IZA Institute of Labor Economics

Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 14085

Whether, When and How to Extend Unemployment Benefits: Theory and Application to COVID-19

Kurt Mitman
Stanislav Rabinovich

JANUARY 2021

I Z A Institute
of Labor Economics

Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 14085

Whether, When and How to Extend Unemployment Benefits: Theory and Application to COVID-19

Kurt Mitman
IIES, Stockholm University, CEPR and IZA

Stanislav Rabinovich
UNC Chapel Hill

JANUARY 2021

ISSN: 2365-9793

IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

Whether, When and How to Extend Unemployment Benefits: Theory and Application to COVID-19*

We investigate the optimal response of unemployment insurance to economic shocks, both with and without commitment. The optimal policy with commitment follows a modified Baily-Chetty formula that accounts for job search responses to future UI benefit changes. As a result, the optimal policy with commitment tends to front-load UI, unlike the optimal discretionary policy. In response to shocks intended to mimic those that induced the COVID-19 recession, we find that a large and transitory increase in UI is optimal; and that a policy rule contingent on the change in unemployment, rather than its level, is a good approximation to the optimal policy.

JEL Classification: J65, E6, H1

Keywords: unemployment insurance, unemployment, optimal policy, COVID-19

Corresponding author:
Kurt Mitman
Institute for International Economic Studies
Stockholm University
SE-106 91, Stockholm
Sweden

E-mail: kurt.mitman@iies.su.se

* This paper supersedes (though is significantly different from) our previously circulated IZA DP No. 13389 on "Optimal Unemployment Benefits in the Pandemic." We are grateful to Johannes Spinnewijn and anonymous referees for very helpful constructive comments. We thank seminar participants at the Third ICEF Conference on Applied Economics for useful suggestions. Support from the European Research Council grant No. 759482 under the European Union's Horizon 2020 research and innovation programme and the Ragnar Söderbergs stiftelse is gratefully acknowledged.

1 Introduction

Extending unemployment insurance (UI) in economic downturns is common policy practice in the United States, as exemplified by the Great Recession and the COVID-19 crisis. The academic and policy debate over the desirability of such a policy continues. At the heart of the discussion is the insurance-incentive tradeoff involved in UI design: it is arguably optimal to extend UI during downturns if its moral hazard cost is lower during those periods. Despite the wealth of literature on this topic, several important questions remain unresolved.

To start with, the standard insurance-incentive tradeoff is complicated because workers' job search behavior responds to their expectations of *future* UI benefits as well as current UI benefits. Further, search behavior depends on future economic conditions in addition to current ones. Therefore, the optimal policy may contain substantial history-dependence, and its shape may depend on the government's ability to commit to future policy actions. Moreover, the general prescription of extending UI in recessions is somewhat vague when it comes to applying it in practice. Should UI be indexed to the unemployment level—commonly the case—or to another economic indicator? Does a crisis, such as COVID-19, call for a large but short-lived UI extension, as implemented under the CARES Act, or a moderate but prolonged one? Does the nature of the economic shock that induced the recession change the policy prescription?

Using a simple dynamic framework, we theoretically and numerically address these questions. We consider a parsimonious environment in which risk-averse workers search for jobs at a cost, facing potentially stochastic search efficiency and separation rates. Our model's two-period version is analytically tractable and allows for a transparent characterization of the optimal policy, both with and without commitment. We use this framework to examine how optimal UI depends on search efficiency and the unemployment level, both current and future.

Our framework provides a dynamic generalization of the standard Baily-Chetty logic (Baily (1978), Chetty (2006)), whereby optimal policy balances the consumption smoothing benefit of UI against its moral hazard cost. Our analysis leads to three insights about optimal UI. First, the moral hazard cost depends most directly on search efficiency rather than the unemployment rate. Thus, it is optimal on theoretical grounds—at least from a purely static perspective—to index UI to the primitive shock, not the unemployment rate. Second, the dynamic nature of the environment complicates the standard Baily-Chetty formula because *future* unemployment benefits distort current search effort and hence have a moral hazard cost *today*. The optimal policy under commitment accounts for this cross-period moral hazard cost. The optimal policy under discretion does not: as we show, it effectively follows a sequence of static Baily-Chetty formulas, which trade off consumption smoothing against the contemporaneous moral hazard cost only. Third, while the level of unemployment does not matter *per se*, its path over time does. Suppose unemployment is expected to fall in the future. In that case, future UI has a low consumption smoothing benefit, which accrues to the small number of future unemployed, but a high moral hazard cost, since it distorts the behavior of all the currently unemployed. If the government can commit to future UI, then promising to cut it in states of low unemployment is a cheap way of providing incentives today.

The second and third insights have important implications for the optimal policy's shape and how it varies with the government's commitment ability. A government with commitment power can use both current and future UI to provide current incentives. This commitment power is particularly advantageous in scenarios of *rapidly falling* unemployment or rapidly rising job-finding ability. In such cases, the optimal policy provides incentives primarily by promising low future UI, leading to a steeply declining UI profile over time. Without such commitment, a government cannot credibly promise to lower UI in the future, worsening the moral hazard problem today. In turn, the government provides less UI today. The no-commitment government, therefore, implements a flatter UI profile in an economy recovering from a crisis.

We illustrate these results by extending the framework to an infinite horizon and computing both the optimal Ramsey policy (with commitment) and the Markov equilibrium policy (without commitment). In response to a negative shock to search efficiency or a destruction of job matches, the policy responses of the two types of government differ: the Ramsey government raises the level of UI benefits more initially but keeps them elevated for a shorter period of time than the Markov government. We also ask how to implement the Ramsey policy—which features complicated history-dependence—if in practice the government can only commit to a simple policy rule. We find that a policy rule conditioning UI on the growth rate in unemployment across periods performs remarkably well in approximating the optimal policy. In contrast, a policy rule conditioning on the level of unemployment would raise UI benefits insufficiently and keep them elevated for an excessively long period of time.

How do we apply our results to the COVID-19 pandemic? In the context of the current crisis, our results suggest that the CARES Act's transitory nature was desirable: not only because the fall in search efficiency itself was transitory but also because front-loading UI is a cheaper way of providing a given amount of incentives. In other words, the optimal policy intertemporally substitutes UI from periods with few unemployed to periods with many unemployed. With credible commitment, intertemporal substitution can be executed at minimal incentive cost.

Relationship to literature

This paper contributes to an already rich existing literature on optimal UI over the business cycle, including Jung and Kuester (2015), Mitman and Rabinovich (2015) and Landais *et al.* (2018) with government commitment, and Pei and Xie (2020) without commitment. These papers undertake thorough quantitative analyses of optimal policy, in particular incorporating general equilibrium effects through labor demand. We have examined the same question in a deliberately simplified framework, which allows us to transparently isolate the key insurance-incentive tradeoff and the bearing of dynamics on it.

This leads to several contributions. We demonstrate the effect of worker expectations and government commitment (or lack thereof) on the standard Baily-Chetty formula, thereby connecting the Baily-Chetty literature with the literature on time-inconsistency. Moreover, our findings - which are robust and likely to emerge in richer models - shed new light on the results found in the aforementioned papers.

For example, our results are consistent with the cuts in UI benefits during economic recoveries advocated in Mitman and Rabinovich (2015) under commitment, and the lack thereof in Pei and Xie (2020) under discretion. Finally, the tendency to front-load UI under commitment is clearly reminiscent of the optimally declining UI profile for an individual unemployed worker in Shavell and Weiss (1979), Hopenhayn and Nicolini (1997), stemming from the ability to use future UI for incentives today.[1] The re-emergence of the same front-loading tendency in designing economy-wide UI in response to aggregate shocks is an important and, to our knowledge, novel insight.

Our analysis also contributes to understanding the appropriate policy response to the COVID-19 crisis. In this regard, our stylized framework complements the growing literature incorporating the more unique features of the pandemic, such as the distinction between temporary and permanent separations (as examined in Gregory *et al.* (2020) and Birinci *et al.* (2020)) and the epidemiological side of the crisis (as applied to a search model by e.g. Kapicka and Rupert (2020), Birinci *et al.* (2020) and Fang *et al.* (2020)). The purpose of our paper is less to provide a comprehensive and quantitative analysis of the recent policy response, and more to provide qualitative insights on the key tradeoffs involved.[2] While our results are of relevance for the COVID-19 crisis, the mechanisms underlying them are applicable more generally, for understanding the optimal UI response in recessions and the central role of expectations in its design.

The paper is organized as follows. In Section 2, we consider a simple two-period environment, which allows for analytical characterization of optimal policy, both with and without commitment. Section 3 extends the analysis to an infinite horizon, showing that the main insights remain intact. In Section 4 we numerically illustrate

[1] As shown by Kolsrud *et al.* (2018), however, the optimal UI profile may no longer be declining in the presence of worker heterogeneity or duration dependence. We discuss how their logic extends to our environment in Section 4.5.

[2] We have also abstracted from two general equilibrium feedback mechanisms. First, we have ignored potential aggregate demand effects induced by providing transfers to the unemployed that could speed the recovery (Kekre (2019); Ravn and Sterk (2016); Den Haan *et al.* (2018)). Our view is that the COVID-19 pandemic (and ensuing policy response with lockdown orders) represents a supply shock and thus that normal demand channels will be muted (see Guerrieri *et al.* (2020) for an alternative view). Second, we have abstracted from firm labor demand and the response of wages and labor force participation to benefit policy (see, e.g.,Hagedorn *et al.* (2013, 2015)).

the main results, by simulating policy responses to shocks intended to mimic the COVID-19 crisis. Section 5 concludes.

2 A two-period model

In this section we consider a two-period model. The simplified environment allows us to analytically characterize the relationship between search efficiency and the moral hazard cost of UI — a key statistic for the optimal policy — and to precisely illustrate the role of government commitment.

