ share of the surplus makes it important to normalize the relative payoffs carefully. I will simply use the equation defined above, but this point should be kept in mind.

I recalibrate the general equilibrium portion of the model for Kalai bargaining, where the values of p and k are 1.0560 and 1.3962 respectively, nearly identical to those from Nash bargaining. As a result, it should come as no surprise that the results of the optimal policy analysis in Table 7 are also very similar to the general equilibrium results from section 5. The welfare gain from reducing UI generosity is slightly higher, while the value of JSA is slightly lower; monitoring is slightly less frequent and slightly less valuable.

Table 7: Numerical Results for Optimal Policy with Kalai Bargaining

	Optimal Value	Welfare Gain	w	λ
UI Replacement Rate r	0.295	0.09%	0.999	1.054
UI Duration N	3 months	0.25%	0.995	1.198
$\{r, N\}$	$\{0.556, 3\}$	0.26%	0.996	1.187
UI Time Path	$\{0.628, 0.598, 0.378, 0.103\}$	0.27%	0.996	1.183
Monitoring:	$\phi_t = \{0.046, 0.066, 0.068, 0.085, 0.146\}$	0.27%	1.001	0.962
	$x_t = \{0.034, 0.216, 0.224, 0.234, 0.244\}$			
JSA with $c_{JSA} = 0.01$		0.17%	1.002	0.924
JSA with $c_{JSA} = 0.04$		-0.03%	1.002	0.918
Job-Creation Subsidy y_w	0.0030	0.00001%	1.000	1.000
Job-Creation Subsidy y_f	1.389	0.003%	1.018	1.003
Combined Program	see Figure 14	0.47%	1.001	0.967

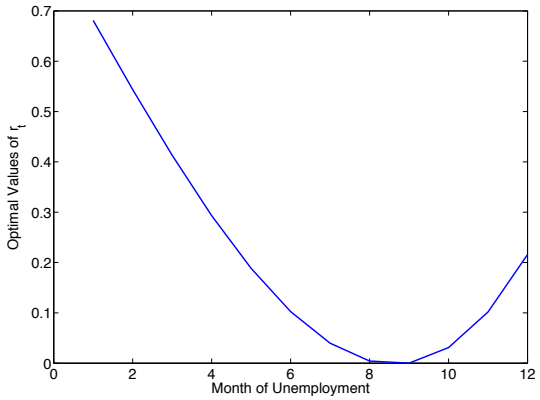
Notes: The last two columns presents the equilibrium values of the wage w and the search effectiveness λ; in the case of job search assistance, this represents λ_w rather than λ_s. Results for optimal monitoring assume a cost of $q = 0.01$ and a standard deviation of monitoring of $\sigma = 0.01$. Results for the optimal combined program use the same values for q and σ and assume $c_{JSA} = 0.02$.

Estimation of the optimal combined program leads to the results in Figure 14, and the results are very similar to the results from the Nash bargaining analysis: the optimal replacement rate takes a U shape, with benefits starting at nearly 70% but declining to zero by the 9th month of unemployment, before rising to around 20% in the final month. The monitoring thresholds and intensities are also similar to the Nash bargaining values.

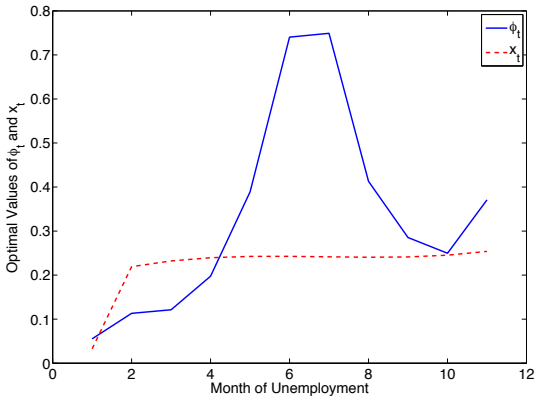
The reason why the results with Kalai bargaining are nearly identical is that the value that disappears from the wage equation when I switch from Nash to Kalai bargaining, $((1-\tau)w +$

Figure 14: Optimal Combined Policy in General Equilibrium with Kalai Bargaining

(a) Optimal Replacement Rates



(b) Optimal Monitoring Regime



$L)^{-R}(1-\tau)$, is simply quite close to 1. However, in an earlier version of the paper, when L was ignored and employed income was simply $w(1-\tau)$, the results were different: with Kalai bargaining, higher wages and lower vacancy creation actually led to *increased* welfare. This further supports the point raised in appendix D: there is no a priori reason to believe that reductions in wages due to bargaining in general equilibrium will be welfare-improving; it depends on the nature of the bargaining problem, and whether or not wages prior to a policy change are inefficiently high or low, as either is possible.