The economy is populated by a continuum of risk-averse workers, who, in each period, can be either employed or unemployed. The economy is subject to aggregate shocks to search efficiency $\zeta_t \geq 0$. Workers have utility

$$\mathcal{U} = \mathbb{E}\left[-\frac{1}{\zeta_1}c\left(S_1\right) + v\left(x_1\right) + \beta\left(-\frac{1}{\zeta_2}c\left(S_2\right) + v\left(x_1\right)\right)\right] \tag{1}$$

where x_t denotes period-t consumption, and S_t denotes period-t search effort, incurred only when unemployed and restricted to be between 0 and 1. The utility function $v\left(x\right)$ satisfies $v' > 0$, $v'' < 0$. The cost of search $c\left(S\right)$ satisfies $c' > 0$, $c'' > 0$, $c'\left(0\right) = 0$ and $c'\left(1\right) = \infty$. In the full-fledged model of the next section, we will assume that ζ_t is stochastic. For the moment, we assume that ζ_1 and ζ_2 are known deterministically before any decisions are made in period 1.

The economy begins with an initial fraction u_0 of workers who are unemployed and $1 - u_0$ who are employed. Unemployment subsequently evolves as follows. At the start of each period, a fraction δ of the employed workers lose their job. We assume that a job loser joins the pool of unemployed job searchers immediately and can find re-employment within the period. The probability that a job searcher finds a job when exerting search effort S is simply S. Thus, end-of-period unemployment follows the law of motion

$$u_1 = (1 - S_1)(u_0 + \delta(1 - u_0)) \tag{2}$$

$$u_2 = (1 - S_2)(u_1 + \delta(1 - u_1)) \tag{3}$$

When employed at the end of period t, workers receive exogenous income w and pay a tax τ. When unemployed, they receive a government-provided unemployment benefit b_t, $t = 1, 2$. Unemployed workers choose S_t at each point in time to maximize expected utility, taking as given the path of search efficiency ζ_t and the government policy b_t, for $t = 1, 2$.

Unemployment benefits are chosen by a benevolent government, who faces an exogenous cost of public funds η. The timing is such that the government announces b_t in each period before workers choose S_t. Below, we will consider both a version where the government can commit to the sequence b_1, b_2 at the beginning of time, as well as one where it re-optimizes b_2 at the start of period 2. We refer to these types of government throughout the paper as *Ramsey* and *Markov*, respectively.

2.1 Optimal search, given policy

We first solve for the workers' optimal choices of S_1 and S_2, given ζ_1, ζ_2 and b_1, b_2 (the detailed derivations are in Appendix A.1). The optimal levels of search effort satisfy:

$$\begin{aligned}\frac{1}{\zeta_1} c'(S_1) =& v(w - \tau) - v(b_1) \\ &+ \beta(1 - \delta)\left[\frac{1}{\zeta_2} c(S_2) + (1 - S_2)(v(w - \tau) - v(b_2))\right]\end{aligned} \tag{4}$$

and

$$\frac{1}{\zeta_2} c'(S_2) = v(w - \tau) - v(b_2) \tag{5}$$

Note that period-1 search effort depends on both period-1 and period-2 unemployment benefits, since the worker anticipates the possibility of remaining unemployed in period 2. Define the elasticities $\varepsilon_{1-S_i,b_j} = d\ln(1-S_i)/d\ln b_j$, $i,j = 1,2$. Differentiating the optimal search conditions (4) and (5), we obtain

$$\varepsilon_{1-S_1,b_1} = \frac{\zeta_1 b_1 v'(b_1)}{(1-S_1)\, c''(S_1)}, \tag{6}$$

$$\varepsilon_{1-S_1,b_2} = \beta(1-\delta)(1-S_2)\frac{\zeta_1 b_2 v'(b_2)}{(1-S_1)\, c''(S_1)}, \tag{7}$$

and

$$\varepsilon_{1-S_2,b_2} = \frac{\zeta_2 b_2 v'(b_2)}{(1-S_2)\, c''(S_2)} \tag{8}$$

These elasticities will be play a key role in the subsequent optimal policy analysis, as they capture the moral hazard cost of UI. Note that, in addition to the standard distortionary effects of UI on contemporaneous search effort captured by (6) and (8), there is also an inter-period distortion captured by (7): future UI benefits distort current search effort.

Next, we examine how the moral hazard cost of UI depends on search efficiency. The sign of this dependence is theoretically ambiguous and depends on the shape of the cost function $c(S)$. Differentiating (6), (7), and (8) with respect to ζ_1 and ζ_2 — and taking into account that S_1 and S_2 depend on ζ_1, ζ_2 via (4) and (5) — yields the following result.

Lemma 1 *All else equal, a necessary condition for the elasticities ε_{1-S_1,b_1} and ε_{1-S_1,b_2} to be increasing in ζ_1, and for the elasticity ε_{1-S_2,b_2} is increasing in ζ_2, is*

$$[(1-S)\, c'''(S) - c''(S)]\, c'(S) < (1-S)\,(c''(S))^2 \tag{9}$$

All else equal, a necessary condition for the elasticities ε_{1-S_1,b_1} and ε_{1-S_1,b_2} to be increasing in ζ_2 is

$$[(1-S)\, c'''(S) - c''(S) > 0 \tag{10}$$

Proof. See Appendix A.2. ■

Condition (9) provides a restriction on the cost function under which the moral hazard cost of UI is increasing in current search efficiency. Similarly, condition (10) provides a restriction under which the moral hazard cost of UI is increasing in *future* search efficiency. Note that, higher ζ_1 and higher ζ_2 move the level of $1-S_1$ in opposite directions. A higher ζ_1 makes search effort less costly and thus raises the optimal level of S_1, all else equal. A higher ζ_2 makes *future* search less costly—lowering the opportunity cost of remaining unemployed today—hence lowers the marginal benefit of finding a job today. Condition (10) says that a higher S_1, all else equal, lowers the elasticity of $1 - S_1$. Condition (9) says that this effect does not outweigh the direct effect of a higher ζ_1, which amplifies this elasticity.[3]

In the subsequent numerical analysis we will assume a functional form for $c(S)$ such that (9)-(10) hold; it turns out that standard functional forms from the literature, e.g. the one used by Mitman and Rabinovich (2015), naturally satisfy these conditions. In doing so, we are motivated by the empirical findings of Kroft and Notowidigdo (2016), who find that the elasticity of unemployment duration with respect to UI does in fact co-vary positively with the unemployment rate. It is worth emphasizing that this empirical result is not theoretically obvious, as discussed here. The derivation in Lemma 1 is, to our knowledge, new in the literature.

In a static (i.e. one-period) model, the conditions (9) and (10) would be sufficient for optimal UI to be decreasing in current ζ. This is not necessarily the case here, precisely because of the additional anticipation effects emphasized in our dynamic setting.

2.2 Optimal UI with commitment (Ramsey)

In this section we assume that the government can commit up front to the policy path. The government is choosing b_1 and b_2 to maximize social welfare using a

[3] To understand these conditions mathematically, observe that we can write the optimal search condition in either period ($t = 1, 2$) as $\ln c'(S_t) = \ln \zeta_t + \ln \Delta_t$, where Δ_t is the marginal benefit of job search (i.e. the right-hand side of equation (4) or (5)). All else equal, a one-percent increase in the marginal benefit Δ_t translates into a one-percent increase in the marginal cost $c'(S_t)$: this is simply a consequence of the worker's optimal search behavior. But the resulting percent change in $1 - S_t$ depends on the mapping from $\ln c'(S)$ to $\ln(1 - S)$; the business cycle dependence of these elasticities therefore depends on how this mapping depends on the level of S.

utilitarian welfare metric

$$\begin{aligned}\mathcal{W} = &(1-u_1)\, v(w-\tau) + u_1 v(b_1) - (u_0 + \delta(1-u_0))\, \frac{1}{\zeta_1} c(S_1) \\ &+ \beta\left[(1-u_2)\, v(w-\tau) + u_2 v(b_2) - (u_1+\delta(1-u_1))\, \frac{1}{\zeta_2} c(S_2)\right] \\ &+ \eta\left[(1-u_1+\beta(1-u_2))\,\tau - u_1 b_1 - \beta u_2 b_2\right]\end{aligned} \tag{11}$$

with S_1 and S_2 determined as functions of b_1 and b_2 through the optimal search conditions (4) and (5), and u_1 and u_2 determined by the laws of motion (2) and (3).

The following result characterizes the optimal levels of unemployment benefits, leading to a two-period version of the standard Baily-Chetty formula.

Proposition 2 *Denote* $\Lambda_1 = \tau + b_1 + \beta(1-\delta)(1-S_2)(\tau + b_2)$, *and* $\Lambda_2 = \tau + b_2$. *Then the allocation under the optimal policy with commitment satisfies*

$$\frac{v'(b_1) - \eta}{\eta} = \left(\frac{\Lambda_1}{b_1}\right) \varepsilon_{1-S_1, b_1} \tag{12}$$

and

$$\beta\frac{v'(b_2) - \eta}{\eta} = \left(\frac{\Lambda_1}{b_2}\right)\left(\frac{u_1}{u_2}\right) \varepsilon_{1-S_1, b_2} + \beta\left(\frac{\Lambda_2}{b_2}\right) \varepsilon_{1-S_2, b_2} \tag{13}$$

Proof. See Appendix A.3. ■

We draw three lessons from this result. First, as is standard in the Baily-Chetty formula, each expression relates the consumption smoothing benefit of unemployment benefits in each period to its moral hazard cost. In turn, the moral hazard cost is captured by the respective elasticity, i.e. the the distortionary effects of benefits on search effort. The terms Λ_1 and Λ_2 are fiscal externality measures, which capture the extent to which a decrease in search effort represents a budgetary loss for the government. The expression for Λ_1 in particular indicates that a period-1 reduction in search effort results in fiscal losses in both periods, since a worker who fails to find a job in period 1 might remain unemployed in period 2.

Second, the elasticities in question, whose expressions are given earlier by (6), (7), and (8), depend on ζ_1 and ζ_2. However, and importantly, they do not directly depend on u_1 and u_2. In fact, the optimal benefit formulas (12) and (13) do not directly feature u_1 or u_2 except for the term $\frac{u_1}{u_2}$ in (13), which we will discuss momentarily. The reason is that both the insurance benefit and the moral hazard cost are proportional to the number of *potentially unemployed workers*. If the unemployment level with which the economy entered the period increases, this raises both the consumption smoothing benefit and the moral hazard cost by the same factor, keeping the resulting optimal benefit level unchanged.

Third, the role of commitment is captured by the presence of ε_{1-S_1,b_2} in (13). Period-2 benefits affect period-1 search effort. The Ramsey planner takes this into account when deciding on period-2 benefits. This also explains the presence of the $\frac{u_1}{u_2}$ term. The insurance benefit of period-2 unemployment benefits applies to u_2 unemployed workers. The moral hazard cost in period 1 applies to u_1 unemployed workers. This means that if u_1 is large and u_2 is small, there is a small ex post benefit and a large ex ante cost. In particular, this channel implies a larger moral hazard cost in faster-recovering economy, since such an economy would have a larger ratio u_1/u_2.

2.3 Optimal UI with discretion (Markov)

We now consider the UI benefits chosen by a government who re-optimizes b_2 in period 2, rather than committing to the path of benefits in period 1. We solve the problem by backward induction.[4] In period 2, the government takes u_1 as given and chooses b_2 to maximize

$$(1-u_2)\,v\,(w-\tau)+u_2v\,(b_2)-(u_1+\delta\,(1-u_1))\,\frac{1}{\zeta_2}c\,(S_2)+\eta\,((1-u_2)\,\tau-u_2b_2) \tag{14}$$

subject to the period-2 law of motion (3) and the period-2 optimal search condition (5). Denote by $b_2=\mathcal{B}_2\,(u_1)$ the period-2 government's optimal policy function,

[4] Formally, we are solving for the subgame perfect equilibrium of a game between two successive governments, where the period-1 government chooses b_1, the period-2 government then chooses b_2, and workers in each period choose search effort taking b_1 and b_2 as given. See, e.g. Kydland and Prescott (1977).

and denote by $\mathcal{W}_2(u_1)$ the resulting maximized value of (35). Then, the period-1 government takes the functions $\mathcal{B}_2(\cdot)$ and $\mathcal{W}_2(\cdot)$ as given and chooses b_1 to maximize

$$(1-u_1)\, v(w-\tau) + u_1 v(b_1) - (u_0 + \delta(1-u_0)) \frac{1}{\zeta_1} c(S_1) + \eta((1-u_2)\tau - u_2 b_2) + \beta \mathcal{W}_2(u_1) \tag{15}$$

subject to laws of motion (2)-(3), the optimal search conditions (4)-(5), and the behavior of the period-2 government $b_2 = \mathcal{B}_2(u_1)$. The following result characterizes the equilibrium choices of b_1 and b_2.

Proposition 3 *Denote $\Lambda_1 = \tau + b_1 + \beta(1-\delta)(1-S_2)(\tau + b_2)$, and $\Lambda_2 = \tau + b_2$. Then the allocation under the optimal policy without commitment satisfies*

$$\frac{v'(b_1) - \eta}{\eta} = \left(\frac{\Lambda_1}{b_1}\right) \varepsilon_{1-S_1, b_1} \tag{16}$$

and

$$\beta \frac{v'(b_2) - \eta}{\eta} = \beta \left(\frac{\Lambda_2}{b_2}\right) \varepsilon_{1-S_2, b_2} \tag{17}$$

Proof. See Appendix A.4. ■

We now contrast the choice of optimal policy under discretion (Markov) and under commitment (Ramsey). First, comparison of (17) with (13) clearly illustrates the role of commitment: the term ε_{1-S_1, b_2} is now absent from the optimal UI formula. The period-2 government trades off the consumption smoothing benefit against the *contemporaneous* moral hazard cost, but does not internalize the fact that period-2 UI benefits distort search effort in the previous period. Thus, each period's government effectively follows a static Baily-Chetty formula. From this, it is straightforward to show that the choice of b_2 is higher under discretion than under commitment.

Second, while the optimal benefit formula in (13) depends on $\frac{u_1}{u_2}$, the optimal benefit formula (17) does not, precisely because $\frac{u_1}{u_2}$ only enters in the term through which period-2 benefits affect period-1 search. This shows that the level of unemployment matters for the wedge between the Markov policy and the Ramsey policy, but it matters via the Ramsey policy, not the Markov policy. In particular, there is no sense here in which the Markov government is tempted to raise benefits more when unemployment is high. Instead, the Ramsey government would like to promise low benefits in future states in which unemployment is low; the Markov government fails to credibly promise this. As a result, the Markov government will set UI too high (relative to the commitment case) particularly in states of *rapidly recovering* unemployment.

Third, we inspect how inability to commit affects period-1 benefits. The form of (16) is exactly the same as that of (12). However, the *magnitude* of the elasticity ε_{1-S_1,b_1} (and, for that matter, Λ_1) changes due to lack of commitment. Since a higher b_2 leads to a lower S_2, the elasticity ε_{1-S_1,b_1} rises, all else equal, by the assumptions made earlier. In turn, this means that the period-1 UI benefits are lower under discretion than under commitment. The inability to commit to future policy worsens the moral hazard problem today.

To summarize the lessons from the two-period model: the government with commitment uses both current and future UI benefits to provide current incentives, and therefore has a tendency to front-load UI benefits, which is absent under discretion. This tendency to front-load UI benefits — and hence the wedge between commitment and discretionary optimal policy — is stronger when economic conditions are rapidly improving, i.e. when search efficiency is rising and unemployment is falling.

3 The full model

We now describe the full model, which differs from the simplified two-period model in two main respects. First, the time horizon is infinite. Second, the aggregate shocks to search efficiency are now stochastic and we add shocks to the separation rate. The economy is populated by a continuum of infinitely-lived risk-averse workers, with utility given by

$$\mathcal{U} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[v\left(x_t\right) - \frac{1}{\zeta_t} c\left(S_t\right) \right] \tag{18}$$

where, as before, x_t denotes period-t consumption, and S_t denotes period-t search effort. We assume that ζ_t and δ_t follow AR(1) processes

$$\ln \zeta_t = \rho_\zeta \ln \zeta_{t-1} + \sigma_\zeta \epsilon_t, \quad \epsilon_t \sim \mathcal{N}(0,1) \tag{19}$$

$$\ln \delta_t = \rho_\delta \ln \delta_{t-1} + \sigma_\delta \nu_t, \quad \epsilon_t \sim \mathcal{N}(0,1) \tag{20}$$

and denote the history of of ζ_t and δ_t shocks up to period t as $\mathcal{Z}^t = \{\zeta_1, ...\zeta_t; \delta_1, ...\delta_t\}$. Unemployment u_t evolves according to the law of motion

$$u_t = (1 - S_t)(u_{t-1} + \delta_t (1 - u_{t-1})) \tag{21}$$

When employed, workers receive exogenous income w and pay a tax τ; when unemployed, they receive $h + b_t$, where h is an exogenous value of home production and b_t is the government-provided unemployment benefit. The unemployment benefit b_t, which is the policy choice of interest, can potentially be contingent on the entire past history of shocks, $\mathcal{Z}^t$.

Unemployed workers choose S_t at each point in time to maximize expected utility, taking as given the government policy $b_t(\mathcal{Z}^t)$. We show in Appendix B.1 that the worker's optimal search behavior leads to the Euler equation for search intensity,

$$\frac{1}{\zeta_t} c'(S_t) = v(w - \tau) - v(h + b_t) + \beta (1 - \delta_t) \mathbb{E}\left(\frac{1}{\zeta_{t+1}} c(S_{t+1}) + (1 - S_{t+1}) \frac{1}{\zeta_{t+1}} c'(S_{t+1}) \right) \tag{22}$$

The Euler equation equates the marginal cost of additional search to the marginal benefit; the latter is the combination of the consumption gain from becoming employed and the benefit of economizing on search costs in the future. Given a policy path $b_t(\mathcal{Z}^t)$ and an initial condition for unemployment u_0, the equilibrium is fully characterized by law of motion (21) and Euler equation (22) .

3.1 Optimal UI with commitment

In this section, we describe the Ramsey problem, i.e. the problem of a benevolent government with full commitment. Such a government chooses the path $b_t(\mathcal{Z}^t)$

together with $S_t(\mathcal{Z}^t)$ and $u_t(\mathcal{Z}^t)$ to maximize

$$\begin{aligned}\mathcal{W} =& \mathbb{E}\sum \beta^t \left[(1-u_t)\, v(w-\tau) + u_t v(h+b_t) - (u_{t-1} + \delta_t (1-u_{t-1}))\,\frac{1}{\zeta_t} c(S_t)\right] \\ &+ \eta \mathbb{E}\sum \beta^t ((1-u_t)\,\tau - u_t b_t)\end{aligned} \tag{23}$$

subject to (21) and (22). We show in Appendix B.2 that the optimal policy path satisfies the recursive equation

$$\frac{v'(h+b_t)-\eta}{\eta} - (1-\delta_t)(1-S_t)\,\frac{u_{t-1}}{u_t}\,\frac{v'(h+b_{t-1})-\eta}{\eta} = \frac{\zeta_t v'(h+b_t)}{(1-S_t)\, c''(S_t)}\Lambda_t, \tag{24}$$

where Λ_t is a measure of the fiscal externality, satisfying

$$\Lambda_t = (\tau + b_t) + \beta(1-\delta_t)\,\mathbb{E}(1-S_{t+1})\,\Lambda_{t+1} \tag{25}$$

The Ramsey equilibrium, for a given cost of funds η, thus consists of sequences $b_t(\mathcal{Z}^t)$, $S_t(\mathcal{Z}^t)$ and $u_t(\mathcal{Z}^t)$, and $\Lambda_t(\mathcal{Z}^t)$ satisfying (21), (22), (24) and (25).

3.2 Optimal UI without commitment

To characterize the optimal policy under discretion, we follow the approach of Klein *et al.* (2008), solving for the Markov equilibrium of a sequential move game between successive governments. In a Markov equilibrium, the government's policy functions and the resulting actions of the private agents are functions only of the aggregate state u, ζ, δ. Let $Z = \{\zeta, \delta\}$ denote the exogenous aggregate states. Policy functions constitute an equilibrium if the current-period government finds it optimal to follow the policy functions given that future governments will follow them.