D Discussion of General Equilibrium Results

The results in section 5 of the paper suggest that the optimal unemployment policy consists of providing both increased insurance, at short durations of unemployment at least, and increased opportunities (from JSA) and incentives (from monitoring) for search. Providing inexpensive JSA and imposing sanctions based on frequent monitoring would improve welfare either on their own or in combination, but the finding in Lawson (2017a) that UI should be dramatically reduced to counter the moral hazard cost no longer holds once other programs are included in the set of policy options: monitoring can deal with a significant portion of the moral hazard costs of UI, allowing even for increased overall generosity.

These general findings hold both in partial and general equilibrium, and the numerical results are similar except in the analysis of the optimal combined policy. Policy options that raise wages, such as JSA and generous UI, are generally slightly less beneficial than in partial equilibrium, and combining both with monitoring, which also tends to raise wages, pushes wages inefficiently high in general equilibrium. Therefore, the optimal combined policy features declining UI benefits in general equilibrium, relative to the nearly flat (and even slightly increasing) benefit path in partial equilibrium.

The fact that most of the general equilibrium results are similar to those from the partial equilibrium setting may seem surprising; the usual intuition is that, if a policy designed to lower unemployment doesn't really lower unemployment very much, it must have failed. A substantial number of papers describe how general equilibrium adjustments can wipe out much of the unemployment reductions generated by labour market programs in partial equilibrium: see, for example,

Holmlund and Lindén (1993) and Algan, Cahuc, and Zylberberg (2002) on public employment programs, Andersen and Svarer (2014) on workfare, and Gautier, Muller, van der Klaauw, Rosholm, and Svarer (2018) and Cahuc and Le Barbanchon (2010) on other active labour market programs. Only Andersen and Svarer (2014) and Gautier, Muller, van der Klaauw, Rosholm, and Svarer (2018) perform any explicit welfare analysis, and both ignore fiscal externalities; however, the focus of each paper on the reduced effectiveness of the policies is strongly suggestive of reduced welfare gains as well. In fact, Holmlund and Lindén (1993) and Algan, Cahuc, and Zylberberg (2002) both make reference to how public employment programs increase "wage pressure"; the asymmetry of this term seems to suggest undesirability.

However, the intuition for why general equilibrium adjustments might make little difference to the results is actually quite simple: when a policy leads wages to be bargained downwards, vacancy creation increases, making it easier to find a job. From the worker's perspective, these effects may nearly cancel each other out, and recall that the zero-profit condition means that firms are always unaffected in equilibrium. Put another way, a reduction in wages that leads to an increase in vacancy creation will generate both more output and more vacancy costs. Which of these dominates depends on a number of factors. Generally, if wages were set at the optimal value conditional on other distortions, then a small increase (or decrease) in wages and the accompanying decrease (or increase) in vacancy creation would have zero first-order welfare impact. To take a particular example, this would hold if the equilibrium was efficient in the first place – for example, if all participants were risk-neutral, there were no pre-existing distortions, and the Hosios condition applied. The same general theoretical point is also made in Landais, Michaillat, and Saez (2018b), though the latter paper emphasizes the effect on optimal policy of deviations from matching efficiency.

Thus, for the welfare impact of a policy to change between partial and general equilibrium requires that one of those assumptions be untrue. In my case, two of the assumptions above are not satisfied: workers are risk-averse, and income taxes impose a distortion on search and vacancy creation. However, the impact of both of these on the efficiency of matching equilibrium are theoretically ambiguous, and depend on the specific calibration; as a result, examination of the impact of risk-aversion and taxation on efficiency of matching in a previous version of this paper found a very complicated pattern of results.

To illustrate this ambiguity, consider a simple illustration using a model with only two states: employment and unemployment. I abstract from unemployment insurance and assume fixed home production h and search intensity $s = 1$ (with search costs ignored), and I will consider risk-aversion and taxation separately, comparing each to a risk-neutral, tax-free baseline.

Starting with risk-aversion, allow utility from consumption to take the form $U(c) = \frac{c^{1-R}}{1-R}$, and the worker value functions take the following form:

$$V_e = U(w) + \beta \left[\delta V_u + (1-\delta)V_e\right]$$
$$V_u = U(h) + \beta \left[\lambda V_e + (1-\lambda)V_u\right]$$

where $\lambda = \frac{M(u\bar{s},v)}{u\bar{s}} = \eta m(\eta)$, where $\eta \equiv \frac{v}{u\bar{s}}$ represents tightness as before and $m(\eta) \equiv \frac{M(u\bar{s},v)}{v}$. The firm's zero-profit condition is identical to that in the main model: $k = \beta m(\eta)\frac{p-w}{1-\beta(1-\delta)}$.