Defined recursively, the Markov equilibrium is described by a value function $\mathcal{V}(u, Z)$ together with policy functions $b = \mathcal{B}(u, Z)$, $S = \mathcal{S}(u, Z)$ and $u'(u, Z)$, such that

1. $b = \mathcal{B}(u, Z)$, $S = \mathcal{S}(u, Z)$ and $u' = u'(u, Z)$ solve

$$\max_{b,S,u'} (1-u') v(w-\tau) + u'v(h+b) - (u+\delta(1-u)) \frac{1}{\zeta} c(S) \\ + \eta((1-u')\tau - u'b) + \beta \mathbb{E} \mathcal{V}(u', Z') \tag{26}$$

subject to

$$u' = (1-S)(u+\delta(1-u)) \tag{27}$$

and

$$\frac{1}{\zeta} c'(S) = v(w-\tau) - v(h+b) \\ + \beta(1-\delta) \mathbb{E} \left(\frac{1}{\zeta'} c(\mathcal{S}(u', Z')) + (1-\mathcal{S}(u', Z')) \frac{1}{\zeta'} c'(\mathcal{S}(u', Z')) \right) \tag{28}$$

2. $\mathcal{V}(u, Z)$ and $\mathcal{B}(u, Z)$, $\mathcal{S}(u, Z)$, $u'(u, Z)$ satisfy

$$\mathcal{V}(u, Z) = (1-u'(u, Z)) v(w-\tau) + u'(u, Z) v(h+\mathcal{B}(u, Z)) - (u+\delta(1-u)) \frac{1}{\zeta} c(\mathcal{S}(u, Z)) \\ + \eta((1-u'(u, Z))\tau - u'(u, Z) b) + \beta \mathbb{E} \mathcal{V}(u'(u, Z), \zeta') \tag{29}$$

The first condition states that the policy functions are optimal given that the future value function of the government is given by $\mathcal{V}$. The second states that today's value is in fact given by $\mathcal{V}$ if the policy functions are followed. This is a system of functional equations, which is a complicated fixed-point problem in general. Given the structure of our model, we show in Appendix B that the problem simplifies further. Specifically, there is a Markov equilibrium such that the policy functions $b = \mathcal{B}(u, Z)$, $S = \mathcal{S}(u, Z)$ and $u'(u, Z)$ depend on Z only, not on u. The feature that enables this is precisely the one leading to the absence of u in equations (16) and (17), characterizing the optimal (discretionary) policy in the two-period model: u affects symmetrically both the consumption smoothing benefit and the moral hazard cost of UI. In addition to the substantive implications discussed earlier, this simplifies the computation of the solution considerably. We show in Appendix B that the path of Markov optimal policy allocations satisfies the difference equation

$$\frac{v'(h+b_t)-\eta}{\eta} = \frac{\zeta_t v'(h+b_t)}{(1-S_t)\, c''(S_t)}\Lambda_t, \tag{30}$$

with Λ_t again given by (25). The Markov equilibrium is thus characterized by sequences $b_t(Z_t)$, $S_t(Z_t)$ and $u_t(u_{t-1}, Z_t)$, and $\Lambda_t(Z_t)$ satisfying (21), (22), (30) and (25). Note that (30) differs from (24) due to the absence of the backward-looking term reflecting the time inconsistency of the Ramsey policy. In words, the Ramsey (commitment) policy calls for higher distortions today if higher distortions were required yesterday. The Markov (discretionary) policy faces no such constraint; as a result, the formula (30) looks very much like a static Baily-Chetty formula, just as the formulas (16) and (17) in the two-period model.

4 Quantitative analysis

In this section we parameterize the full model and characterize the behavior of the optimal policy under commitment (Ramsey) and discretion (Markov), given various paths of economic shocks. The model period is one week. We assume that utility of consumption takes the functional form $v(x) = \ln x$, and that the cost of search has the functional form

$$c(S) = A\left[\frac{(1-S)^{-(1+\psi)}-1}{1+\psi} - S\right], \tag{31}$$

which satisfies all the assumptions made above; in particular it satisfies (9)-(10) and ensures that the optimal search effort is always strictly between 0 and 1. We set the discount factor equal to $\beta = 0.99^{\frac{1}{2}}$ to match a 4% annual discount rate. We set $\delta = 0.0081$ to match the weekly job separation rate from the CPS. We jointly estimate the disutility parameters in the search cost function $A = 3$ and $\psi = 1.9$ so that the model is consistent with the average unemployment rate and an elasticity of unemployment duration with respect to unemployment benefits of 0.12.[5] Finally, we normalize the wage to 1, so that b is interpreted as a replacement rate.[6] We set the value of home production $h = 0.2$ to match estimates of the drop in consumption upon unemployment (e.g. Cox *et al.* (2020)).

In all the experiments below, we consider the optimal policy response to an unexpected shock starting from steady state, which we assume has an unemployment benefit replacement rate of $b = 0.45$ and unemployment rate of $u = 0.04$ (to match the pre-COVID unemployment rate[7]). This raises the question of whether to interpret the steady state of the US economy as optimal. We choose the following strategy. For the Ramsey experiment, we choose a cost of funds η so that the US allocation is the steady state Ramsey optimum. For the Markov experiment, we re-compute the cost of funds η so that the US allocation is the steady state of the Markov equilibrium. We make this assumption to facilitate comparison between the Markov and Ramsey policies. As we consider mean reverting shocks from steady state, under both policy scenarios the economy begins and returns to the same steady state. The difference between the two policy paths can thus be entirely attributed to the commitment ability of the government along the transition, rather than its preference for a higher/lower UI on average.

[5]We note that there is an ongoing and active debate regarding the effects of unemployment benefits (levels and duration) on worker search effort (micro effects) and firm vacancy creation (macro effects). In innovative work using administrative data from Missouri, Johnston and Mas (2018) find significant affects of potential benefit duration on worker search effort, as measured through exits into employment (though, (Karahan *et al.*, 2019), also looking at Missouri find a smaller role for search effort). However, other work during the Great Recession by Rothstein (2011) finds an elasticity of 0. Thus, we see our calibration choice as within the range of recent estimates, and more on the conservative side. We show in Appendix C that our results are robust to different calibrations.

[6]We abstract from the impact of unemployment benefits on re-employment wages, which is also the subject of an ongoing and active debate.

[7]Our results are not sensitive to the choice of steady state unemployment in the ranges experienced in the post-War U.S.

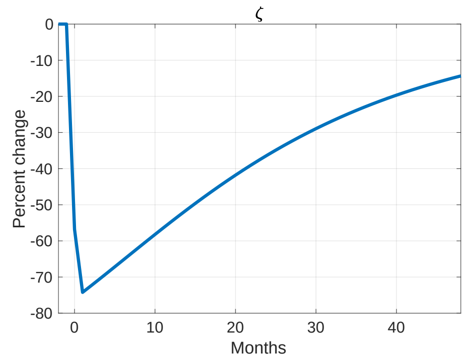
4.1 A deterioration in search efficiency

In our first experiment, we simulate the optimal policy response to a recession triggered by a decline in search efficiency, ζ_t. Starting from a steady state at $t = 0$, the economy experiences a one-time negative innovation ϵ_0 leading to a decline in ζ_t. After period 0 there are no future shocks and ζ_t mean reverts according to Eq. 19. Agents have perfect foresight of the entire future path of ζ_t — making this effectively an "MIT shock" to the economy (Boppart *et al.* (2018)). The simulated path of ζ_t is illustrated in Figure 1a.

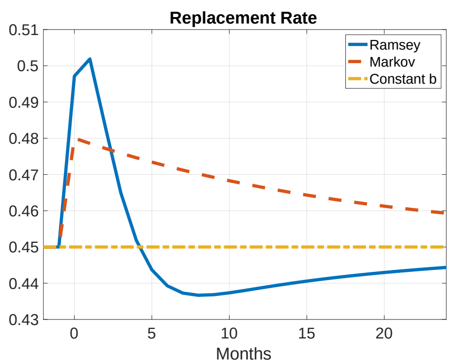
Figure 1 clearly illustrates the contrast in policy responses between the Ramsey and Markov governments. The government with commitment power responds to the adverse shock by substantially raising unemployment benefits at the onset of the recession, and then quickly cutting them back. The Markov policy response features a smaller but more prolonged rise in benefits, reflecting exactly the mechanism discussed earlier: the inability to commit to lower benefits upon the future recovery worsens the moral hazard problem today. Worth noting is the similarity in unemployment rates under the two policies. Under the Ramsey policy, the moral hazard effects of the initial rise in benefits are mitigated by the commitment to lower them in the future.

4.2 A one-time destruction of job matches

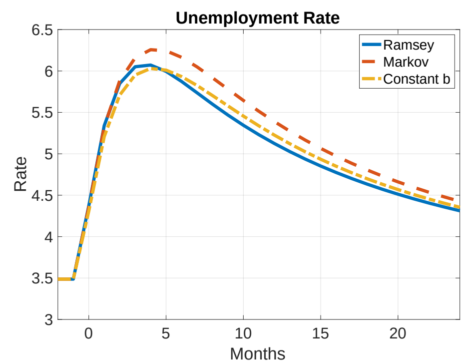
The difference between the Ramsey and Markov responses is even more stark in the second experiment, which simulates the response to a large, one-time job destruction. Figure 2 illustrates the responses to a destruction of job matches that results in a rise of unemployment to 11%, without any subsequent shocks. The separation shock implies that the economy is in a state of temporarily high unemployment, which is falling back to steady state from the initial period onwards. The Ramsey government optimally responds to the resulting downward trajectory of unemployment by raising benefits initially - when unemployment is high - and lowering them in future periods - when unemployment is lower. By doing so, it manages to reallocate unemployment insurance from periods with few unemployed into periods with many unemployed; it



(a) The path of ζ_t.



(b) UI benefits under Ramsey, Markov and constant policies.



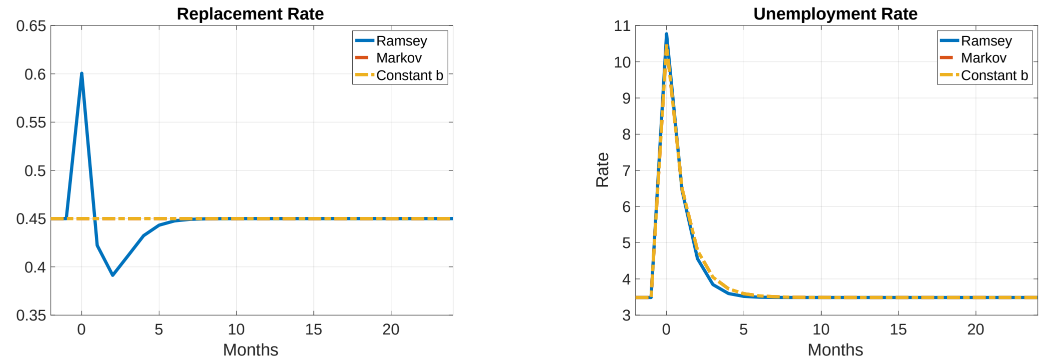
(c) Unemployment under Ramsey, Markov and constant policies.

Figure 1: Response to mean-reverting ζ shock: Ramsey vs. Markov.

does so without worsening current moral hazard, since current job searchers anticipate the future fall in benefits. By contrast, the Markov policy does not react to the destruction shock at all, because a one-time job destruction does not affect the contemporaneous moral hazard elasticities.

4.3 A COVID-19 type shock

Our third experiment is intended to capture, in a stylized way, an economic crisis akin to the one triggered by COVID-19. We treat the COVID-19 recession as a combination of a temporary rise in δ_t and a prolonged fall in ζ_t. We can think of these



(a) UI benefits under Ramsey, Markov and constant policies.

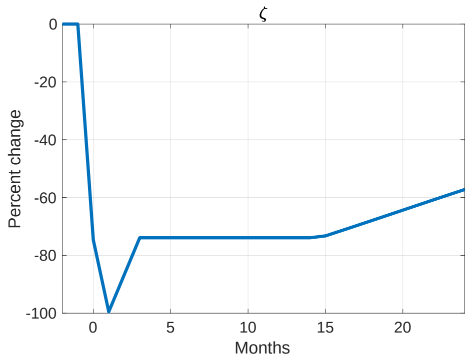
(b) Unemployment under Ramsey, Markov and constant policies.

Figure 2: Response to one-time job destruction: Ramsey vs. Markov.

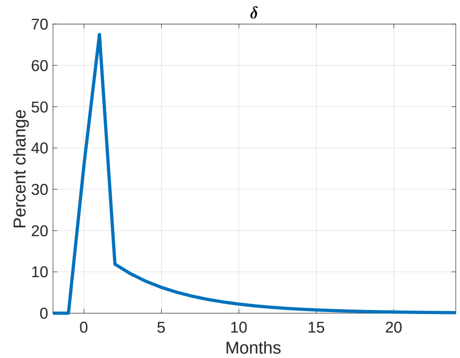
as encompassing policy responses and the decline in economic activity resulting from the spread of the virus. For example, the adverse shocks reflect NPI's, such as orders to limit restaurants to take-out only and stay-at-home orders, as well as reluctance or inability to search due to the fear of becoming infected, along with a shortage of newly posted job openings. We choose the paths for δ and ζ to roughly correspond to the separation rate from the Job Openings and Labor Turnover survey by the BLS, and the decline in economic activity from Bognanni *et al.* (2020), respectively.

Figure 3 plots the time paths of the ζ_t and δ_t shocks, as well as the policy responses under the Ramsey and Markov policy; it also shows the time path of unemployment under each policy response and under a constant-UI policy for reference purposes. The broad message is consistent with the previous analysis.

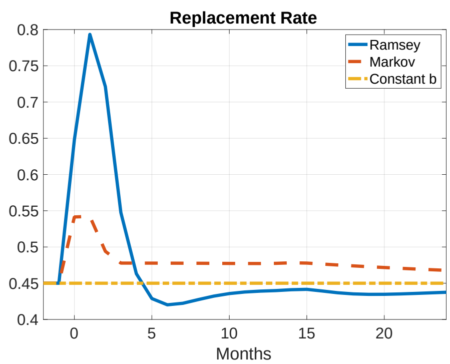
The Ramsey policy features a much larger initial rise in benefits. This is both because the Ramsey policy responds more on impact to the decline in ζ, and because the Ramsey policy responds more to the high unemployment triggered by the increase in δ. While this looks as if the government simply responds to high unemployment by raising benefits, this is not the mechanism here: instead, the optimal policy correctly anticipates that unemployment will subsequently fall, calling for a declining time profile of UI rather than a high level per se. It is also apparent that the Markov policy tracks very closely the simulated path of ζ_t: in particular it does not lower



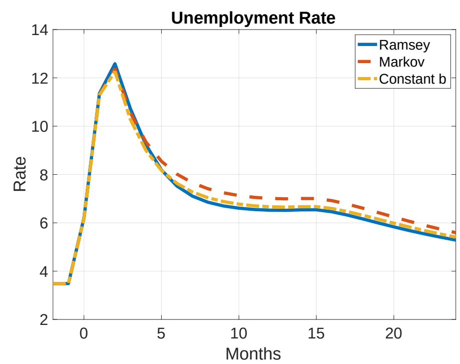
(a) The path of ζ_t.



(b) The path of δ_t.



(c) UI benefits under Ramsey policy.



(d) UI benefits under Markov policy.

Figure 3: Response to COVID-type shock: Ramsey vs. Markov.

benefits until the contemporaneous ζ_t recovers itself, whereas the Ramsey policy lowers benefits preemptively, while search efficiency is still stagnant, in order to provide forward-looking incentives.

Importantly, the unemployment rate is very similar across policies (Ramsey, Markov, and constant benefits). The welfare gains from the Ramsey policy come about because the Ramsey planner reallocates UI from periods with few unemployed to periods with many unemployed. The latter still search just as intensively despite higher benefits today, because they expect the future cut in benefits. By contrast, the Markov government does not raise benefits as much in the crisis because it cannot commit to lowering them in the recovery.

4.4 Implementing the Ramsey policy

Finally, we address the question of implementing the Ramsey policy in practice. The preceding analysis suggests that a simple policy rule conditioning UI on the *level* of unemployment is unlikely to perform well, for two reasons. First, it is ζ_t, rather than u_t, that directly affects the moral hazard cost of UI. Since unemployment typically lags search efficiency, a policy rule contingent on the unemployment level is likely to keep UI benefits high for too long. Second, conditioning on ζ_t, the optimal Ramsey policy also captures a significant degree of history-dependence, since economic conditions in the past have affected the promises made for the current period.

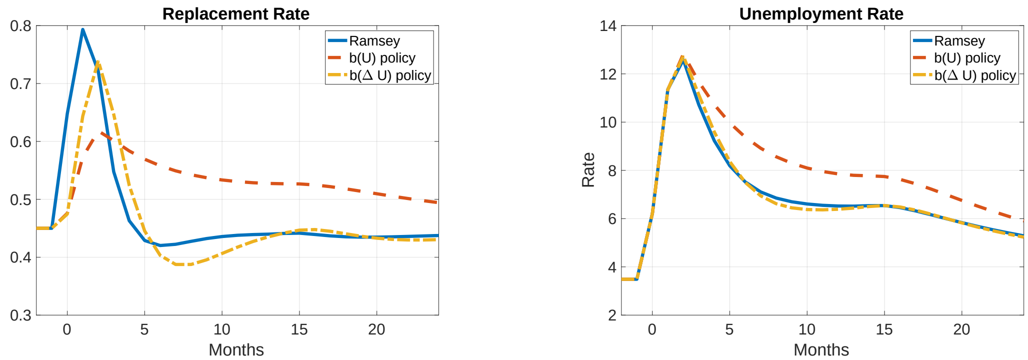
While a comprehensive quantitative analysis of optimal policy rules is beyond this paper, we explore how well simple policy rules perform. We show two things in our numerical examples. First, we confirm that a policy rule contingent on the unemployment level results in keeping UI benefits high for too long.[8] Second, we find that a policy rule conditioning UI on the *change* in three-month moving average of the unemployment rate between t and $t-1$ performs remarkably well in terms of approximating the optimal Ramsey policy. Note that the current federal-state extended benefits (EB) program has triggers based on the level and change in the three-month moving average of the unemployment rate, so we believe that these are within the class of feasible simple rules to implement.

We illustrate these points by running the following numerical experiments. First, we simulate the optimal Ramsey policy in the COVID-19 experiment, in which ζ_t and δ_t are assumed to evolve as Section 4.3. Having obtained the model-generated series for the optimal path of b_t and the resulting unemployment rate, we then use the series to estimate a policy rule of the form

$$b_t = b_{ss} + \gamma^{level} \left(u_{t-1} - u_{ss}\right) + \nu_t, \tag{32}$$

where b_{ss} and u_{ss} are the steady-state levels of UI benefits and unemployment. We

[8] An implementation that depends on the three-month moving average of the unemployment rate yields similar conclusions.



(a) UI benefits .

(b) unemployment

Figure 4: Comparison of simple policy rules.

term this policy rule the *level* rule. In the second experiment, we estimate an alternative policy rule contingent on the change in the moving-average of unemployment, $\overline{u}$, rather than the level,

$$b_t = b_{ss} + \gamma^{change} \left(\overline{u}_{t-1} - \overline{u}_{t-2}\right) + \nu_t, \tag{33}$$

terming this policy rule the *change* rule. We obtain $\gamma^{level} = 1.8$ and $\gamma^{change} = 13.7$. While the path of unemployment under the change rule closely follows that of the optimal Ramsey policy, the level rule, by keeping unemployment benefits high after search efficiency has recovered (because unemployment is still high) propagates the high unemployment further, generating hysteresis (see, e.g., Mitman and Rabinovich (2019)).

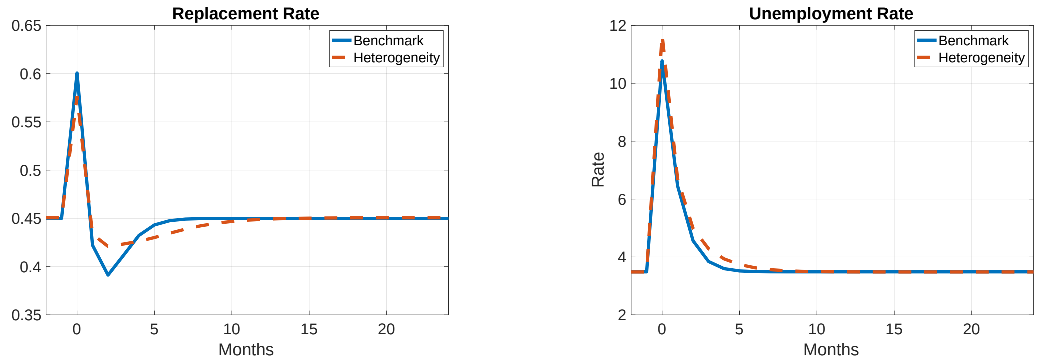
4.5 Robustness: the effects of heterogeneity

Our analysis thus far has assumed an environment with ex-ante homogeneous workers, and economy-wide shocks that hit all the workers identically. However, the literature is replete with evidence of duration dependence in unemployment, whether it is due to human capital depreciation, dynamic selection on ability, or employer discrimination. More specific to the COVID-19 crisis, there is ample evidence of heterogeneous effects of the pandemic, which disproportionately affected service sectors and workers unable to work from home. Motivated by these considerations, we examine how worker heterogeneity affects our results.