I focus on Nash bargaining, and solving the equations above for V_u, I find:

$$\rho(p-w)w^{-R} = \frac{(1-\rho)(1-\beta(1-\delta))}{1-\beta+\beta(\delta+\lambda)}\left[\frac{w^{1-R}-h^{1-R}}{1-R}\right].$$

Let $A \equiv \frac{(1-\rho)(1-\beta(1-\delta))}{1-\beta+\beta(\delta+\lambda)}$, and differentiate both sides with respect to R, assuming λ fixed and a starting value of $w = 1$; the result is:

$$(1-R)w^{-R-1}\left[Aw + \rho w + \rho(p-w)R\right]\frac{dw}{dR} = -Ah^{1-R}\ln(h) - \rho(p-w)w^{-R}.$$

We know that when $R = 0$, the Nash wage is the efficient one if $\rho = \chi$, so the interesting question is what happens to w as R increases. The left-hand side is initially negative, until R reaches 1, but the sign of the right-hand side is ambiguous, because risk-aversion raises the worker's fallback position $U(h)$ if $h < w$, but lowers marginal utility and thus the bargaining power of the worker. Thus, it is entirely possible that risk-aversion could lead the Nash bargain to generate wages that are inefficiently low *or* inefficiently high, depending on the parameters of the model.

Meanwhile, if we now consider a risk-neutral setting but allow for income taxation, the value functions are:

$$V_e = w(1-\tau) + \beta\left[\delta V_u + (1-\delta)V_e\right]$$
$$V_u = h + \beta\left[\lambda V_e + (1-\lambda)V_u\right].$$

I can simplify the Nash bargaining equation to:

$$\rho(p-w)(1-\tau) = \frac{(1-\rho)(1-\beta(1-\delta))}{1-\beta+\beta(\delta+\lambda)}\left[w(1-\tau)-h\right]$$

and the derivative of wages with respect to the tax rate is given by:

$$(1-\tau)(A+\rho)\frac{dw}{d\tau} = Aw - \rho(p-w).$$

Once again, the effect is ambiguous, because a positive tax rate lowers utility, requiring wages to increase to compensate, but it also weakens the worker's bargaining power. In the efficient allocation, wages should increase with taxes to split the surplus efficiently between workers and firms, but there is no reason to expect Nash bargaining to deliver the efficient allocation in the presence of distortionary taxes: $\frac{dw}{d\tau}$ depends on a variety of parameter values.[46]

Therefore, both risk-aversion and marginal income taxes are likely to cause the equilibrium to deviate from efficiency, but in ambiguous directions, because there are countervailing effects on various margins. In certain calibrations, such as the ones in this paper, increases in wages tend to be welfare-reducing, but the reverse could easily be true as well. In light of this, the most robust general conclusion may be that there is no particularly strong reason to expect general equilibrium results to deviate significantly from partial equilibrium results in any particular direction – unless the search equilibrium deviates significantly from the Hosios condition.

The important point to remember is this: the fact that general equilibrium adjustments may offset or alter the original partial equilibrium impact of a program does *not* mean that the program has no effect. Rather, the effect has been channelled into a different margin: instead of only affecting the quantity of a good produced, the price may be affected as well. This, of course, means that individuals will be affected differently by the policy than they would in partial equilibrium, and those effects need to evaluated on a case by case basis. But there should be no general presumption that the policy will have a smaller welfare impact in general equilibrium; the effect might be smaller, or it might even be larger.[47] In the current analysis, I find that policies that

[46]The only other paper that I am aware of that points out that marginal income taxation distorts the matching equilibrium is Hagedorn and Manovskii (2008). They assume Kalai bargaining – though they claim to have assumed Nash bargaining – and risk-neutrality of workers. In that setting, they also find that equilibrium wages are too high.

[47]As an example, consider the analysis of optimal college tuition subsidies in Lawson (2017b); there, I find that subsidies should be greatly increased in a partial equilibrium setting, as this will internalize a fiscal externality and encourage increased college enrollment, with resulting gains in future wages and thus in tax revenues. When I extend the model to general equilibrium, I confirm the finding of Heckman, Lochner, and Taber (1998) that if tuition subsidies lead to a reduction in relative skilled wages, this will offset the subsidy and greatly reduce the enrollment impact. However, I still find a role for increased tuition subsidies, because they induce indirect redistribution to less-skilled individuals, with a positive welfare impact.

reduce wages in general equilibrium have a larger welfare impact than in partial equilibrium, but the effects are small in most cases; only for the combined policy is the effect significant, where the partial equilibrium optimum features a combination of policies – generous and lengthy UI, JSA, and monitoring – which each tend to raise wages, necessitating cuts in UI at longer durations. However, the difference in the effect on most unemployed individuals is fairly modest.