We now consider a modification of our environment in which search efficiency differs by worker type, which can be high or low. Specifically, a fraction φ of workers have high search efficiency $\zeta_t \alpha_h$, and $1-\varphi$ of workers have search efficiency $\zeta_t \alpha_l$, with $0 < \alpha_l < \alpha_h$, where both α_l and α_h are time-invariant. The economy-wide moral hazard cost of UI now depends not only on aggregate ζ_t, but also on the fraction of low types among the unemployed. We calibrate $\varphi = 0.3$, $\alpha_h/\alpha_l = 10$ and $\alpha_h = 2.7$, to match the same steady-state unemployment rate as in the homogeneous worker case. In steady state, in particular, the pool of unemployed consists disproportionately of low-type workers (whose unemployment rate is three times higher than the high-type workers), for whom the moral hazard cost of UI is lower than for high-types, by the arguments made earlier.

We then consider how the heterogeneity interacts with aggregate shocks. In our first experiment, we consider a one-time destruction of job matches starting out of steady state, as in Section 4.2. The optimal policy response is illustrated in Figure 5. Since the destruction shock hits all employed workers equally, the composition of the unemployment pool temporarily shifts toward high-type workers, for whom moral hazard is relatively high. The composition of the unemployed then gradually reverts toward the original steady state (which had a relatively high proportion of low types), as the high-type workers find jobs faster than the low-type workers. The initial prevalence of high-type unemployed workers dampens the initial rise in UI, whereas the subsequent recovery in the fraction of low-type unemployed workers dampens its fall. This dynamic selection effect flattens the UI profile, consistent with the insights of Kolsrud *et al.* (2018).

The size of this effect depends on both the ability distribution and the turnover post-initial shock. In particular, since regular layoffs continue to occur after the initial shock, newly laid-off high-type workers continue to enter the pool of unemployed even as the pool of legacy unemployed shifts toward low types. Because the fraction of the former is significant, this tempers the dynamic selection effect.

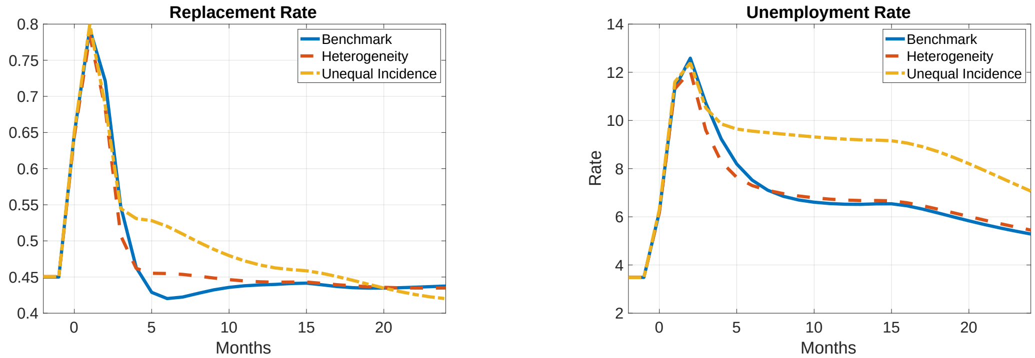


(a) UI benefits .

(b) unemployment

Figure 5: Response to a one-time job destruction: Benchmark vs. model with heterogeneity.

Next, we consider a combination of destruction shocks and a decline in aggregate search efficiency, as in Section 4.3. An additional layer of complexity arises because of potential interaction between the aggregate shock and the heterogeneity. In the above, we assumed that the destruction shock hit both types equally - resulting in a temporary increase in the fraction of high-type unemployed, which then declines back, leading to dynamic selection. It is quite plausible, particularly in the COVID-19 episode, that the workers hit the most by the adverse shocks are the very workers with low search efficiency, e.g. service sector workers with few work-from-home opportunities. Indeed, Gregory *et al.* (2020) provide evidence that the separation shocks induced by the pandemic may have disproportionately affected workers that take significantly longer to find stable jobs in the future. We illustrate this possibility in Figure 6. The curve labeled "Benchmark" illustrates the optimal policy without heterogeneity. The curve labeled "Heterogeneity" illustrates the optimal policy with heterogeneity, assuming that the negative shock hits both types symmetrically. Finally, "Unequal incidence" illustrates the optimal policy when low types bear the brunt of the pandemic and are subject to both higher job destruction and a larger decline in search efficiency. The dynamic selection effect is present, but initially muted, as the initial composition of the unemployment pool changes by



(a) UI benefits .

(b) unemployment

Figure 6: Response to COVID-type shock: Benchmark vs. model with heterogeneity.

less than when there is equal incidence of the destruction shock on the two types. However, as the high-types experience a milder shock to search effort the dynamic selection manifests itself more quickly as the high types find jobs. At that stage the original mechanism kicks in, whereby the optimal policy tracks the (more severe) ζ shock experienced by the low types. So benefits stay elevated, though at a lower level, and slowly decline providing the same dynamic incentives discussed in the benchmark. Thus, the presence of heterogeneity suggests a milder slope for the decline in benefits. Nonetheless, we still find that a change rule more closely approximates the optimal policy than one that depends on the level, such that our implementation conclusions are robust to the inclusion of heterogeneity.

5 Discussion

We have revisited the question of whether, when, and how to extend UI in recessions. The broad lesson is that expectations matter. People's job search behavior depends on future UI benefits as well as future labor market conditions. A government with commitment power takes advantage of this by front-loading UI, i.e., back-loading incentive provision when the labor market is recovering from a crisis. Inability to commit may manifest itself as a positive correlation between UI and unemployment, even though unemployment levels *per se* do not dictate the government's policy response.

The specific policy recommendation is for UI to track the growth rate of unemployment rather than its level. The change in unemployment between periods is a good proxy for search efficacy, which governs the moral hazard cost of unemployment insurance. Further, committing to lower UI when unemployment is falling provides proper search incentives for the unemployed workers in previous periods. It does so at minimal cost in terms of consumption insurance: it provides insurance to the many unemployed workers at the onset of the crisis while promising to cut it for the few unemployed workers at its conclusion.

References

BAILY, M. N. (1978). Some aspects of optimal unemployment insurance. *Journal of Public Economics*, **10** (3), 379–402.

BIRINCI, S., KARAHAN, F., MERCAN, Y. and SEE, K. (2020). *Labor Market Policies during an Epidemic*. Working paper.

BOGNANNI, M., HANLEY, D., KOLLINER, D. and MITMAN, K. (2020). *Economics and Epidemics: Evidence from an Estimated Spatial Econ-SIR Model*. Tech. rep., Board of Governors of the Federal Reserve System (US).

BOPPART, T., KRUSELL, P. and MITMAN, K. (2018). Exploiting mit shocks in heterogeneous-agent economies: the impulse response as a numerical derivative. *Journal of Economic Dynamics and Control*, **89**, 68–92.

CHETTY, R. (2006). A general formula for the optimal level of social insurance. *Journal of Public Economics*, **90** (10-11), 1879–1901.

COX, N., GANONG, P., NOEL, P., VAVRA, J., WONG, A., FARRELL, D. and GREIG, F. (2020). Initial impacts of the pandemic on consumer behavior: Evidence from linked income, spending, and savings data. *University of Chicago, Becker Friedman Institute for Economics Working Paper*, (2020-82).

DEN HAAN, W. J., RENDAHL, P. and RIEGLER, M. (2018). Unemployment (fears) and deflationary spirals. *Journal of the European Economic Association*, **16** (5), 1281–1349.

FANG, L., NIE, J. and XIE, Z. (2020). Unemployment insurance during a pandemic. *Federal Reserve Bank of Kansas City Working Paper*, (20-07).

GREGORY, V., MENZIO, G. and WICZER, D. G. (2020). *Pandemic Recession: L or V-Shaped?* Tech. rep., National Bureau of Economic Research.

Guerrieri, V., Lorenzoni, G., Straub, L. and Werning, I. (2020). *Macroeconomic Implications of COVID-19: Can Negative Supply Shocks Cause Demand Shortages?* Tech. rep., National Bureau of Economic Research.

Hagedorn, M., Karahan, F., Mitman, K. and Manovskii, I. (2013). *Unemployment Benefits and Unemployment in the Great Recession: the Role of Macro Effects*. Economics working paper, University of Pennsylvania.

—, Manovskii, I. and Mitman, K. (2015). *The impact of unemployment benefit extensions on employment: the 2014 employment miracle?* Tech. rep., National Bureau of Economic Research.

Hopenhayn, H. A. and Nicolini, J. P. (1997). Optimal unemployment insurance. *Journal of Political Economy*, **105** (2), 412–38.

Johnston, A. C. and Mas, A. (2018). Potential unemployment insurance duration and labor supply: The individual and market-level response to a benefit cut. *Journal of Political Economy*, **126** (6), 2480–2522.

Jung, P. and Kuester, K. (2015). Optimal labor-market policy in recessions. *American Economic Journal: Macroeconomics*, **7** (2), 124–56.

Kapicka, M. and Rupert, P. (2020). Labor markets during pandemics. *Manuscript, UC Santa Barbara*.

Karahan, F., Mitman, K. and Moore, B. (2019). Individual and market-level effects of ui policies: Evidence from missouri. *FRB of New York Staff Report*, (905).

Kekre, R. (2019). *Unemployment Insurance in Macroeconomic Stabilization*. Working paper.

Klein, P., Krusell, P. and Rios-Rull, J.-V. (2008). Time-consistent public policy. *The Review of Economic Studies*, **75** (3), 789–808.

Kolsrud, J., Landais, C., Nilsson, P. and Spinnewijn, J. (2018). The optimal timing of unemployment benefits: Theory and evidence from sweden. *American Economic Review*, **108** (4-5), 985–1033.

Kroft, K. and Notowidigdo, M. J. (2016). Should unemployment insurance vary with the unemployment rate? theory and evidence. *The Review of Economic Studies*, **83** (3), 1092–1124.

Kydland, F. E. and Prescott, E. C. (1977). Rules rather than discretion: The inconsistency of optimal plans. *Journal of political economy*, **85** (3), 473–491.

Landais, C., Michaillat, P. and Saez, E. (2018). A macroeconomic approach to optimal unemployment insurance: Theory. *American Economic Journal: Economic Policy*, **10** (2), 152–81.

Mitman, K. and Rabinovich, S. (2015). Optimal unemployment insurance in an equilibrium business-cycle model. *Journal of Monetary Economics*, **71**, 99–118.

— and — (2019). Do unemployment benefit extensions explain the emergence of jobless recoveries?

Pei, Y. and Xie, Z. (2020). A quantitative theory of time-consistent unemployment insurance. *Journal of Monetary Economics*.

Ravn, M. O. and Sterk, V. (2016). *Macroeconomic fluctuations with HANK & SAM: An analytical approach*. CEPR Discussion Paper No. DP11696.

Rothstein, J. (2011). *Unemployment Insurance and Job Search in the Great Recession*. NBER Working Papers 17534, National Bureau of Economic Research, Inc.

Shavell, S. and Weiss, L. (1979). The optimal payment of unemployment insurance benefits over time. *Journal of Political Economy*, **87** (6), 1347–62.

A Derivations for the two-period model

A.1 Optimal search given policy

This section provides the derivations leading to the optimal search conditions (4) and (5). We solve the worker's problem backwards. A worker entering period 2 unemployed has the value

$$U_2 = \max_{s_2} -\frac{1}{\zeta_2} c\left(s_2\right) + s_2 v\left(w-\tau\right) + \left(1-s_2\right) v\left(b_2\right), \tag{34}$$

and a worker entering period 2 employed has the value

$$W_2 = \left(1-\delta\right) v\left(w-\tau\right) + \delta\left[\max_{s_2} -\frac{1}{\zeta_2} c\left(s_2\right) + s_2 v\left(w-\tau\right) + \left(1-s_2\right) v\left(b_2\right)\right]. \tag{35}$$

The optimal S_2 clearly satisfies (5). Then, a worker unemployed in period 1 solves A worker entering period 1 unemployed therefore has the value

$$\max_{s_1} -\frac{1}{\zeta_1} c\left(s_1\right) + s_1\left(v\left(w-\tau\right) + \beta W_2\right) + \left(1-s_1\right)\left(v\left(b_1\right) + \beta U_2\right), \tag{36}$$

The optimal S_1 then solves $\frac{1}{\zeta_1} c'\left(S_1\right) = v\left(w-\tau\right) - v\left(b_1\right) + \beta\left(W_2 - U_2\right)$, which leads to (4).

A.2 Comparative statics of the elasticities

Proof of Lemma 1. Differentiation of ε_{1-S_1,b_1}, given by (6), with respect to ζ_1 (keeping policy and future variables fixed) gives

$$\frac{d}{d\zeta_1}\frac{\zeta_1}{(1-S_1)\,c''(S_1)} = \frac{1}{(1-S_1)\,c''(S_1)} - \frac{\zeta_1\left[(1-S_1)\,c'''(S_1)-c''(S_1)\right]}{\left((1-S_1)\,c''(S_1)\right)^2}\frac{\partial S_1}{\partial \zeta_1} \tag{37}$$

$$= \frac{1}{(1-S_1)\,c''(S_1)} - \frac{\zeta_1\left[(1-S_1)\,c'''(S_1)-c''(S_1)\right]}{\left((1-S_1)\,c''(S_1)\right)^2}\frac{c'(S_1)}{\zeta_1 c'(S_1)} \tag{38}$$

$$= \frac{1}{(1-S_1)\,c''(S_1)}\left[1-\frac{\left[(1-S_1)\,c'''(S_1)-c''(S_1)\right]c'(S_1)}{(1-S_1)\left(c''(S_1)\right)^2}\right], \tag{39}$$

where the second line follows from differentiating the worker's optimal search condition (4) with respect to ζ_1. The above quantity is positive if and only if (9) holds. The same argument applies when differentiating ε_{1-S_2,b_2}, given by (6), with respect to ζ_2. Next, differentiation of ε_{1-S_1,b_1} with respect to ζ_2 (again, keeping policy and future variables fixed) gives

$$\frac{d}{d\zeta_2}\frac{\zeta_1}{(1-S_1)\,c''(S_1)} = -\frac{\zeta_1\left[(1-S_1)\,c'''(S_1)-c''(S_1)\right]}{\left((1-S_1)\,c''(S_1)\right)^2}\frac{\partial S_1}{\partial \zeta_2}. \tag{40}$$

By the worker's optimality condition (5), the derivative of the right-hand side of (4) with respect to ζ_2 is $-\frac{1}{\zeta_2^2}c(S_2)<0$, so that $\frac{\partial S_1}{\partial \zeta_2}<0$. This means that the expression in (40) is positive if and only if (10) holds. ■

A.3 Optimal unemployment insurance with commitment

Proof of Proposition 2. Let λ_1 and $\beta\lambda_2$ be the Lagrange multipliers on the laws of motion (2) and (3), and let μ_1 and $\beta\mu_2$ be the Lagrange multipliers on the incentive constraints (4) and (5). Then the first-order conditions for b_1, b_2, S_1, S_2,

u_1, and u_2, respectively, are:

$$u_1 \left(v' \left(b_1\right) - \eta\right) = v' \left(b_1\right) \mu_1 \tag{41}$$

$$\beta u_2 \left(v' \left(b_2\right) - \eta\right) = \beta v' \left(b_2\right) \left(\mu_1 \left(1-\delta\right) \left(1 - S_2\right) + \mu_2\right) \tag{42}$$

$$\left(\lambda_1 - \frac{1}{\zeta_1} c' \left(S_1\right)\right) \left(u_0 + \delta \left(1 - u_0\right)\right) = \frac{1}{\zeta_1} c'' \left(S_1\right) \mu_1 \tag{43}$$

$$\left(\lambda_2 - \frac{1}{\zeta_2} c' \left(S_2\right)\right) \left(u_1 + \delta \left(1 - u_1\right)\right) = \frac{1}{\zeta_2} c'' \left(S_2\right) \mu_2 \tag{44}$$

$$\lambda_1 = v\left(w - \tau\right) - v\left(b_1\right) + \eta \left(\tau + b_1\right) + \beta \left(1 - \delta\right) \left[\frac{1}{\zeta_2} c\left(S_2\right) + \left(1 - S_2\right) \lambda_2\right] \tag{45}$$

$$\lambda_2 = v\left(w - \tau\right) - v\left(b_2\right) + \eta \left(\tau + b_2\right) \tag{46}$$

Combining (41)-(46) with (2)-(3) (4)-(5) gives us

$$\frac{v'\left(b_1\right) - \eta}{\eta} = \left[\tau + b_1 + \beta \left(1-\delta\right) \left(1 - S_2\right) \left(\tau + b_2\right)\right] \frac{\zeta_1 v'\left(b_1\right)}{\left(1 - S_1\right) c''\left(S_1\right)} \tag{47}$$

and

$$\begin{aligned} \beta \frac{v'\left(b_2\right) - \eta}{\eta} =& \beta \left(1-\delta\right) \left(1 - S_2\right) \left[\tau + b_1 + \beta \left(1-\delta\right) \left(1 - S_2\right) \left(\tau + b_2\right)\right] \frac{u_1}{u_2} \frac{\zeta_1 v'\left(b_2\right)}{\left(1 - S_1\right) c''\left(S_1\right)} \\ &+ \beta \left[\tau + b_2\right] \frac{\zeta_2 v'\left(b_2\right)}{\left(1 - S_2\right) c''\left(S_2\right)} \end{aligned} \tag{48}$$

Finally, combining (47)-(48) with (6)-(8) gives us (12) and (13). ■

A.4 Optimal unemployment insurance with discretion

We solve the optimal policy problem backwards. We begin by solving the problem of the period-2 government, which maximizes (14) subject to (3) and (5), taking u_1 as given. Letting λ_2 and μ_2 be the multipliers on (3) and (5), we obtain the first-order conditions for b_2, S_2 and u_2, respectively, as

$$u_2 \left(v'\left(b_2\right) - \eta\right) = \mu_2 v'\left(b_2\right), \tag{49}$$

$$\left(\lambda_2 - \frac{1}{\zeta_2} c'\left(S_2\right)\right)\left(u_1 + \delta\left(1 - u_1\right)\right) = \frac{1}{\zeta_2} c''\left(S_2\right)\mu_2, \tag{50}$$

and

$$\lambda_2 v\left(w - \tau\right) - v\left(b_2\right) + \eta\left(\tau + b_2\right) \tag{51}$$

Combining (49)-(51) with (3) and (5) yields

$$\frac{v'\left(b_2\right) - \eta}{\eta} = \left[\tau + b_2\right] \frac{\zeta_2 v'\left(b_2\right)}{\left(1 - S_2\right) c''\left(S_2\right)}, \tag{52}$$

which, from (8), is equivalent to (17). Note that the resulting solution $b_2 = \mathcal{B}_2\left(u_1\right)$ turns out to be independent of u_1, since b_2 and S_2 are uniquely pinned down by (52) and (5).

We next turn to the problem of the period-1 government. Since b_2 and S_2 do not depend on u_1 as established above, maximizing (15) is equivalent to maximizing (11) subject to (2)-(3), (4)-(5), and the additional constraint (52). The first-order conditions for b_1, S_1, and u_1, therefore, are still given by (41), (43), and (45), which simplifies to (16).

B Derivations for the infinite-horizon model

B.1 Optimal search given policy

Throughout, let $\mathcal{Z}^t = \{\zeta_1, ...\zeta_t\}$ denote the history of shocks. Let $W_t = W_t\left(\mathcal{Z}^t\right)$ be the value of a worker entering period t employed, and $U_t = U_t\left(\mathcal{Z}^t\right)$ the value of a worker entering period t unemployed. These values satisfy the Bellman equations

$$W_t = \left(1 - \delta_t\right)\left[v\left(w - \tau\right) + \beta \mathbb{E}_t W_{t+1}\right] + \delta_t\left[v\left(h + b_t\right) + \beta \mathbb{E}_t U_{t+1}\right] \tag{53}$$

$$U_t = \max_S -\frac{1}{\zeta_t} c\left(S\right) + S\left[v\left(w - \tau\right) + \beta \mathbb{E}_t W_{t+1}\right] + \left(1 - S\right)\left[v\left(h + b_t\right) + \beta \mathbb{E}_t U_{t+1}\right] \tag{54}$$

where the period-t expectation is taken with respect to ζ_{t+1} and dependence on $\mathcal{Z}^t$ is suppressed for notational convenience. From (54), the first-order necessary condition for the optimal $S = S_t$ is

$$\frac{1}{\zeta_t} c'\left(S_t\right) = v\left(w-\tau\right) - v\left(h+b_t\right) + \beta \mathbb{E}_t\left[W_{t+1} - U_{t+1}\right] \tag{55}$$

Subtracting (54) from (53) also gives

$$W_t - U_t = \frac{1}{\zeta_t} c\left(S_t\right) + \left(1-\delta_t - S_t\right)\left\{v\left(w-\tau\right) - v\left(h+b_t\right) + \beta \mathbb{E}_t\left[W_{t+1} - U_{t+1}\right]\right\} \tag{56}$$

Combining (55) with (56) gives (22).

B.2 Ramsey problem: optimal UI with commitment

The Ramsey problem consists of maximizing (23) subject to (21) and (22). Dependence on $\mathcal{Z}^t$ is understood throughout. Letting $\beta^t \lambda_t$ and $\beta^t \mu_t$ be the Lagrange multipliers on (21) and (22), we find the first-order conditions for b_t, S_t and u_t, respectively, to be

$$u_t\left(v'\left(b_t\right) - \eta\right) = \mu_t v'\left(b_t\right) \tag{57}$$

$$\left(\lambda_t - \frac{1}{\zeta_t} c'\left(S_t\right)\right)\left(u_{t-1} + \delta_t\left(1-u_{t-1}\right)\right) = \left[\mu_t - \left(1-\delta_t\right)\left(1-S_t\right)\mu_{t-1}\right] \frac{1}{\zeta_t} c''\left(S_t\right) \tag{58}$$

$$\lambda_t = v\left(w-\tau\right) - v\left(b_t\right) + \eta\left(\tau + b_t\right) + \beta\left(1-\delta_t\right)\mathbb{E}_t\left(\frac{1}{\zeta_{t+1}} c\left(S_{t+1}\right) + \left(1-S_{t+1}\right)\lambda_{t+1}\right) \tag{59}$$

The term $\lambda_t - \frac{1}{\zeta_t} c'\left(S_t\right)$ is the fiscal externality from job search, and it is positive because the worker does not internalize that their job search affects future net government revenues. Define $\Lambda_t = \left(\lambda_t - \frac{1}{\zeta_t} c'\left(S_t\right)\right)/\eta$. Combining (59) with (22) it is easy to see that Λ_t satisfies (25). Combining (57) with (58) to eliminate μ_t and μ_{t-1}, and substituting for $\left(u_{t-1} + \delta_t\left(1-u_{t-1}\right)\right)$ using (21), then gives the expression (24).

B.3 Markov equilibrium: optimal UI without commitment

Consider the problem of maximizing (26) subject to (27) and (28). Let λ and μ be the Lagrange multipliers on (27) and (28). Then the first-order conditions for b, S, and u', respectively, are:

$$u'\left(v'(b)-\eta\right)=\mu v'(b) \tag{60}$$

$$\left(\lambda-\frac{1}{\zeta}c'(S)\right)(u+\delta(1-u))=\mu\frac{1}{\zeta}c''(S) \tag{61}$$

$$\begin{aligned}\lambda =& v(w-\tau)-v(b)+\eta(\tau+b)\\ &+\beta(1-\delta)\mu\mathbb{E}\left(1-\mathcal{S}\left(u',Z'\right)\right)\frac{1}{\zeta'}c''\left(\mathcal{S}\left(u',Z'\right)\right)\mathcal{S}_u\left(u',Z'\right)+\beta\mathbb{E}\mathcal{V}_u\left(u',Z'\right)\end{aligned} \tag{62}$$

The envelope condition is

$$\mathcal{V}_u(u,Z)=(1-\delta)\left(\frac{1}{\zeta}c(\mathcal{S}(u,Z))+(1-\mathcal{S}(u,Z))\lambda\right) \tag{63}$$

We now want to solve for a Markov equilibrium in which $\mathcal{S}_u(u,Z)=0$, i.e. the optimal policy functions depend on Z but not on u. First, combining (60) with (61) and using (27), we can eliminate μ and get

$$\frac{v'(b)-\eta}{\eta}=\frac{\zeta v'(b)}{(1-S)c''(S)}\Lambda \tag{64}$$

where $\Lambda=\left(\lambda-\frac{1}{\zeta}c'(S)\right)/\eta$. Next, combining (62) with (63) and assuming future $\mathcal{S}_u=0$, we get that Λ satisfies

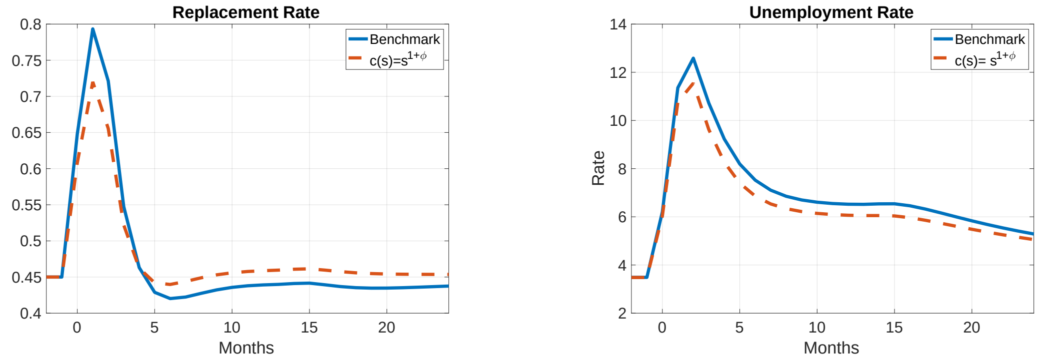
$$\Lambda=\tau+b+\beta(1-\delta)\mathbb{E}\left(1-\mathcal{S}\left(u',Z'\right)\right)\Lambda' \tag{65}$$

And so (64), (65) and (28) give us as system of functional equations in $b=\mathcal{B}(\zeta)$, $S=\mathcal{S}(\zeta)$ and $\Lambda=\Lambda(\zeta)$ which can be solved independently of u. In sequence form, (64) is (30).

C Robustness to search cost calibration

In this section, we explore the robustness of our results to both the specification of the search technology and its precise parameterization. We first consider an alternative, commonly used, search technology:

$$c(S)=A\frac{S^{1+\phi}}{1+\phi} \tag{66}$$



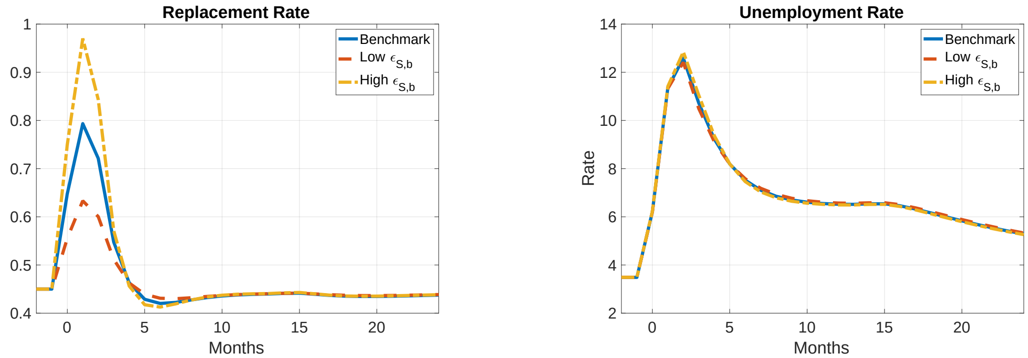
(a) UI benefits .

(b) unemployment

Figure 7: Comparison of search cost functions.

It can be verified that this search cost function likewise satisfies conditions 9 and 10 for sufficiently large ϕ (which turns out to always be the case in our calibration). Below, we display the Ramsey policy in response to the "COVID" shock with this alternative cost function. We set $\phi = 2$ and $A = 95$, which yields the same steady state unemployment as the benchmark and also a micro-elasticity of 0.11. The results are plotted in Figure 7. While the exact magnitudes are not identical, the qualitative conclusions are unchanged by this choice of functional form.

Next, we return to our original specification of the search cost, but conduct sensitivity analysis with respect to the choice of parameters. In the benchmark we calibrated to a conservative value of the elasticity of search to benefits of 0.12. We recalibrate A and h to generate steady states with identical unemployment, but higher (0.16) or lower (0.09) elasticity. These correspond to $h = 0$ and $h = 0.3$, compared to a benchmark of $h = 0.2$. We then re-run the benchmark "COVID" shock and compute the Ramsey policy. We plot the path of benefits and unemployment under those three scenarios in Figure 8. While the dynamics of the unemployment rate are largely unaffected by the calibration of the search elasticity, the magnitude of the increase in benefits is sensitive to the calibration. However, the overall *shape* of the optimal benefit path is unchanged. Perhaps surprisingly, benefits are *higher* when the elasticity of search to benefits it *higher*. What underlies the result is that when the elasticity of search to benefits is higher, that elasticity itself is more sensitive to shocks to ζ, so that for the same size shock the moral hazard cost falls by more for the



(a) UI benefits .

(b) unemployment

Figure 8: Comparison of search cost parameterization.

high elasticity calibration than the low elasticity one. Thus, the Ramsey planner optimally provides higher benefits when the search efficiency cost shock hits.